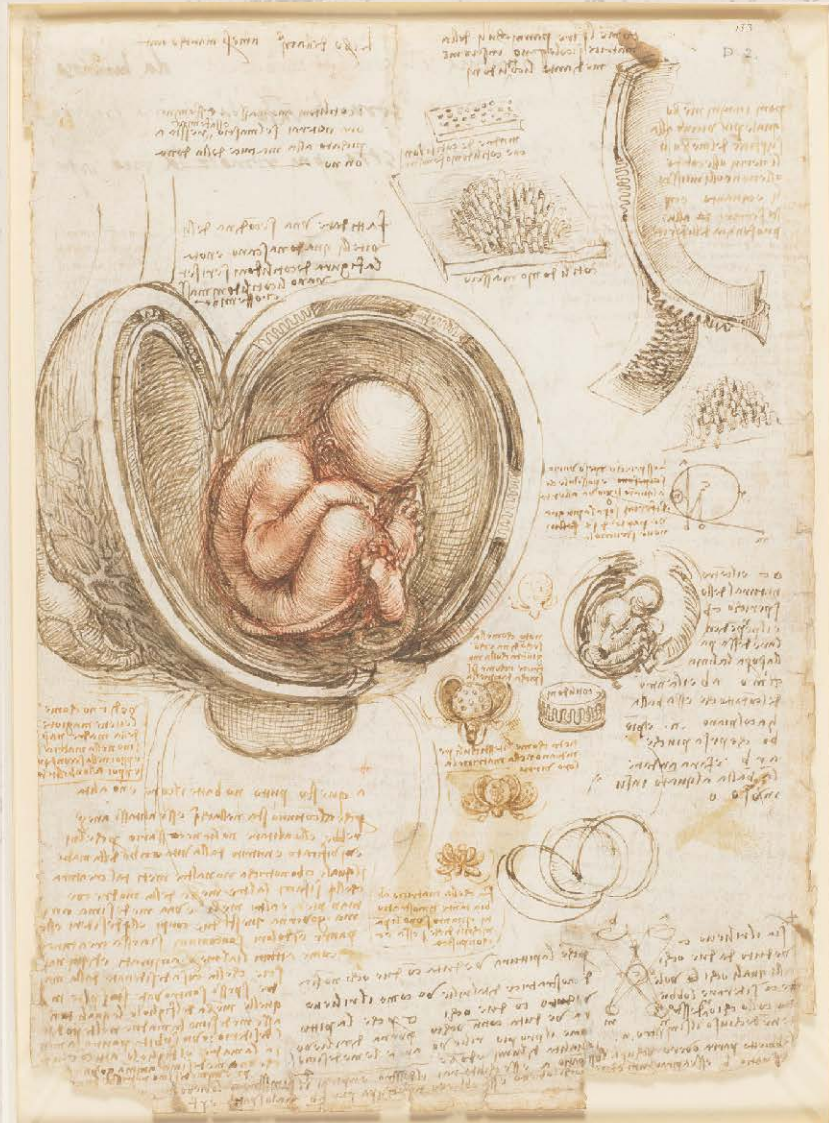


HEALTH IN TRANSITION

Translating developmental origins of health and disease science to improve future health in Africa



ANDREW J MACNAB,
ABDALLAH DAAR & CHRISTOFF PAUW
EDITORS

Health in Transition: Translating developmental origins of health and disease science to improve future health in Africa

Published by African Sun Media under the SUN PReSS imprint

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First edition 2020

ISBN 978-1-928357-74-2

ISBN (e-book) 978-1-928357-75-9

<https://doi.org/10.18820/9781928357759>

Set in Arno Pro 12/14

Cover design, typesetting and production by African Sun Media

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CONTENTS

The STIAS Series	vii
Acknowledgement	viii
Dedication	ix
Introduction: Notes on 'The Fetus in the womb' by Leonardo da Vinci <i>Macnab, A.J.</i>	1
Background	
1. International Society for Developmental Origins of Health and Disease's work at the Stellenbosch Institute for Advanced Study <i>Daar, A., Pauw, C. & Macnab, A.J.</i>	7
2. Ensuring healthier trajectories that start in early life to assist non-communicable disease prevention in Africa: A life-course approach <i>Norris, S.A.</i>	15
3. The implications of developmental origins of health and disease for Africa: What can be learnt from available data? <i>Byass, P.</i>	25
4. Mapping of developmental origins of health and disease to 'Sustainable Development Goals' and implications for public health in Africa <i>Kajee, N., Daar, A., Macnab, A.J. & Sobngwi, E.</i>	37
5. Relation between famine and health in future generations: Potential knowledge translation to Africa <i>Roseboom, T.J.</i>	51
Focus areas for intervention	
6. The fundamental importance of breastfeeding for health and development <i>Martin, R.D.</i>	67

7.	The challenges of breastfeeding in poor urban areas in sub-Saharan Africa <i>Kimani-Murage, E.W., Wekesah, F.M., Wanjohi, M., Nyamasege, C.K., Mutoni, S. & Macharia, T.</i>	103
8.	How environmental exposures early in life might influence phenotypes of non-communicable diseases in Africa <i>Mandy, M., Lule, S.A. & Nyirenda, M.J.</i>	127
9.	Hyperglycaemia in pregnancy <i>Sobngwi, E.</i>	143
10.	Diabetes in pregnancy: lessons for developing countries <i>Yajnik, C.S., Wagle, S.S., Kumaran, K. & Krishnaveni, G.V.</i>	161
Measures to impact outcome		
11.	Photo-essays: a creative format for effective communication <i>Stothers, L., Mukisa, R. & Macnab, A.J.</i>	185
12.	The World Health Organization's 'Health-Promoting School' model: a potential avenue for developmental origins of health and disease education in Africa <i>Macnab, A.J.</i>	203
13.	An approach to reduce the blindness burden in sub-Saharan Africa: special focus on childhood blindness <i>Marmamula, S., Bharadwaj, S.R., Keefe, J. & Balasubramanian, D.</i>	233
14.	School-based initiatives to reduce malaria morbidity and promote academic achievement in children <i>Macnab, A.J.</i>	247
15.	Intersectoral approaches to health and non-communicable disease prevention in Africa <i>Oni, T.</i>	291
16.	Celebrity health promotion messaging: novel opportunities to engage youth in the developmental origins of health and disease <i>Macnab, A.J. & Mukisa, R.</i>	307
Index		331

The STIAS series

The Stellenbosch Institute for Advanced Study (STIAS) was born from a simple but powerful conviction: in this part of the world special initiatives are required to create and maintain an environment where we can generate and engage with conceptual frameworks and knowledge that may guide us in tracking and co-shaping global academic developments and that will allow us to address the 'big' questions and issues South Africa and the African continent face, also in a global context.

STIAS has been moulded in the tradition of Institutes for Advanced Study across the globe. It distinguished itself by encompassing all disciplines from the natural to the social sciences and humanities (with a particular emphasis on research grounded in multi-disciplinarity), by maintaining a focus on the African and South African context, and by striving towards contemporary relevance, also by actively creating avenues for communicating the results of its research projects to a wider public.

The STIAS series publications, of which this is the sixteenth volume, are thus aimed at a broad public which will naturally vary with specific research themes. Straddling the academic world and the forum of an engaging public is a challenge that STIAS accepts; we trust that each STIAS publication reflects the 'creative space for the mind' in which it is rooted, stimulates public interest and debate, and contributes to informed decision making at various levels of our society.

Further information about STIAS and its research programme may be found at www.stias.ac.za.

Edward Kirumira
STIAS Director
Stellenbosch
November 2020

stias
PUBLICATION

Acknowledgement

The editors wish to acknowledge the guidance and creativity of Wikus van Zyl and Carla Rautenbach of African Sun Media which have ensured that this volume reflects the expertise of the 'Health in Transition' group, maintains the high publication standards of African Sun Media, and continues the tradition of excellence of the STIAS Book Series.

Andrew Macnab
20 December 2020

Dedication



This book is dedicated to the memory of Peter Byass

In addition to our work together, Peter was a distinguished scientist and internationally respected academic.

Professor of Global Health; Director, Umeå Centre for Global Health Research,
Umeå University, Umeå, Sweden

Honorary Professor of International Health University of Aberdeen, Aberdeen, Scotland

Honorary Professor, School of Public Health, University of the Witwatersrand,
Johannesburg, South Africa.



INTRODUCTION: NOTES ON 'THE FETUS IN THE WOMB' BY LEONARDO DA VINCI

Andrew J Macnab¹

This work must begin with the conception of man, and describe the nature of the womb and how the foetus lives in it, up to what stage it resides there, and in what way it quickens into life and feeds. Also, its growth and what interval there is between one stage of growth and another. What it is that forces it out from the body of the mother, and for what reasons it sometimes comes out of the mother's womb before the due time. – Leonardo da Vinci.²

1 Stellenbosch Institute for Advanced Study, Wallenberg Research Centre at Stellenbosch University, Stellenbosch, South Africa; Faculty of Medicine, Department of Paediatrics, University of British Columbia, Vancouver Canada.

2 Dunn, P.M. 1997. Leonardo Da Vinci (1452–1519) and reproductive anatomy. *Archives of Disease in Childhood - Fetal and Neonatal Edition*, 77(3):F249. [<https://doi.org/10.1136/fn.77.3.f249>].



The Fetus – pen and ink drawing – Leonardo da Vinci, 1611. Cover illustration reproduced by gracious permission of Her Majesty Queen Elizabeth II, Royal Collection Trust (inventory number 919102) / © Her Majesty Queen Elizabeth II 2019.

Leonardo da Vinci wrote these words when planning the book, *Of the Human Figure*, with anatomist Marc Antonio Della Torre.³ Far in advance of any concepts on the developmental origins of health and disease (DOHaD), Da Vinci, it can be argued, established informed inquiry into life during the first 1 000 days, by studying male and female reproductive anatomy, performing 30 dissections and drawing meticulous detail from the dissection of the cadaver of a pregnant woman, and a child of two years.⁴ He also wrote about the impact on health of diet, medicine and alcohol, and the importance of exercise and mental health.⁵ His pursuit of knowledge and seminal contributions to the understanding of human anatomy and physiology were indeed precursors to current inquiry into the importance of life during the first 1 000 days, making his illustration appropriate as the cover for this book.

The premature death of his collaborator was likely the reason that their book, *Of the Human Figure*, was never published. As we know Leonardo, however, left a unique and visionary series of anatomical drawings completed between 1510-1512, with perhaps the most famous being, *The Fetus in the Womb*, c.1511; housed in the Royal Collection at Windsor Castle and reproduced as the cover of this book by gracious permission of Her Majesty The Queen.⁶

In this small drawing (30.4 x 22 cm), made with red and black chalk and pen and ink, the fetus is shown in the now-familiar ‘fetal’ position with legs crossed at the ankles and the umbilical cord wrapped around the crossed legs. The uterus appears cut-through and opened-out, with an ovary in the left margin and the membranes in cross-section. Small ancillary sketches show the uterine membranes unfurling like the petals of a flower, details of the cord vessels, umbilical vein and the fetal liver and stomach.⁷

Leonardo’s drawings are considered to be the first to correctly depict the human fetus within the uterus, and illustrate cord vessels connecting to the liver. Leonardo is also credited with showing the uterus with only one chamber; thus contradicting theories of multiple uterine chambers which in the case of twins were believed

3 Ibid.

4 Gilson, H. 2020. Leonardo da Vinci's Embryological Drawings of the Fetus. *The Embryo Project Encyclopedia*. [<http://www.leonardo-da-vinci.net/embryo-in-the-womb/>] (Accessed 10 September 2019).

5 Dunn, 1997.

6 Royal Collection Trust. 2020. *Leonardo da Vinci (Vinci 1452-Ambiose 1519): Recto: The fetus in the womb. Verso: Notes on reproduction, with sketches of a fetus in utero, etc. c.1511*. [<https://bit.ly/31mOO7p>].

7 Ibid.

to hold each fetus in a separate compartment. Furthermore, these drawings and his accompanying notes illustrate his understanding of the umbilical cord blood vessels "not taking origin in any vein of the pregnant woman."⁸ Arguably, Leonardo thus pre-empted the discovery of the two independent, non-mixing fetal and maternal circulations made subsequently by Harvey and Hunter. And, while the quote below indicates that he did not identify the role of the heart or lungs in utero from his dissection of the dead fetus, he did write that the fetus was nourished by the mother.

In the case of this child the heart does not beat and it does not breathe because it lies continually in water. And if it were to breathe it would be drowned, and breathing is not necessary to it because it receives life and is nourished from the life and food of the mother.⁹

While accounts of this drawing often describe the fetus as being in the breech position, this arguably cannot be stated with certainty, as obviously we do not know the gestation of the pregnancy depicted. The gestation of the fetus at the time of Leonardo's dissection is relevant, as a fetus does not adopt the final position from which she/he will be delivered (either cephalic or breech) until between the 32nd and 36th week of pregnancy,¹⁰ hence there is a question as to whether this fetus had adopted the presentation from which delivery would have occurred. Physical criteria are used to reliably determine the maturity (gestational age) of a newly born infant from examination of various anatomical structures, but these markers do not appear to have been applied to estimate the gestational age of Leonardo's fetus previously. Two of the most reliable relate to the appearance of the ears and the soles of the feet, and as these parts of the fetus are clearly illustrated, their appearance can be used to estimate the maturity of Leonardo's fetus. From these, the gestation is probably close to term (40 weeks), as Leonardo draws ears with cartilage that appears well developed, and includes skin creases over the entire surface of the foot.¹¹ Hence, it is likely the fetus was a breech presentation.

As remarkable as Leonardo work is it proves not to be perfect; interestingly, the placenta as depicted is probably that of a cow from a previous animal dissection,

and Da Vinci also misbelieved that the umbilical cord was responsible for taking the fetus' urine outside of the uterus.¹²

Da Vinci never published his anatomical sketches; 'the fetus in the womb' and related work and observations were included in the third volume of his private notebooks which he left to his friend and pupil, Francesco Melzi. These notebooks, bought from his heirs, have since 1690 been part of the Royal Collection of Her Majesty The Queen.¹³ Leonardo's anatomical drawings demonstrate the rigour and inquisitiveness of a scientist as well as the skill of an artist and are rightly seen as the foundation of modern anatomical illustration.¹⁴ It is argued in parallel that his writing contains wisdom far ahead of its time when written 500 years ago, and I suggest that together, his words and images are relevant again today as unique ways to convey the message of DOHaD. Who can argue with his health advice?

If you would keep healthy, follow this regimen:

do not eat unless you feel inclined, and sup lightly; chew well, and let what you take be well cooked and simple. He who takes medicine does himself harm; do not give way to anger and avoid close air; hold yourself upright when you rise from table and do not let yourself sleep at midday. Be temperate with wine, take a little frequently, but not at other than the proper mealtimes, not on an empty stomach; neither protract nor delay the (visit to the) privy. When you take exercise, let it be moderate. Do not remain with the belly recumbent and the head lowered, and see that you are well covered at night. Rest your head and keep your mind cheerful; shun wantonness, and pay attention to diet.¹⁵

8 Ibid.

9 Dunn, 1997.

10 Cleveland Clinic. 2020. Fetal positions for birth. *Cleveland Clinic, Health Library: Articles*. [<https://my.clevelandclinic.org/health/articles/9677-fetal-positions-for-birth>].

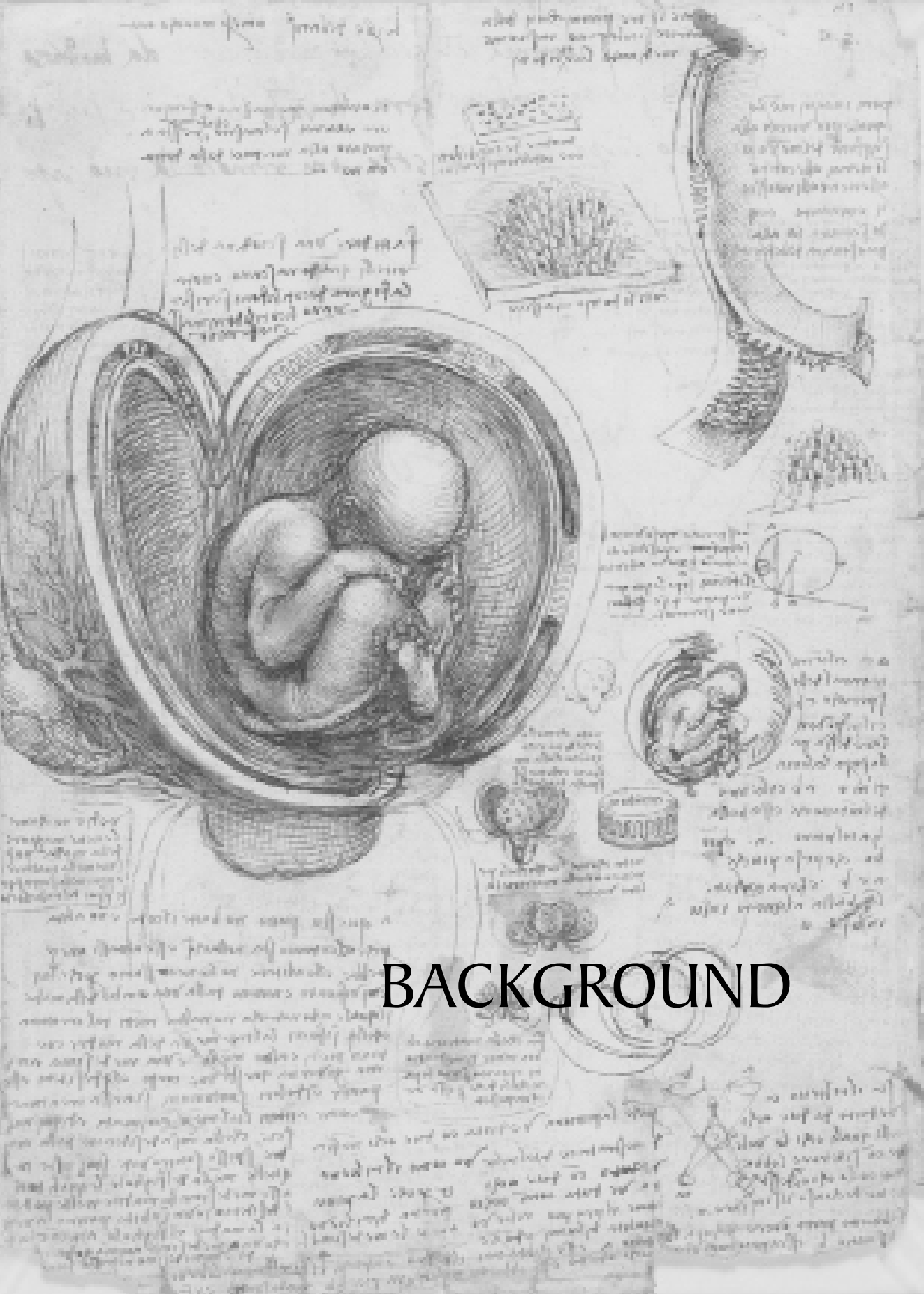
11 Parkin, J.M., Hey, E.N. & Clowes, J.S. 1976. Rapid assessment of gestational age at birth. *Archives of Disease in Childhood - Fetal and Neonatal Edition*, 51(4):259-263. [<https://doi.org/10.1136%2Fadc.51.4.259>].

12 Cataldi, L. & Fanos, V. 2000. Leonardo da Vinci and his studies on the human fetus and the placenta. *Acta Biomed Ateneo Parmense*, 71(Supplement 1):405-406.

13 Royal Collection Trust, 2020.

14 Gilson, 2020.

15 Dunn, 1997.



BACKGROUND



I

INTERNATIONAL SOCIETY FOR DEVELOPMENTAL ORIGINS OF HEALTH AND DISEASE'S WORK AT THE STELLENBOSCH INSTITUTE FOR ADVANCED STUDY

Abdallah Daar,¹ Christoff Pauw² and Andrew J Macnab³

This chapter describes the core group at the Stellenbosch Institute for Advanced Study (STIAS) who have contributed to the long-term theme project, 'Health in Transition'. It also describes what this book is about, why it is crucial, and the different strands and topics that are covered.

Introduction

STIAS has launched several long-term research projects based on selected strategic themes. These are:⁴

- 1 Dala Lana School of Public Health, University of Toronto.
- 2 Stellenbosch Institute for Advanced Study (STIAS), Wallenberg Research Centre, Stellenbosch University, Stellenbosch, South Africa.
- 3 Department of Paediatrics, Peter Wall Institute for Advanced Studies, University of British Columbia, Vancouver; STIAS.
- 4 Stellenbosch Institute for Advanced Study (STIAS). 2020. Ideas/Themes. [<https://stias.ac.za/ideas/themes/>].

- Being Human Today
- Crossing Borders
- The Future of Democracy
- Understanding Complexity
- Sustainable Agro-Ecosystems
- University and Society
- Health in Transition

These projects are team-driven and conducted by STIAS fellows during and between consecutive periods of residence (annually or biennially over three to four years). In this time, they convene workshops or conferences at STIAS, direct and conduct research in support of the project goals, and nominate other scholars to join the core group from time to time. The long-term projects have led to international colloquia, roundtable meetings, policy briefs and a growing collection of seminal publications, including volumes in the STIAS Series.

The 'Health in Transition' theme (Convener: Abdallah Daar)

'Health in Transition' is a continually evolving multi-disciplinary umbrella field that is in urgent need of innovative research and fresh thinking. While it is global, the health challenges are nowhere as stark as in Africa where most sub-Saharan African countries face a double burden. According to the Lancet Commission on the Future of Health in sub-Saharan Africa, health challenges such as infectious diseases, malnutrition, and child and maternal mortality persist.⁵ At the same time, new challenges arise from an increasing burden of chronic non-communicable diseases – mental health disorders; injuries; and health problems related to climate change and environmental degradation.⁶ Despite the progress achieved, life

5 Daar, A.S., Singer, P.A., Persad, D., Pramming, S., Matthews, D., Beaglehole, R., Bernstein, A., Borysiewicz, L., Colagiuri, S., Ganguly, N., Glass, R., Finewood, D., Koplan, J., Nabel, E., Sarna, G., Sarrafzadegan, N., Smith, R., Yach, D. & Bell, J. 2007. Grand Challenges in Chronic Non-Communicable Diseases. *Nature*, (450):494-496. [<https://doi.org/10.1038/450494a>].

6 STIAS. 2016. *Moving Towards Early Implementation in Africa*. Workshop on the Developmental Origins of Health and Disease and Sustainable Development Goals, 21-23 September. [<http://stias.ac.za/events/dohad-sdgs-moving-towards-early-implementation-in-africa/>].

expectancy and most population health indicators lag behind most low income and middle-income countries in other parts of the world. The situation is worse in fragile countries, rural areas, urban slums, and conflict zones, and among the poor, the disabled, and the marginalised.

The burden of chronic non-communicable diseases is becoming increasingly severe. At the same time, nutritional challenges brought about by a nutritional transition includes a high and co-existing burden of both under-nutrition and obesity/overweight, with a huge and growing burden on children. While many are overweight or obese, a significant proportion of people go hungry every day. These burdens all affect the health of mothers and their children, who are programmed to develop chronic diseases in later life and transmit that burden to the next generation through various mechanisms, including epigenetics. Scholars working in the field of the developmental origins of health and disease (DOHaD) study the dimensions of how early life events affect future health, mostly in the development and expression of chronic non-communicable diseases; and the mechanism of how that predisposition or programming is transmitted across generations.

These multiple transitions related to health, including technological ones, have significant implications for health services, social support and morbidity and mortality rates. Both the field of study of 'Health in Transition' and planners and policy developers of national health services are genuinely beset with poverty of reliable health-related data.

A measure of the importance and impact of chronic non-communicable diseases on societies include the facts that by 2020, globally, chronic non-communicable diseases (diabetes, heart disease, stroke) will cause 60 per cent of deaths worldwide, and 80 per cent of those will be in low- and middle-income countries.⁷ However, 44 per cent of these deaths are preventable with behavioural and pharmaceutical interventions. In the next 20 years, globally, chronic non-communicable diseases will cost more than 30 trillion US dollars (48 per cent of global Gross Domestic Product). Importantly, mounting evidence highlights how millions of deaths can be averted and economic losses reduced by billions of dollars if added focus is put on the prevention of chronic non-communicable diseases. In this context, the World Health Organization (WHO) estimates that population-based prevention measures for all low- and middle-income countries would cost two billion US dollars per year. This cost amounts to less than 0.40 US dollars per person.⁸ It is

7 Ibid.

8 World Health Organization (WHO). 2018. Non-communicable diseases. [<http://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases>].

generally accepted that the best opportunity, with likely the highest returns on investment, is early childhood development, or as a WHO report states:

The early child period is considered to be the most important developmental phase throughout the lifespan. Healthy early child development (ECD) – which includes the physical, social/emotional, and language/cognitive domains of development, each equally important – strongly influences well-being, obesity/stunting, mental health, heart disease, competence in literacy and numeracy, criminality and economic participation throughout life. What happens to the child in the early years is critical for the child’s developmental trajectory and life course.⁹

To this end, our core group has set out to contribute and focus on sub-Saharan Africa. Members are:

- Abdallah Daar, University of Toronto, Canada
- Shane Norris, University of Witwatersrand, South Africa
- Andrew Macnab, University of British Columbia, Vancouver, USA
- Peter Byass, University of Umea, Sweden
- Justine Davies, University of Birmingham, UK
- Tessa Roseboom, University of Amsterdam
- Moffat Nyirenda, London School of Hygiene and Tropical Medicine and MRC/UVRI, Uganda
- Eugene Sobngwi, University of Younde, Cameroon
- Atul Singhal, University College, London
- Chittaranjan Yajnik, Diabetes Research Centre, Pune, India
- Tolullah Oni, University of Cape Town/ University of Cambridge, UK
- Christoff Pauw, STIAS
- Dorairajan Balasubramanian, LV Prasad Eye Institute, Hyderabad, India

Major activities of the STIAS DOHaD Group

The DOHaD Core Group was convened under the ‘Health in Transition’ theme, with the title, *DOHaD and SDGs: Towards Early Implementation in Africa*. It started

9 WHO. 2007. *Early Child Development: A Powerful equalizer*. March. [http://www.who.int/maternal_child_adolescent/documents/ecd_final_m30/en/].

work in September 2016 and launched at a STIAS and Africa-wide workshop on DOHaD.¹⁰

Seven of the papers from the STIAS DOHaD group and colleagues were published in an Africa themed issue of the *Journal of DOHaD* (Table 1.1). These publications illustrate the range of interests of the core group, and also the type of subjects under the DOHaD umbrella.

Table 1.1 Papers in an Africa-themed issue of the *Journal of Developmental Origins of Health and Disease* (J DOHaD):

Macnab, A., Daar, A., Norris, S. & Pauw, J. 2018. Advancing the DOHaD agenda in Africa. <i>J DOHaD</i> , 9(1):2-4. [https://doi.org/10.1017/S2040174417001052].
Kajee, N., Sobngwi, E., Macnab, A. & Daar, A. 2018. The Developmental Origins of Health and Disease and Sustainable Development Goals: Mapping the way forward. <i>J DOHaD</i> , 9(1):5-9. [https://doi.org/10.1017/S2040174417000630].
Pentecost, M., Ross, F. & Macnab, A. 2018. Beyond the dyad: Making Developmental Origins of Health and Disease (DOHaD) interventions more inclusive. <i>J DOHaD</i> , 9(1):10-14. [https://doi.org/10.1017/S2040174417000629].
Macharia, T., Ochola, S., Mutua, M. & Kimani-Murage, E. 2018. Association between household food security and infant feeding practices in urban informal settlements in Nairobi, Kenya. <i>J DOHaD</i> , 9(1):20-29. [https://doi.org/10.1017/S2040174417001064].
Macnab, A. & Mukisa, R. 2018. Priorities for African youth for engaging in DOHaD. <i>J DOHaD</i> , 9(1):15-19. [https://doi.org/10.1017/S2040174417000423].
Redinger, S., Norris, S., Pearson, R., Richter, L. & Rochat, T. 2018. First trimester antenatal depression and anxiety: Prevalence and associated factors in an urban population in Soweto, South Africa. <i>J DOHaD</i> , 9(1):30-40. [https://doi.org/10.1017/S204017441700071X].
Rochat, T., Houle, B., Stein, A., Pearson, R., Newell, M. & Bland, R. 2018. Psychological morbidity and parenting stress in mothers of primary school children by timing of acquisition of HIV infection: A longitudinal cohort study in rural South Africa. <i>J DOHaD</i> , 9(1):41-57. [https://doi.org/10.1017/S204017441700068X].

Other papers from the group include a call-to-action paper, a paper in the *Lancet Global Health*, and papers on the WHO ‘Health-Promoting Schools’ programme and the issues of messaging.¹¹

Energised by the DOHaD Core Group and under the leadership of Shane Norris, an Africa chapter of the International DOHaD Society was created, with some

10 STIAS. 2016. *DOHaD and SDGs: Moving Towards Early Implementation in Africa*. STIAS workshop, 21-23 September. [https://bit.ly/3pg33ox].

11 Norris, S.A., Daar, A., Balasubramanian, D., Byass, P., Kimani-Murage, E., Macnab, A., Pauw, C., Singhal, A., Yajnik, C., Akazili, J., Levitt, N., Maatoug, J., Mkhwanazi, N., Moore, S.E., Nyirenda, M., Pulliam, J.R.C., Rochat, T., Said-Mohamed, R., Seedat, S., Sobngwi, E., Tomlinson, M., Toska, E., Van Schalkwyk, C. 2017. Understanding and acting on the developmental origins of health and disease in Africa would improve health across generations. *Global Health Action*, 10(1):1334985. [https://doi.org/10.1080/16549716.2017.1334985]; Davies, J.I., Macnab, A.J., Byass, P., Norris, S.A., Nyirenda, M., Singhal, A., Sobngwi, E. & Daar, A. 2018. Developmental Origins of Health and Disease

members of the STIAS DOHaD Group appointed to its scientific advisory board. This Society officially launched at the DOHaD Summit in Rotterdam in October 2017.

In November 2017, the STIAS Core Group, together with the African Academy of Sciences and the MRC Developmental Pathways for Health Research Unit at the University of the Witwatersrand, organised a very successful Summer School at STIAS, attended by graduate students and post-doctoral fellows from around Africa.¹² An enthusiastic group of potential future African leaders who became the founding members of the Africa chapter of the International DOHaD Society was created. An important outcome of that workshop was the creation of a Network of Young African Scientists dedicated to DOHaD research. The successful model for the Summer School would have been reprised at STIAS in April 2020, had it not been for the restrictions imposed globally by the Covid-19 outbreak.

This book in the STIAS series is an important legacy from the DOHaD Core Group. The scope of topics included in this volume reflects the breadth of DOHaD science and the reach required for intervention measures to impact future health outcomes.

The background section sets out what the fundamental issues are. WHO has identified non-communicable diseases as one of the ten leading threats to global health, and in Africa, while communicable diseases are still the continent's immediate disease burden, there is a growing awareness of the 'epidemic' nature of the increase in non-communicable diseases on the continent. This increase has major health and economic implications, hence the need to understand what present and future data can contribute. There are key areas of DOHaD epidemiology aligned with the current United Nations' 'Sustainable Development Goals' initiatives, hence the potential for synergistic strategies as a way forward. Moreover, the historical impact of famine on health has relevance in Africa, where undernutrition is still a health determinant for a significant part of the population.

in Africa – influencing early life. *Lancet Global Health*, 6:244-245. [[https://www.thelancet.com/pdfs/journals/langlo/PIIS2214-109X\(18\)30036-6.pdf](https://www.thelancet.com/pdfs/journals/langlo/PIIS2214-109X(18)30036-6.pdf)]; Macnab, A.J. and Mukisa, R. 2019. Celebrity endorsed music videos: innovation to foster youth health promotion. *Health Promotion International*, 34(4):716-725. [<https://doi.org/10.1093/heapro/day042>]; Macnab, A.J. & Mukisa, R. Reducing the global burden of poor oral health through school-based programmes. *International Journal of Epidemiology*, 47(5):1379-1382. [<https://doi.org/10.1093/ije/dyy180>].

12 STIAS. 2017. Developmental Origins of Health and Disease Translational Science: from Cell to Society. *Summer school*, 21-24 November. [<https://bit.ly/3ki9Mut>].

The section on focus areas for intervention highlights the fundamental importance to human health of breastfeeding and addresses the challenges in urban areas of sub-Saharan Africa to ensure appropriate infant nutrition through the first 1 000 days of life. How environmental exposures early in life may influence the phenotypes of non-communicable diseases in Africa is described, as this is an essential fundamental science component able to contribute to future evidence-based intervention relevant to DOHaD. The epidemic of diabetes is discussed as this is central to current DOHaD science and thinking; the impact on health and the economy of hyperglycaemia and has valuable lessons for low and middle-income countries.

Measures with the potential to impact future outcomes are needed. The broad-ranging interests and expertise of the DOHaD Core group are reflected in this section. With a multi-lingual society where levels of education vary, the ability of photos and pictures to communicate key ideas and actions in lay essays and scientific reports offers a creative and effective means of communication. How we engage young people in the context of DOHaD is a challenge. The WHO Health-Promoting School model has proven valuable as a conduit for youth health promotion globally and offers a potential avenue to educate more than a billion children about DOHaD worldwide. However, a fundamental issue is what 'messages' will resonate with youth and which 'messengers' they will identify with most effectively? There is evidence from schools in Africa that celebrities, and their music, in particular, can be a positive influence. A fundamental step in initiating effective intervention is the need to broker intersectoral approaches and partnerships. It is also necessary to recognise that morbidity from traditional diseases that burden school-age children like malaria has to be addressed in parallel with health promotion if benefits are to be accrued from any strategies aimed at educating the next generation effectively about DOHaD.

At present, the Core Group is working to ensure the long-term sustainability of the group's work. To this end the group is developing applications for grant funding from major international agencies, to building the capacity of young scientists through funding for PhDs and post-doctoral positions; building networks; fostering excellence in DOHaD research; and targeted advocacy and policy interventions. Some of the potential areas of research projects include modelling DOHaD attributable morbidity and mortality; new studies of food security; breastfeeding, skin-to-skin care (e.g. Kangaroo Mother Care) that also involves fathers; and Fetal Alcohol Syndrome.



2

ENSURING HEALTHIER TRAJECTORIES THAT START IN EARLY LIFE TO ASSIST NON-COMMUNICABLE DISEASE PREVENTION IN AFRICA: A LIFE-COURSE APPROACH

Shane A Norris¹

Non-communicable diseases are increasing globally, particularly in low- and middle-income countries. For countries on the African continent, this is of particular concern as the combination of a persisting burden of infectious disease coupled with a burgeoning of non-communicable diseases could cripple already strained health care systems. The current paradigm subscribes heavily on detection, treatment and management of patients with non-communicable diseases. This perspective is important, but a more balanced approach that strengthens prevention efforts is also needed.

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Prevention should start early – adult prevention efforts may be too late given the evidence from developmental origins of health and disease (DOHaD) science. A life-course perspective, which views preconception, pregnancy, infancy, childhood and adolescence as windows of opportunity to nudge health and development trajectories in a beneficial direction is useful to consider when contemplating strategies to promote prevention. Furthermore, framing prevention efforts across the life course stages to optimise health and nutrition may have significant shorter- and longer-term, and intergenerational benefits. Successful prevention will not only curb the non-communicable diseases epidemic but also has the potential to impact human capital development.

Non-communicable disease burden

WHO has identified non-communicable diseases as one of the ten leading threats to global health, resulting in 41 million people dying each year (71 per cent of deaths) (Figures 2.1 and 2.2).² While previously more common in high-income countries and rare in low- and middle-income countries, cardiovascular disease and type 2 diabetes are now plateauing/decreasing in high-income countries and rapidly rising in low- and middle-income countries.³ Mortality rates from non-communicable diseases in many low- and middle-income countries have now exceeded those in high-income countries; are occurring at younger ages and more aggressively in low- and middle-income countries; are creating crippling economic, societal and personal costs, with worse still to come.⁴

In Africa, communicable diseases still overshadow the continent's disease burden, but a recent study has shown a significant increase in non-communicable diseases between 1990 and 2017. The authors concluded that within the current decade, non-communicable diseases would surpass communicable, maternal, neonatal, and nutritional diseases as the leading cause of ill-health and death in sub-Saharan Africa.⁵ The implications of this conclusion have profound consequences for health

2 World Health Organization (WHO). 2019. Ten threats to global health in 2019. *WHO: Newsroom*. [www.who.int/emergencies/ten-threats-to-global-health-in-2019].

3 NCD Risk Factor Collaboration. 2017. Worldwide trends in blood pressure from 1975 to 2015: a pooled analysis of 1479 population-based measurement studies with 19.1 million participants. *The Lancet*, 389(10064), January:37. [https://doi.org/10.1016/S0140-6736(16)31919-5].

4 Institute for Health Metrics and Evaluation (IHME). 2020. GBD Compare. IHME: Measuring what matters. [http://vizhub.healthdata.org/gbd-compare/]; International Diabetes Federation (IDF). 2019. Worldwide toll of diabetes. *IDF Diabetes Atlas*. 9th Edition. [https://diabetesatlas.org/en/sections/worldwide-toll-of-diabetes.html].

5 Bloom, D.E., Cafiero, E.T., Jané-Llopis, E., Abrahams-Gessel, S., Bloom, L.R.,

systems across Africa buckling under the current strain of infectious diseases and severely compromised by a growing epidemic of non-communicable diseases. Both Gouda and colleagues (Charlson, Sorsdahl, Ahmadzada, Ferrari, Erskine, Leung, Santamauro, Lund, Aminde, Mayosi, Kengne, Harris, Achoki, Wiysonge, Stein and Whiteford, 2019) and the accompanying commentary by Bigna and Noubiap highlighted that the estimates are 'not optimal'.⁶ They recommended the need for improved epidemiological health data in sub-Saharan Africa. A concern with such data is that it only captures the recent history, perhaps before the rapid transition effects underway (persisting undernutrition during the first 1 000 days, burgeoning obesity in later life, and chronic infectious disease exposure) in sub-Saharan Africa have fully manifested. These estimates could, consequently, be grossly underestimated.⁷

The double burden of malnutrition and developmental origins of health and disease

A recent Lancet series has highlighted the 'double' burden of the malnutrition reality in African and other low- and middle-income countries – i.e. the simultaneous existence within individuals, families and communities of both undernutrition and overweight/obesity.⁸ The urban transition is fuelling obesity in low- and middle-income countries (diets become less diverse, more energy-dense and processed,

Fathima, S., Feigl, A.B., Gaziano, T., Mowafi, M., Pandya, A., Prettner, K., Rosenberg, L., Seligman, B., Stein, A.Z., & Weinstein, C. 2011. *The Global Economic Burden of Noncommunicable Diseases*. Geneva: World Economic Forum. [www.weforum.org/reports/global-economic-burden-non-communicable-diseases].

6 Gouda, H.N., Charlson, F.J., Sorsdahl, K. & Ahmadzada, S., Ferrari, A.J., Erskine, H., Leung, J., Santamauro, D., Lund, C., Aminde, L.N., Mayosi, B.M., Kengne, A.P., Harris, M., Achoki, T., Wiysonge, C.S., Stein, D.J. & Whiteford, H. 2019. Burden of non-communicable diseases in sub-Saharan Africa, 1990-2017: results from the Global Burden of Disease Study 2017. *The Lancet Global Health*, 7(10), October:e1375-e1387. [https://doi.org/10.1016/S2214-109X(19)30374-2]; Bigna J.J.R. & Noubiap, J.J.N. 2019. The rising burden of non-communicable diseases in sub-Saharan Africa. *The Lancet Global Health*, 7(10), September:PE1295-E1296. [https://doi.org/10.1016/S2214-109X(19)30370-5].

7 Global Burden of Disease Study 2013 Collaborators. 2015. Global, regional, and national incidence, prevalence, and years lived with disability for 301 acute and chronic diseases and injuries in 188 countries, 1990-2013: a systematic analysis for the Global Burden of Disease Study 2013. *The Lancet*, 386(9995), June:743-800. [https://bit.ly/2UdD7vy].

8 Branca, F., Demaio, A., Udomkesmalee, E. & Baker, P. A new nutrition manifesto for a new nutrition reality. *The Lancet*, 395(10217), December:8-10. [https://doi.org/10.1016/S0140-6736(19)32690-X].

and intakes of wholegrain foods, fresh fruit and vegetables, decline) against a background of generations of nutritional deprivation and co-existing with persisting food insecurity, micronutrient deficiencies and anaemia. These factors, directly or in combination with adiposity, may increase susceptibility to cardiovascular disease and type 2 diabetes.⁹ Indeed, nutrition-related risk factors, such as impaired glucose control, obesity, poor diets and micronutrient deficiencies, significantly contribute to global mortality (Figure 2.3).

The double burden of malnutrition emerges across the life course with a more frequent scenario in Africa the undernutrition in fetal life and infancy followed by later overnutrition (excess weight gain in childhood and adolescence, and adult obesity). Research in the field of DOHaD has shown that undernutrition in early life increases adult non-communicable disease risk.¹⁰

Disease burden from communicable, maternal, neonatal and nutritional diseases, World

Total disease burden from communicable, maternal, neonatal and nutritional diseases, measured in DALYs (Disability-Adjusted Life Years) per year. DALYs are used to measure total burden of disease - both from years of life lost and years lived with a disability. One DALY equals one lost year of healthy life.

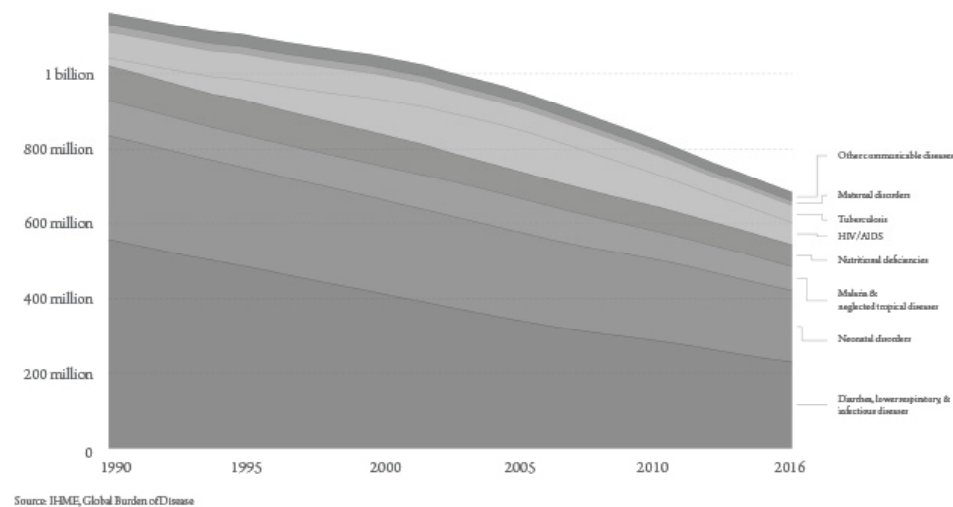


Figure 2.1 Globally, over time, the communicable disease has been declining.¹¹

9 Clarke, R. 2019. Nutrition and Emerging Risk Factors for CVD. In: BNF (British Nutrition Foundation), Stanner, S., Coe, S. & Frayn, K.N. (eds). *Cardiovascular Disease: Diet, Nutrition and Emerging Risk Factors*, 2nd Edition. Hoboken, New Jersey: Wiley-Blackwell.

10 Healthy Life Trajectories Initiative (HeLTI). 2020. A research initiative to develop and test interventions to prevent obesity in children and promote child development: A collaboration between Canada, China, India, South Africa and WHO. *HeLTI Net*. [https://helti-net.org/wp-content/uploads/2020/01/HeLTI-Overview-v2020-.pdf].

11 IHME Global Burden of Disease. 2017. Disease burden from communicable, maternal, neonatal and nutritional diseases, World. *Our World in Data*. Chart. [https://ourworldindata.org/grapher/disease-burden-from-communicable-diseases].

Total disease burden by cause, World

Total disease burden measured as Disability-Adjusted Life Years (DALYs) per year. DALYs measure the total burden of disease - both from years of life lost due to premature death and years lived with a disability. One DALY equals one lost year of healthy life.

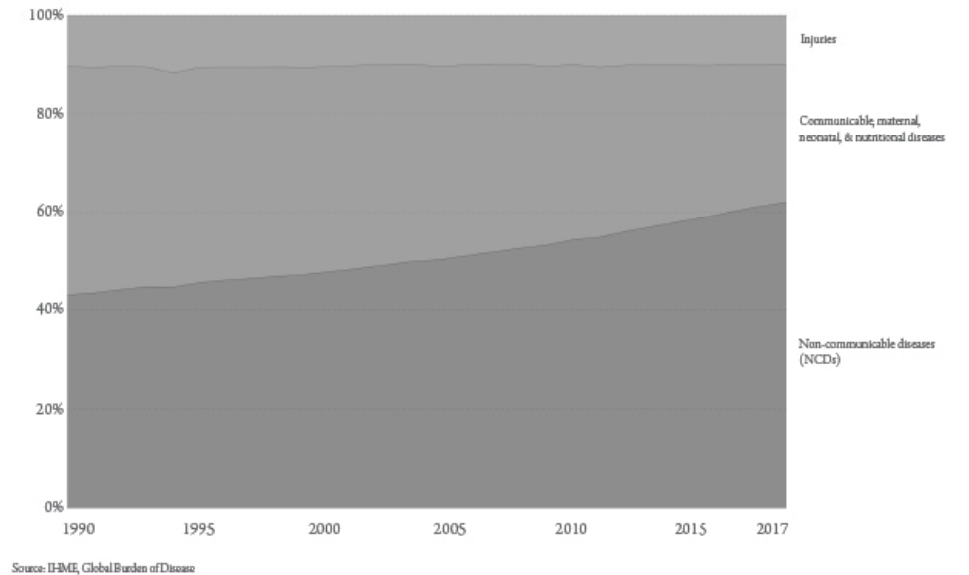


Figure 2.2 Globally, over time, the non-communicable diseases burden is surpassing communicable disease.¹²

neonatal and nutritional diseases, World. *Our World in Data*. Chart. [https://ourworldindata.org/grapher/disease-burden-from-communicable-diseases].

12 IHME Global Burden of Disease. 2017. Total disease burden by cause, World. *Our World in Data*. Chart. [https://ourworldindata.org/grapher/total-disease-burden-by-cause].

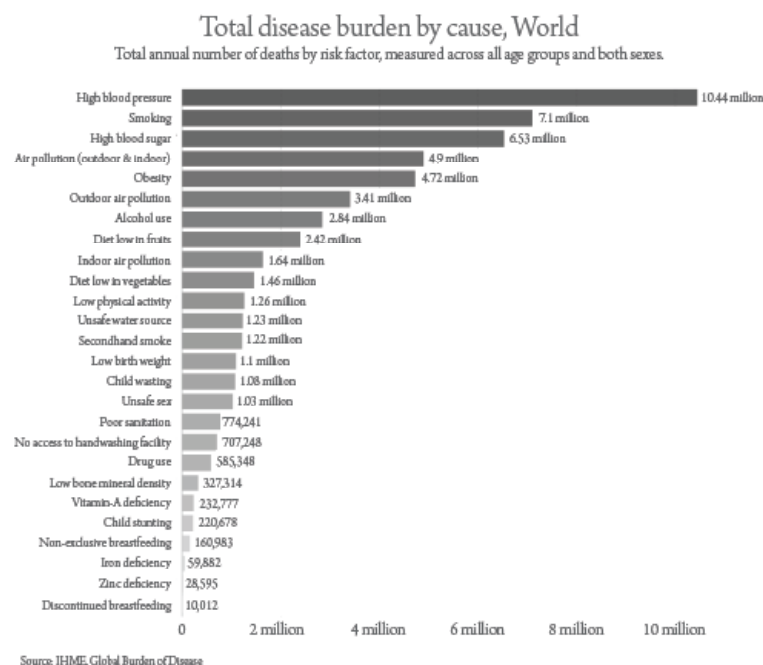


Figure 2.3 Nutrition-related risk factors contribute significantly to global mortality estimates.¹³

Initial evidence from studies shows lower birth weight (a proxy for fetal undernutrition) associates with an increased risk of adult cardiovascular disease and type 2 diabetes.¹⁴ Animal studies showed that under-nourishing pregnant mothers led to fetal growth restriction, multiple changes in the adult offspring (low muscle mass, increased adiposity, abnormal pancreatic, liver and kidney structure, altered secretion of and sensitivity to insulin and other hormones) as well as diabetes and hypertension.¹⁵ These studies suggest that early life undernutrition disrupting the development of critical metabolic tissues results in permanently reduced metabolic ‘capacity’. In human populations, the highest risk of cardiovascular disease and type 2 diabetes is in men and women who were light and thin at birth and in

13 IHME Global Burden of Disease. 2017. Number of deaths by risk factor, World, 2017. *Our World in Data*. Chart. [https://bit.ly/38gUy6x].

14 Ibid.; Hales, C.N. & Barker, D.J. 1992. Type 2 (non-insulin-dependent) diabetes mellitus: the thrifty phenotype hypothesis. *International Journal of Epidemiology*, 42(5), October:1215-1222. [https://doi.org/10.1093/ije/dyt133].

15 Warner, M.J. & Ozanne, S.E. 2010. Mechanisms involved in the developmental programming of adulthood disease. *Biochemical Journal*, 427(3), April:333-347. [https://doi.org/10.1042/BJ20091861].

infancy (having the lowest metabolic capacity) but gained the highest body mass index as children or adults (developing the greatest metabolic ‘load’).¹⁶ These effects, whereby insults occurring in critical ‘plastic’ periods of early development have long-term consequences, are known as developmental programming. DOHaD research suggests that non-communicable disease risk is influenced not only by exposure to the well-known load factors such as obesity but also by the capacity acquired during early development – a missing link in understanding non-communicable disease trends in low- and middle-income countries.¹⁷ It is now known that early life exposures, other than undernutrition, programme an increased non-communicable disease risk. Fetal ‘overnutrition’, the excess transfer to the fetus of glucose, lipids and other fuels when the mother is obese, gains excess weight during pregnancy, or develops gestational diabetes mellitus, causes fetal hyperinsulinism and adiposity (macrosomia, high birth weight) and this is another dominant cause of later life obesity and type 2 diabetes.¹⁸ Data from the Birth to Twenty Plus cohort showed that if a girl was obese by age five years, she is 45 times more likely to be an obese adult.¹⁹ Also, low birth weight was associated with a 10 per cent higher risk of adult impaired fasting glucose (a precursor to diabetes), and excessive weight gain from age four to the end of adolescence had a 32 per cent greater risk of impaired fasting glucose.²⁰ Therefore, ‘developmental programming’ in early life is an important contributing determinant of an individual’s biological trajectory and their long-term health.

16 Bhargava, S.K., Sachdev, H.S., Fall, C.H. & Osmond, C. 2004. Relation of serial changes in childhood body-mass index to impaired glucose tolerance in young adulthood. *New England Journal of Medicine*, 350(9), February:865-875. [https://doi.org/10.1056/NEJMoa035698]; HeLTI, 2020.

17 Hanson, M. & Gluckman, P. 2011. Developmental origins of noncommunicable disease: population and public health implications. *American Journal of Clinical Nutrition*, 94(6 Supplement):1754S-1758S. [https://doi.org/10.3945/ajcn.110.001206]; Warner & Ozanne, 2010; HeLTI, 2020.

18 Wells J.C., Sawaya, A.L., Wibaek, R., Mwangome, M., Poullas, M.S., Yajnik, C.S. & Demaio, A. 2019. The double burden of malnutrition: aetiological pathways and consequences for health. *The Lancet*, 395(10217):75-88. [https://doi.org/10.1016/S0140-6736(19)32472-9]; Warner & Ozanne, 2010; Bhargava & Sachdev, 2004.

19 Lundeen, E.A., Norris, S.A., Adair, L.S., Richter, L.M. and Stein, A.D. 2016. Sex differences in obesity incidence: 20-year prospective cohort in South Africa. *Pediatric Obesity*, 11(1):75-80. [https://doi.org/10.1111/ijpo.12039].

20 Norris, S.A., Osmond, C., Gigante, D., Kuzawa, C.W., Ramakrishnan, L., Lee, N., Ramirez-Zea, M., Richter, L., Stein, A., Tandon, N. & Fall, C.H.D. 2012. Size at birth, weight gain in infancy and childhood, and adult diabetes risk in five low- or middle-income country birth cohorts. *Diabetes Care*, 35(1):72-79. [https://doi.org/10.2337/dc11-0456].

What is the Life-Course Health and Development Framework?

Life-course frameworks have their roots in sociological research, for example, Elder's studies on the development of children affected by the Great Depression in America in the 1930s.²¹ The central thesis of this life-course framework is that "the life course of individuals is embedded in and shaped by the historical times and places they experience over their lifetime", and that "the developmental impact of a succession of life transitions or events is contingent on when they occur in a person's life".²² The Life Course Health and Development Framework ('the Framework') brings both these approaches in focus with the biopsychosocial model. The Framework is particularly useful for child and adolescent science as it recognises the complex, dynamic interaction between our biology (our genes, systems and organs) and environmental cues (our nutrition, physical and social environment).

The Framework provides public health with a powerful lens to identify opportunities for interventions and policies that can optimise life-course trajectories (see Figure 2.4). We can minimise the risk of disease (accumulative damage over time) and promote a healthier life-course trajectory, by optimising parental (both men and women) preconception health. Peak biological capacity during childhood and adolescence, for example, minimised growth faltering, maximised cognitive potential, and optimised body composition (bone, lean and fat mass) must be promoted. Peak capacity during mid-adulthood must also be maintained, and the decline in older adults (for example, maintaining healthy bone mineral density and muscle mass) minimised.

Life-course approach: implication for Africa

A life-course framework underscores intergenerational susceptibility to diseases such as obesity and non-communicable diseases. A startling recent meta-analysis demonstrated that, if a mother is obese before conceiving a baby, then her child has almost three times greater risk of being obese.²³ Consequently, there is a growing appreciation that a life-course framework can assist us to not only understand the origins of non-communicable diseases but, more importantly, identify

21 Elder Jr., G.H. 1998. The Life Course as Developmental Theory. *Child Development*, 69(1), March:1-12. [<https://doi.org/10.1111/j.1467-8624.1998.tb06128.x>].

22 Lundeen et al., 2016.

23 Heslehurst, N., Vieira, R., Akhter, Z., Bailey, H., Slack, E., Ngongalah, L., Pemu, A., Rankin, J. 2019. The association between maternal body mass index and child obesity: A systematic review and meta-analysis. *PLoS Medicine*, 16(6), June:e1002817. [<https://doi.org/10.1371/journal.pmed.1002817>].

opportunities for prevention²⁴ – such as the period of preconception (including adolescence), pregnancy and infancy to avert non-communicable disease-risk in men and women and their offspring.

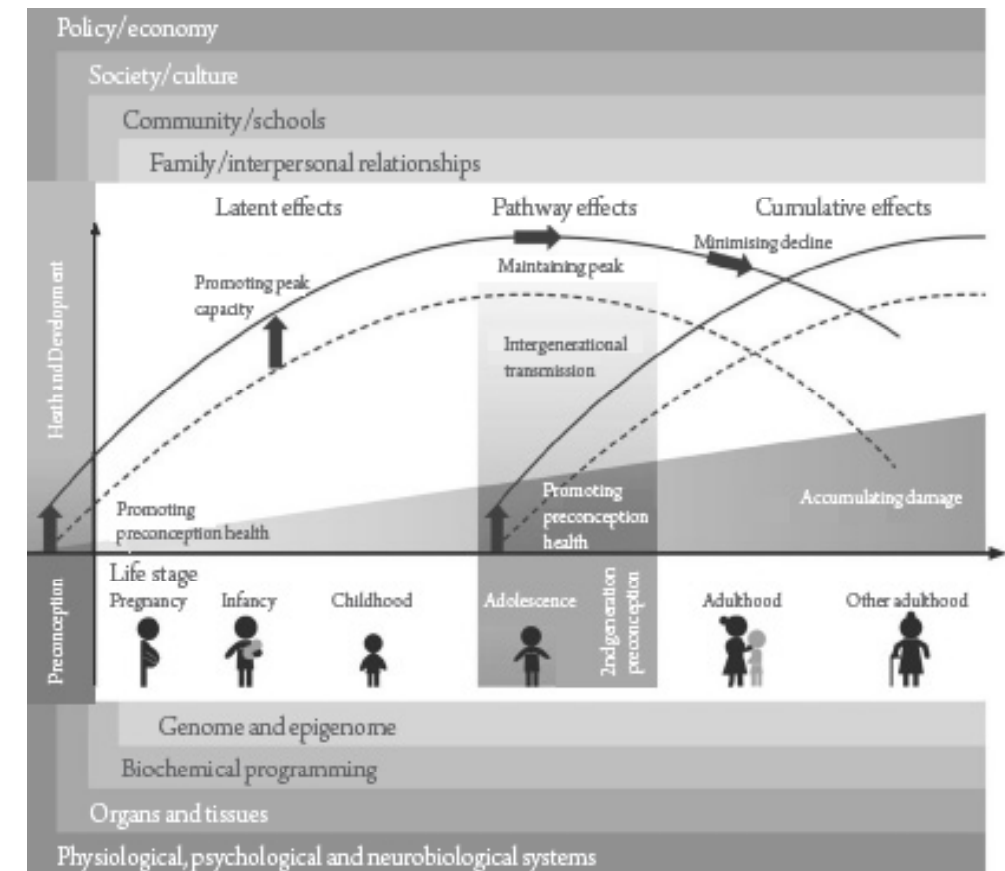


Figure 2.4 Life-course approach to optimising health and development.²⁵

24 Norris, S.A., Lakeb, L. & Draper, C.E. 2019. Child health matters: A life course perspective. In: Shung-King, M., Lake, L., Sanders, D. & Hendricks, M. (eds). *South African Child Gauge 2019*. Cape Town: Children's Institute, University of Cape Town. [<https://bit.ly/3eVgB2q>].

25 Halfon, N., Forrest, C.B., Lerner, R.M. & Faustman, E. (eds). 2018. *Handbook of Life Course Health Development*. [https://doi.org/10.1007/978-3-319-47143-3_14]; Jacob, C.M., Baird, J., Barker, M., Cooper, C. & Hanson, M. 2017. *The Importance of a Life-course Approach to Health: Chronic disease risk from preconception through adolescence and adulthood*. White Paper. WHO. [<https://bit.ly/3glivtQ>].

Conclusion

The interaction between socio-environmental cues and our biology, particularly in the earlier years, shapes our health across the life course. Better policies, healthier cities, and positive individual behavioural choices during sensitive periods of biological development can help firm up a strong foundation that will shape health across generations. To realise this possibility in Africa, we need more investment in:

- Programmes that optimise maternal, paternal and child nutrition and health, as one strategy to offset obesity and non-communicable diseases risk;
- Multisectoral collaborations across governments, civil society, academia, funding agencies and NGOs to identify solutions to complex health challenges across the life course;
- Research to identify and test solutions that build up the evidence base to bolster prevention strategies.



3

THE IMPLICATIONS OF DEVELOPMENTAL ORIGINS OF HEALTH AND DISEASE FOR AFRICA: WHAT CAN BE LEARNT FROM AVAILABLE DATA?

Peter Byass¹

There is a broad spectrum of knowledge globally that shows that specific exposures in early life – during pregnancy and early childhood – might affect what happens at various later stages of life. The scientific field behind this has become known as the developmental origins of health and disease (DOHaD). The underlying mechanisms may be complex, and understanding and analysing the epidemiology of the causes and effects are complicated. Long-term individual data, often across generations, are the best way into understanding the precise nature of such effects. Therefore, much of the research that has been done in this area has happened where detailed, individual data on health and welfare are a routine part of social structures – for example, in Scandinavian countries.

1 Stellenbosch Institute for Advanced Study (STIAS), Wallenberg Research Centre, Stellenbosch University, Stellenbosch, South Africa; Department of Epidemiology and Global Health, Umeå University, Sweden.

Nevertheless, it is reasonable to suppose similar exposures and effects might apply within African populations – the difference being that relevant details are much less likely to be documented. Since there is no quick fix for implementing data collection that spans generations, the only indirect clues as to how DOHaD may be affecting Africans is to consider how available data sources might be used in derivative analyses. In this chapter, an example is presented of taking a relationship established elsewhere between breastfeeding and obesity, applied to public-domain estimates on breastfeeding and childhood obesity in Africa, and analysed to estimate the magnitude of the likely consequences of non-breastfeeding on childhood obesity in Africa. This approach is much less rigorous than the ideal situation where specific individuals' breastfeeding histories could be related to their later individual obesity, but it offers some clues as to the likely magnitude of this particular issue in Africa, and offers a proof-of-principle for this general approach.

Introduction

The central hypothesis underlying the concept of DOHaD is that exposures to various risks in utero and early childhood – often characterised as the first 1 000 days – are key drivers of adult health and disease, and such effects may include epigenetic transgenerational inheritance.² Many examples of this have been demonstrated in populations where long-term individual health data have been collected and curated, either in longitudinal birth cohorts or in register-based national information systems. For example, a review of intergenerational studies in Australia and New Zealand found 21 studies, using intergenerational linked data on 38 600 mothers, 14 206 partners and 38 390 babies.³ In countries with long-established national register systems, such as Sweden, individual data exist in a wide range of official registers that, subject to suitable ethical considerations, can be linked and analysed with public health hypotheses and DOHaD effects.⁴

2 Heindel, J.J. 2018. The developmental basis of disease: update on environmental exposures and animal models. *Basic and Clinical Pharmacology and Toxicology*, 125(Supplement 3), August: 5-13. [<https://doi.org/10.1111/bcpt.13118>].

3 Townsend, M.L., Riepsamen, A., Georgiou, C., Flood, V.M., Caputi, P., Wright, I.M., Davis, W.S., Jones, A., Larkin, T.A., Williamson, M.J. & Grenyer, B.F.S. 2016. Longitudinal Intergenerational Birth Cohort Designs: A Systematic Review of Australian and New Zealand Studies. *PLoS ONE*, 11(3), March:e0150491. [<https://doi.org/10.1371/journal.pone.0150491>].

4 Lindgren, U., Nilsson, K., De Luna, X. & Ivarsson, A. Data resource profile: Swedish microdata research from childhood into lifelong health and welfare (Umeå SIMSAM Lab). *International Journal of Epidemiology*, 45(4), May:dyv358. [<https://doi.org/10.1093/ije/dyv358>].

In Africa, however, the situation is very different in that hardly any longitudinal data covering individual lives for 50 or more years exist. An example of a small-scale exception would be the Medical Research Council in The Gambia's data collection at the beginning of 1950, with individual follow-up in the Keneba area.⁵ The collection of health data in Africa has been mostly survey-based, and even repeated large scale surveys like the United States-sponsored Demographic and Health Surveys programme, did not attempt to revisit the same individuals in subsequent survey rounds. Although demographic and health surveys have now covered more than 40 sub-Saharan countries in over 200 cross-sectional surveys, each of which typically involved thousands of households and tens of thousands of individuals, the lack of any individual longitudinal linkages makes these data not immediately amenable to analyses of DOHaD effects.⁶

Because of the lack of ideal data for analysing DOHaD effects in Africa, attention must be given to if and how available data can be used indirectly, possibly together with other information such as outputs from large-scale modelled estimates like those produced by the Global Burden of Disease programme – to derive estimates of the impact of DOHaD effects on contemporary and future health in Africa.⁷

Conceptually characterising DOHaD and its effects

In principle, DOHaD links early-life exposures to later-life outcomes. This section sets out the concepts that might be assessed further in the African context.

An overall concept of measuring DOHaD effects

Since DOHaD is an over-arching mechanism, rather than a disease entity, there has to be consideration of wide ranges of risk exposures and disease outcomes at different stages of life, partially determined by each other, not necessarily in unique 1:1 mapping. No disease entity in adult life is likely to be uniquely caused by a specific developmental exposure, but a fraction of many disease entities could be attributable to particular earlier exposures. An overall understanding of DOHaD effects would, therefore, need to be based on estimating the attributable population

5 Rayco-Solon, P., Moore, S.E., Fulford, A.J. & Prentice, A.M. 2004. Fifty-year mortality trends in three rural African villages. *Tropical Medicine & International Health*, 9(11), January:1151-1160. [<https://bit.ly/32wZDny>].

6 Croft, T.N., Marshall, A.M.J. & Allen, C.K. 2018. Guide to DHS Statistics. *DHS-7: The Demographic and Health Surveys Program*. Rockville, Maryland, USA: ICF International. [<https://bit.ly/3hcPlyp>].

7 Blakely, T. 2018. Major strides in forecasting future health. *The Lancet*, 392, November:e14-e15. [[https://doi.org/10.1016/S0140-6736\(18\)31861-0](https://doi.org/10.1016/S0140-6736(18)31861-0)].

fractions of specific exposure-disease dyads, and then summing over all such dyads to arrive at mortality or morbidity effects attributable to DOHaD.

Figure 3.1 shows a conceptual framework for DOHaD in which the inner circle represents life stages from one generation to the next, and the marginal notes represent various examples of risk exposures, ameliorating strategies and disease outcomes. These examples are by no means exhaustive but serve as illustrations of some of the exposure-disease dyads that might need to be considered in an overall assessment of DOHaD effects.

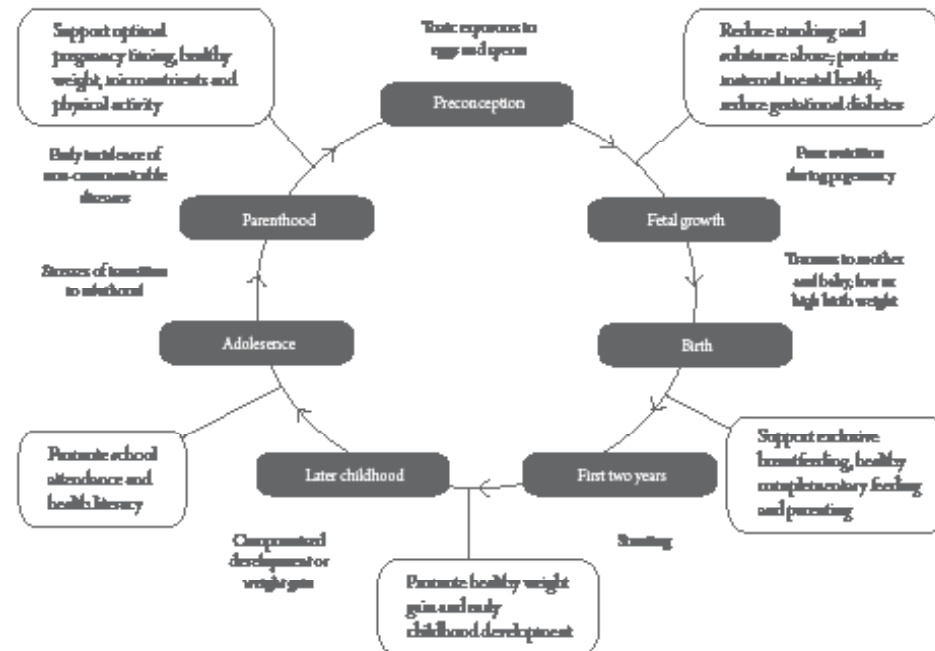


Figure 3.1 Conceptual framework for DOHaD effects with indicative examples.⁸

8 Norris, S.A., Daar, A., Balasubramanian, D., Byass, P., Kimani-Murage, A., Macnab, A., Pauw, C., Singhal, A., Yajnik, C., Akazili, J., Levitt, N., Maatoug, J., Mkhwanazi, N., Moore, S.A., Nyirenda, M., Pulliam, J.R.C., Rochat, T., Said-Mohamed, R., Seedat, S., Sobngwi, E., Tomlinson, M., Toska, E. & Van Schalkwyk, C. 2017. Understanding and acting on the developmental origins of health and disease in Africa would improve health across generations. *Global Health Action*, 10(1):1334985. [https://doi.org/10.1080/16549716.2017.1334985].

Characterising specific DOHaD exposure-disease dyads

Before considering exposure-disease dyads at the population level, each such dyad needs to be characterised in terms of what the specific exposure is; what the specific disease outcome is; and what the relative risk to an individual of the specific disease outcome is. Having established that very little is known in Africa about the specifics of DOHaD effects, there are not, in general, going to be specific data on these individual relative risks in African populations. Thus a first major assumption has to be made to proceed – that at the individual level, relative risks of DOHaD exposures as evidenced from other settings are likely to be similar for individual Africans. Making this assumption – even if it is not universally true – will allow the use of the substantial DOHaD literature from settings where more extensive data are available and have been analysed, as the basis for characterising exposure-disease dyads.

Quantifying specific exposures in African populations

A wide range of exposures may be of interest in the DOHaD context, and will generally be time-bound, both in terms of chronological time and age. Examples could include proportions of maternal alcohol consumption during pregnancy; abnormal birth weight; non-fatal birth asphyxia; and lack of breastfeeding. Some data may be available from population surveys, such as demographic and health surveys material, that cover a large proportion of Africa in a reasonably systematic way over recent decades.⁹ Age and sex-specific population proportions subject to particular exposures over a range of chronological time are needed, preferably on a country-by-country basis.

Quantifying specific disease outcomes in African populations

Disease outcomes of interest will largely fall into two categories:

- deaths in later life from particular causes, or
- long-term diseases in adult life that reduce healthy life expectancy.

In some cases, specific diseases may cause both losses of healthy years as well as leading to death. Primary data from Africa on cause-specific mortality and reductions in healthy life due to specific diseases are not generally available, but extensive outputs from modelled estimates are produced, for example by the Global Burden of Disease programme, that are also projected into the future.¹⁰

9 Blakely, 2018.

10 Ibid.

Attributing proportions of specific disease outcomes to specific exposures

The combination of retrospective survey data relating to exposures and future projections of disease outcomes create possibilities of relating exposures at a young age to outcomes at older ages. Re-using outputs from modelled estimates is methodologically somewhat risky in that the underlying assumptions of the models are not always explicit. If important assumptions were linking early life exposures to later life outcomes embedded in the estimates, methodological problems could arise in the re-analysis. However, outcomes of interest in the DOHaD context are not likely to be solely, or even mostly, driven by specific early-life exposures, and so this risk is probably not great.

A proof-of-principle example of attributing a DOHaD effect to African populations

As proof-of-principle for the concepts on assessing the effects of DOHaD exposures set out above a specific exposure-disease dyad example is presented here as an illustration. Starting from well-established relationships characterising the protective effects of breastfeeding on childhood and adolescent obesity, we will estimate the proportion of childhood obesity attributable to a lack of breastfeeding for each country in sub-Saharan Africa, over time. A meta-analysis from Harder, Bergmass, Kallischnigg and Plagemann suggests that six months of breastfeeding is associated with at least a 20 % reduction in the risk of childhood obesity.¹¹ Although that finding was not specifically linked to Africa, for this purpose, it will be assumed to be generally applicable.

Data sources

Estimates of the proportion of newborns being breastfed for at least six months, and of obesity levels during childhood and adolescence, are needed for each country in sub-Saharan Africa. Both the World Bank and the United Nations Children's Fund publish point estimates of six-month breastfeeding proportions, though the regularity of observations is patchy, depending on surveys being undertaken.¹²

- 11 Harder, T., Bergmass, R., Kallischnigg, G. & Plagemann, A. 2005. Duration of breastfeeding and risk of overweight: a meta-analysis. *American Journal of Epidemiology*, 162(5), October:397-403. [<https://doi.org/10.1093/aje/kwi222>].
- 12 The World Bank Group. 2019. Exclusive breastfeeding (% of children under 6 months). *UNICEF, State of the World's Children, Childinfo, and Demographic and Health Surveys*. [<https://data.worldbank.org/indicator/SH.STA.BFED.ZS>]; United Nations Children's Fund (UNICEF). 2018. Infant and Young Child Feeding: Exclusive breastfeeding,

Together they provide 267 country-year points for 48 countries in sub-Saharan Africa between 1985 and 2015. The Global Burden of Disease programme has created modelled estimates of obesity rates by country, year and age for the same period.¹³

Data management

For the six-months breastfeeding data, only available for country-years in which an appropriate survey was carried out, a line was fitted through the points for each country to generate a full set of country-year proportions (P_{BF6}) from 1980 to 2015. A lower limit of 0.05 of births having six-months breastfeeding was imposed as a constraint where extrapolations fell below that level. Proportions of births not having six-months breastfeeding ($P_{\text{not } BF6}$) were calculated as $1 - P_{BF6}$. Figure 3.2 shows a scatter plot of $P_{\text{not } BF6}$ estimates for 48 sub-Saharan countries from 1980 to 2015. Considerable variation exists between countries in terms of level and rate of change over time in these estimates.

- Predominant breastfeeding. *UNICEF Data: Monitoring the situation of children and women*. [<https://data.unicef.org/topic/nutrition/infant-and-young-child-feeding/>].
- 13 Institute for Health Metrics and Evaluation. 2015. Obesity and Overweight Prevalence 1980-2015. *Global Burden of Disease Study 2015*. [<http://ghdx.healthdata.org/record/global-burden-disease-study-2015-gbd-2015-obesity-and-overweight-prevalence-1980-2015>].

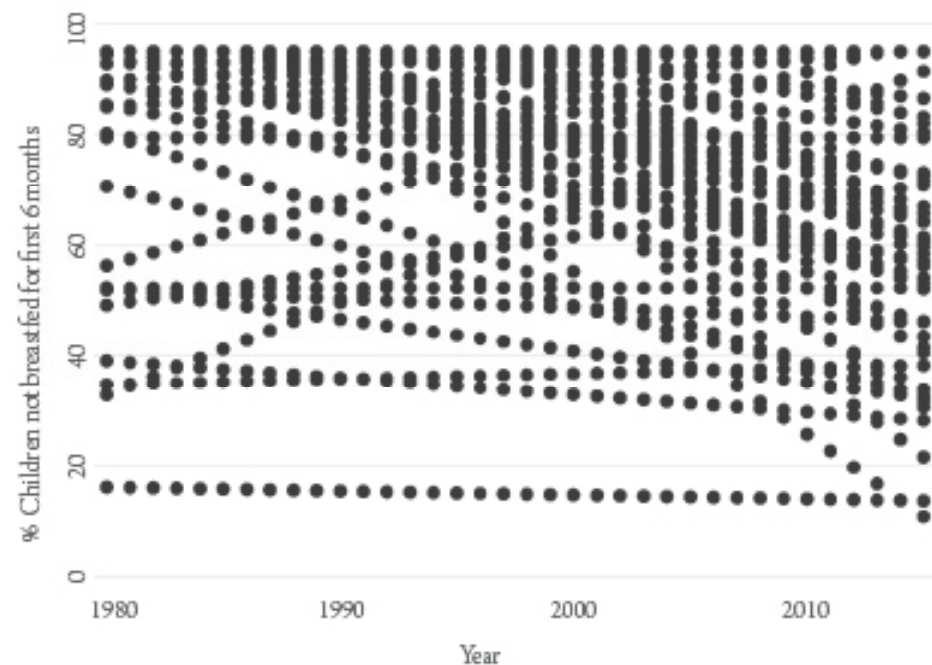


Figure 3.2 Scatter plot of the estimated proportion of children not breastfed for the first six months, for 48 sub-Saharan countries from 1980 to 2015.

From the Global Burden of Disease estimates, proportions with obesity P_{OBS} and number with obesity N_{OBS} were available for each country-year by sex and age-group (two-four years, five-nine years, 10-14 years, 15-19 years). These estimates are shown for 48 sub-Saharan countries and four age groups from 1980 to 2015 in Figure 3.3.

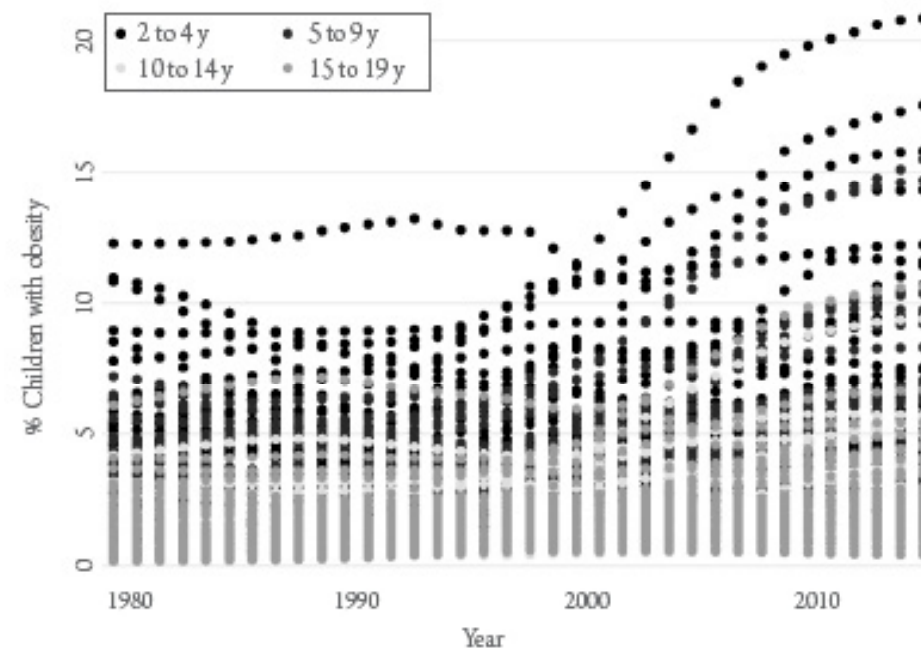


Figure 3.3 Scatter plot of the estimated proportion of children with obesity for 48 countries from 1980 to 2015.

Population in each group was calculated as N_{OBS}/P_{OBS} . Since the breastfeeding data were not available by sex, P_{OBS} and population for each country-year from 1980 to 2015 were put into a single file not disaggregated by sex.

Linking breastfeeding and childhood obesity data

The breastfeeding and childhood obesity data were merged into a single file covering 48 countries and 459 unique combinations of obesity-year and breastfeeding-year, ranging from P_{BF6} in 1980 with P_{OBS} estimated in 1982 (thus contributing to the two-four years age group) to P_{BF6} in 2013 with P_{OBS} estimated in 2015.

Attributing the effect of missed breastfeeding on the number of obese children

For each of the 22 032 records linking country, obesity-year and breastfeeding-year, the attributable population proportion can be calculated in the standard way, based on the original assumption that six-month breastfeeding leads to a 20 % reduction in childhood obesity. Thus the relative risk of obesity in the absence of six-month breastfeeding $RR_{OBS} = 1/(1-0.2) = 1.25$, and so the population proportion of obesity

attributable to not breastfeeding could be calculated for each country/obesity-year/breastfeeding-year as

$$AF_{P_!BF6} = (P_{!BF6} \cdot x (RR_{OBS} - 1)) / (1 + (P_{!BF6} \cdot x (RR_{OBS} - 1)))$$

and hence the number of children with obesity attributable to non-breast feeding could be calculated as

$$N_{OBS_!BF6} = N_{OBS} \cdot x AF_{P_!BF6}$$

Summarising the data over country, time and age-group

It is relatively straightforward to analyse those numbers for sub-Saharan Africa as a whole and specific countries and periods, having done the basic calculation of the number of child-years with obesity attributable to a lack of breastfeeding. The 22 032 records in 3.4 above were collapsed into 5 376 records representing 112 possible obesity-year by age-group combinations for each of the 48 countries. Figure 3.4 shows the % child-years with obesity for each country, by decade, together with the proportion attributable to a lack of breastfeeding.

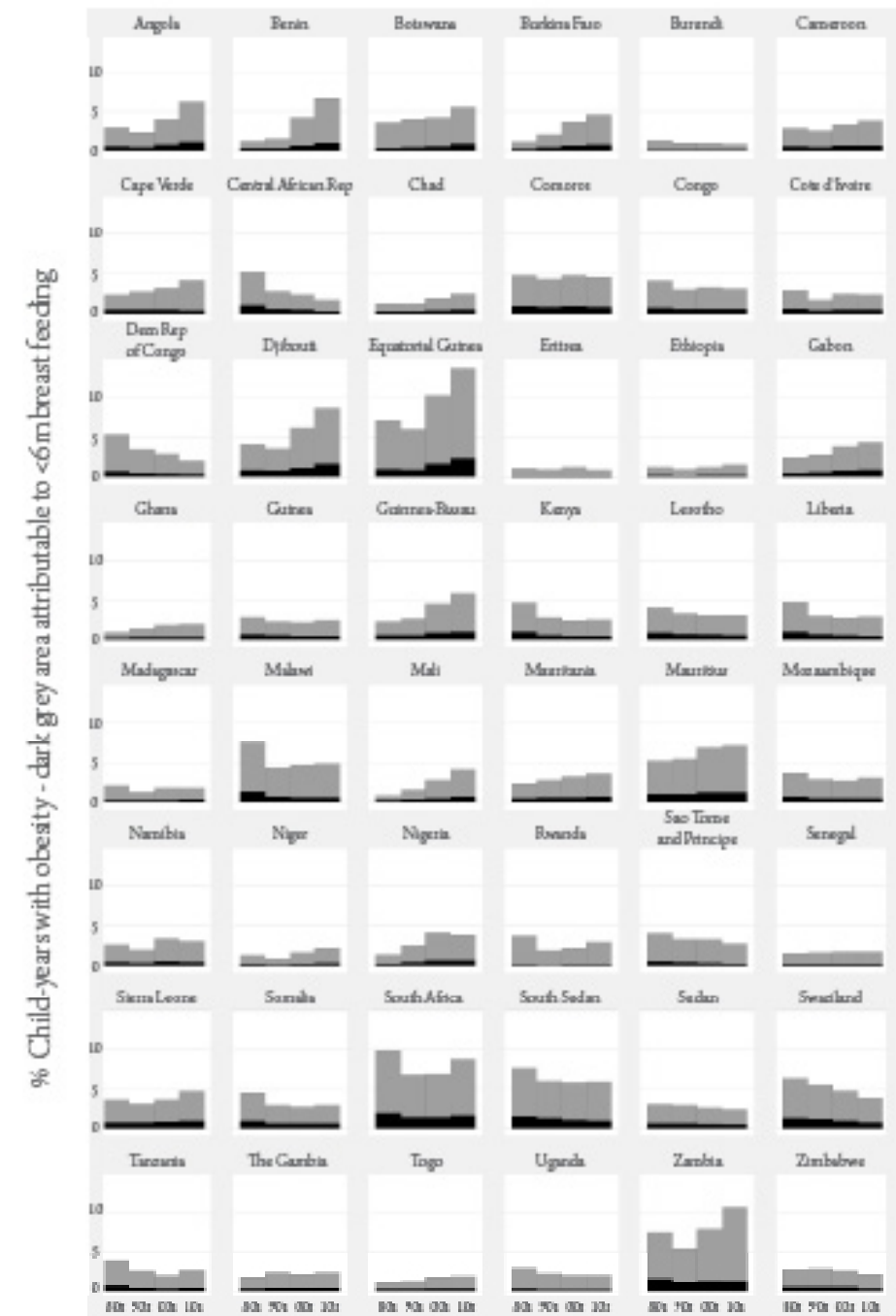


Figure 3.4 Percentage of child-years with obesity by decade for each country, with proportion attributable to lack of six-month breastfeeding.

Overall findings

The overall analysis covered 10.3 billion child-years over 48 countries during 1980-2015 (3.1 % characterised as obese; 16.1 % of obesity attributed to a lack of breastfeeding). There were considerable differences between countries, with Burundi showing the lowest proportion of obesity (0.97 %) and Equatorial Guinea the highest (10.6 %). Rwanda had the lowest proportion of obesity attributable to a lack of breastfeeding (3.6 %) and Djibouti the highest (19.1 %).

Conclusion

The proof-of-principle example shown above demonstrates the potential of bringing together such data as may be available to estimate the effects of specific exposure-disease dyads in Africa. In this case, the onset of available data for the exposure – lack of six-month breastfeeding – across Africa and a separate dataset on the disease – childhood obesity – were successfully combined to arrive at estimates of the proportion of overall child obesity that could be attributed to the lack of breastfeeding. All estimates, including the source material for breastfeeding and obesity, have to be understood in the context of the assumptions made and methods used.

In principle, a similar process could be followed for other DOHaD exposure-disease dyads, assuming that relevant data sources could be located, and thus arrive at some estimates of the total later-life burden of early life exposures. This process would be a much more complicated task than the relatively simple example for one dyad presented here.



4

MAPPING OF DEVELOPMENTAL ORIGINS OF HEALTH AND DISEASE TO 'SUSTAINABLE DEVELOPMENT GOALS' AND IMPLICATIONS FOR PUBLIC HEALTH IN AFRICA

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Sustainable development is the pathway to the future we want for all. It offers a framework to generate economic growth, achieve social justice, exercise environmental stewardship and strengthen governance
– Ban Ki-Moon, Former Secretary-General of the United Nations.⁵

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 - 5 United Nations Secretary-General. 2013. *Secretary-General's remarks at a G20 working*

A call for new approaches and knowledge systems has emerged, to map the way forward for the ‘Sustainable Development Goals’ in Africa.⁶ Public health on the continent, calls for an approach to effect changes to reach the goals proposed by the World Health Organization.⁷ It is against this backdrop that the developmental origins of health and disease (DOHaD) are proposed as a framework of implementation for specific Sustainable Development Goals.⁸

The DOHaD concept identifies the origins of health and disease, and also elucidates early mechanisms for achieving these goals. Numerous Sustainable Development Goals are specifically applicable to the DOHaD concept, and DOHaD and Sustainable Development Goals have immense synergistic potential. The chapter identifies gaps in which DOHaD may offer direct, informed solutions to the hurdles encountered in Sustainable Development Goals achievement strategies, and these have direct public health implications for the continent.

Health and Sustainable Development Goals

Health and development are inextricably linked, advocated by the evidence that investing in health is beneficial to socio-economic development. The converse is too, that socio-economic development results in not only improved health of communities but the preservation of human capital.

The United Nations proposed the ‘Sustainable Development Goals’ as a global agenda to be embraced and achieved by the 2030 target. These Sustainable Development Goals encompass 17 specific global goals which have now advanced on the predecessor, the Millennium Development Goals.⁹

dinner on ‘Sustainable Development for All’, St. Petersburg, Russian Federation, 5 September 2013. [https://bit.ly/2Ui4C7i] (Accessed 8 February 2017).

6 Sachs, J.D. 2012. From millennium development goals to sustainable development goals. *The Lancet*, 379(9832), June:2206-2211. [https://doi.org/10.1016/S0140-6736(12)60685-0].

7 World Health Organization (WHO) Commission on Macroeconomics and Health. 2001. *Macroeconomics and health: investing in health for economic development: executive summary/report of the Commission on Macroeconomics and Health*. [https://bit.ly/3pjD2F6] (Accessed 25 March 2017).

8 Gluckman, P.D. & Hanson, M.A. 2006. The developmental origins of health and disease: an overview. In: Gluckman, P.D. & Hanson, M.A. (eds). *Developmental Origins of Health and Disease*. Cambridge: Cambridge University Press. pp.1-5.

9 United Nations. 2015. *Transforming our world: the 2020 Agenda for Sustainable Development (A/RES/70/1)*. United Nations: Sustainable Development. [https://bit.ly/2EkuzOX] (Accessed 10 November 2016).

The Sustainable Development Goals (Table 4.1) are comprehensive and address four dimensions as part of the global vision for sustainable development. These are:

- Inclusive Social Development
- Environmental Sustainability
- Inclusive Economic Development
- Peace and Security

Beyond the 17 goals and 169 targets, is a greater call to action in terms of developing communities, fostering prosperity and protecting our planet, by creating lasting partnerships and developments.

Table 4.1 The Sustainable Development Goals¹⁰

Goal 1 -	End poverty in all its forms everywhere.*
Goal 2 -	End hunger, achieve food security and improved nutrition and promote sustainable agriculture.*
Goal 3 -	Ensure healthy lives and promote wellbeing for all at all ages.*
Goal 4 -	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.*
Goal 5 -	Achieve gender equality and empower all women and girls.*
Goal 6 -	Ensure availability and sustainable management of water and sanitation for all.*
Goal 7 -	Ensure access to affordable, reliable, sustainable and modern energy for all.
Goal 8 -	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.
Goal 9 -	Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation.
Goal 10 -	Reduce inequality within and among countries.*
Goal 11 -	Make cities and human settlements inclusive, safe, resilient and sustainable.*
Goal 12 -	Ensure sustainable consumption and production patterns.
Goal 13 -	Take urgent action to combat climate change and its impacts.*
Goal 14 -	Conserve and sustainably use the oceans, seas and marine resources for sustainable development.
Goal 15 -	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.
Goal 16 -	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.
Goal 17 -	Strengthen the means of implementation and revitalise the Global Partnership for Sustainable Development.
*UN Sustainable Development Goals directly relatable to DOHaD marked with an asterisk	

10 The Federal Council of Switzerland. n.d. 2030 Agenda for Sustainable Development. *Switzerland around the world*. [https://bit.ly/2EgKRsn].

Many of the interlinked Sustainable Development Goals relate, directly or indirectly, to human growth, survival and thriving, which are also the concerns of the DOHaD agenda.

The DOHaD concept

The DOHaD concept is now gaining momentum on a global scale and was initially developed from epidemiological studies of mortality from childhood, extending into adult life.

The accumulating evidence from DOHaD studies persuasively shows how early-life exposures during conception, pregnancy, infancy and childhood can have a great impact on health and disease risk in later life.

DOHaD in Africa

The Cape Town DOHaD Manifesto, compiled in 2015, summarised the major early-life exposures that might impact later health, including environmental factors, external toxins, age of the pregnancy, as well as psychological and physiological stress.¹¹

There is evidence supporting the specific impact that these stressors may have in increasing the risk for both short- and long-term illness and mortality, from both infectious diseases and chronic non-communicable diseases such as cardiovascular disease, type 2 diabetes, certain cancers, chronic lung diseases and mental illness. In particular, non-communicable conditions are on the increase in Africa.¹²

Specifically, with this focus, a four-year initiative at the Stellenbosch Institute for Advanced Study (STIAS) titled, *DOHaD and SDGs: Moving Towards Early*

Implementation in Africa, has led to progress.¹³ Part of the impetus for this work came from a DOHaD summit held in Cape Town in 2015, captured in the Cape Town DOHaD Manifesto.¹⁴

The collaborative thinking generated from meetings at STIAS in 2016 strongly supported the approach to the implementation of Sustainable Development Goals and DOHaD simultaneously, with DOHaD supporting countries in prioritising areas of concern, including

- the closure of the policy-implementation gap;
- setting interim targets to enhance political accountability;
- transforming interim targets into specific three-five-year action plans;
- strengthening monitoring frameworks that reflect the interconnectedness of Sustainable Development Goals in an integrated manner; and
- the cost of action plans to inform national budgets.¹⁵

Further, it should be possible to jointly monitor and evaluate implementation – which would, therefore, support the design of interventions that serve both Sustainable Development Goals and DOHaD.

The examples illustrated in Table 4.2 reflect just a few of the many that link DOHaD and Sustainable Development Goals. It displays how these developmental insights can be made to support each other. In applying these principles, the expected enhancement of human capital may lead to lasting positive change for people and the planet.

11 International Society for developmental origins of health and disease (DOHaD). 2015. The Cape Town Manifesto – November 2015: A healthy start builds a bright future. *International Society for DOHaD*, Cape Town. [<https://bit.ly/3aJwzFD>] (Accessed 10 November 2016).

12 BMC Public Health. 2017. *Physical activity and overweight/obesity among Malaysian adults: findings from the 2015 National Health and morbidity survey*, 21 September. [<https://bit.ly/3aHqeRW>]; Chatora, R. 2016. Health in SDGs: would an SDG linked approach help? Personal communication, September; Kim Streatfield, P., Khan, W.A., Bhuiya, A., Hanifi, S.M., Alam, N., Bagagnan, C.H., Sie, A., Zabré, P., Lankoandé, B., Rossier, C. & Soura, A.B. 2014. Adult non-communicable disease mortality in Africa and Asia: evidence from INDEPTH Health and Demographic Surveillance System sites. *Global Health Action*, 7, October:25365. [<https://doi.org/10.3402/gha.v7.25365>].

13 Daar, A., Balasubramanian, D. & Byass, P. 2016. *DOHaD and SDGs: moving towards early implementation*. [<https://bit.ly/2EpVvws>] (Accessed 12 January 2017).

14 International Society for DOHaD, 2015.

15 Norris, S.A., Daar, A., Balasubramanian, D., Byass, P., Kimani-Murage, E., Macnab, A., Pauw, C., Singhal, A., Yajnik, C., Akazili, J., Levitt, N., Maatoug, J., Mkhwanazi, N., Moore, S.E., Nyirenda, M., Pulliam, J.R.C., Roachat, T., Said-Mohamed, R., Seedat, S., Sobngwi, E., Tomlinson, M., Toska, E. & Van Schalkwyk, C. 2017. Understanding and acting on the developmental origins of health and disease in Africa would improve health across generations. *Global Health Action*, 10(1):1334985. [<https://doi.org/10.1080/16549716.2017.1334985>].

Table 4.2 Mapping the Sustainable Development Goals which directly relate to the DOHaD concept

Sustainable Development Goal (SDG) ¹⁶	Potential DOHaD interventions	Advantages	Examples
Eliminate poverty	<ul style="list-style-type: none"> Early reproductive education Early childhood development Promote school attendance and health literacy 	<ul style="list-style-type: none"> Child spacing, planned parenthood, mothers able to balance work Enhanced employment opportunities 	<ul style="list-style-type: none"> Micro-clinics in Nairobi slums¹⁷ Health information for migrants: a pilot project to increase health information accessibility for migrants in Vietnam¹⁸
Eliminate hunger	<ul style="list-style-type: none"> Promote Breastfeeding programmes Encourage nutritionally balanced complementary feeding Improve community environment for food growth 	<ul style="list-style-type: none"> Access to highly nutritious and immune-supportive food for new-borns Decrease financial burden of bottle-feeding cost on poor families Low-cost fresh produce from community 	<ul style="list-style-type: none"> Saving Brain initiatives¹⁹ Perinatal vitamin supplementation²⁰
Good health	<ul style="list-style-type: none"> Maternal-child bonding Focus on first 1 000 days of life Promote good antenatal care Teach young mothers and fathers about alcohol and smoking effects 	<ul style="list-style-type: none"> Increased mental and physical capacity of the youth Decreased burden of disease due to poor ante-, peri- and postnatal care Limiting the incidence of foetal alcohol syndrome/respiratory disease 	<ul style="list-style-type: none"> A community-based model of delivery of Kangaroo Mother Care for improving child survival and brain development in low-birthweight newborns²¹

Sustainable Development Goal (SDG) ¹⁶	Potential DOHaD interventions	Advantages	Examples
Quality education	<ul style="list-style-type: none"> Early access to mental stimulation and eye-contact (first 1 000 days) Promote access to books and toys to increase brain development Inform and educate parents on pro-social behaviour 	<ul style="list-style-type: none"> Improved mental capacity and social development Achievement of fine and gross motor development On-going supportive environment to learn life skills 	<ul style="list-style-type: none"> Health-Promoting Schools²²
Gender equity	<ul style="list-style-type: none"> Reproductive Health Education Increased employment opportunities for women Supportive work environment for female employees Equal gender schooling access 	<ul style="list-style-type: none"> More equitable society Improved gender relations Enhanced social cohesion 	<ul style="list-style-type: none"> ZanaAfrica – Safe, quality and affordable sanitary pads for women and girls in East Africa²³
Clean water and sanitation	<ul style="list-style-type: none"> Encourage good hygiene practices, hand-washing and appropriate waste disposal Increase recycling of waste 	<ul style="list-style-type: none"> Decreased environmental toxins Prevention of spread of diarrheal disease Decrease child mortality 	<ul style="list-style-type: none"> Peepoo: a biodegradable toilet²⁴ turning human waste into valuable fertiliser²⁵

16 WHO, 2017.

17 McKague, K., Menke, M. & Arasaratnam, A. 2014. Access Afya: micro-clinic health franchise designed for scale. In: Alon, I. (ed). *Social Franchising*. Kings Cross, London: Palgrave Macmillan. pp.61-79.

18 Munuswamy, S. 2016. Mobile App for accurate and simple Disability Assessment and Support. *Grand Challenges Canada*. [www.grandchallenges.ca/grantee-stars/0649-01-10/] (Accessed 12 January 2017).

19 Sanner, T.A., Roland, L.K. & Braa, K. 2012. From pilot to scale: towards an mhealth typology for low-resource contexts. *Health Policy Technology*, 1, September:155-164. [https://doi.org/10.1016/j.hlpt.2012.07.009].

20 Harvard University. 2020. Saving brains. *Center on the Developing Child*. [https://bit.ly/2QanbIB] (Accessed 12 January 2017).

21 McKague, Menke & Arasaratnam, 2014.

22 WHO. 2013. *What is a health promoting school?* [https://bit.ly/311Ovdn] (Accessed 10 October 2016). See also West, P., Sweeting, P. & Leyland, A. 2004. School effects on pupil's health behaviours: evidence in support of health promoting school. *Research Papers in Education*, 19(3), September:261-291. [https://doi.org/10.1080/02671522.2004.10058645].

23 Roenen, C. 2016. Working with microfinance clients to increase access to affordable and reliable healthcare. *Grand Challenges Canada*. [https://bit.ly/3eS1TuS] (Accessed 14 March 2017). See also Mukuria, M. 2012. *Expanding women's access to safe, affordable sanitary pads from renewable resources*. [https://bit.ly/3eQlg7t] (Accessed 12 January 2017).

24 Vinneras, B., Hedenkvist, M., Nordin, A. & Wilhelmson, A. 2009. Peepoo bag: self-sanitising single use biodegradable toilet. *Water Science & Technology*, 59(9), February:1743-1749. [https://doi.org/10.2166/wst.2009.184].

25 Dua, T., Tomlinson, M., Tablante, E., Britto, P., Yousfzai, A., Daelmans, B., Darmstadt, G.L. 2016. Global research priorities to accelerate early child development in the sustainable development era. *Lancet Global Health*, 4(12), October:e887-889. [https://doi.org/10.1016/S2214-109X(16)30218-2 2016].

Sustainable Development Goal (SDG) ¹⁶	Potential DOHaD interventions	Advantages	Examples
Reduced inequalities and social protection	<ul style="list-style-type: none"> Assess and support disabled individuals Support policies which encourage reporting of social injustices Strict anti-abuse legislation 	<ul style="list-style-type: none"> More actively involved community members Decreased burden of mental illness and psychological disorders 	<ul style="list-style-type: none"> Mobile App for accurate and simple Disability Assessment and Support²⁶
Make cities and human settlements inclusive, safe, resilient and sustainable ²⁷	<ul style="list-style-type: none"> Increase access to basic services through micro-clinics Mental health support Microfinance structures 	<ul style="list-style-type: none"> Sustainable economic growth Equal access to resources Equal participation and decision-making Gender Equality 	<ul style="list-style-type: none"> Working with microfinance clients to increase access to affordable and reliable healthcare²⁸

Links between DOHaD and Sustainable Development Goals

While it can be seen that DOHaD evidence interlinks with many of the Sustainable Development Goals, particularly strong examples can be found in the context of Goal 2 – to end hunger, achieve food security, improve nutrition and promote sustainable agriculture.²⁹

The evidence surrounding breastfeeding and the first 1 000 days of life represents ‘low-hanging fruit’ in our targets to improve childhood development, but the incentives to improve this component of DOHaD are considerable. However, there is a legitimate concern that to date there has been a disproportionate focus on women as the stakeholders of their children’s future health and wellbeing, and

as those primarily responsible for being the ‘agents of change’ for improved health in the next generation.³⁰

There is good reason to be more inclusive than at present during knowledge transfer related to DOHaD. At the same time, fathers are integral to achieving change, and engaging both genders, together, particularly in youth-focused initiatives such as the WHO’s Health-Promoting School-based programmes is overdue. Evidence shows an interest in youth for aspects of the DOHaD agenda (e.g. the fact that a healthy child will earn more in their lifetime than an unhealthy one).³¹ Dialogue in schools can identify what ‘messages’ and which ‘messengers’ are likely to resonate with young people. A school-based programme promoting nutrition can translate into improvements in recipients’ health literacy. Hence, it is likely that greater awareness and understanding of DOHaD concepts are possible in particular, as well as improvement in general self-efficacy and a young person’s potential to achieve health-related goals. This understanding applies particularly to nutrition and food security. Schools that include pupil participation in garden projects have shown that such activities can enhance academic performance and contribute in a positive way to the acquisition and practice of multiple life skills, including several related to improved nutrition and the ability to achieve greater food security.³²

Another target with particular promise is Kangaroo Mother Care, so-called because this form of caregiving resembles marsupial care, as the mother holds her newborn infant clad only on a diaper against the skin of her chest with a cover wrapped around the pair.³³ Continuous periods of this type of skin to skin contact in the first hours of life are known to have neuroendocrine effects that benefit them both. For the mother, this applies particularly in the context of lactation and improved bonding behaviour, and for the infant better weight gain occurs, brain development

26 Bhutta, Z.A., Das, J.K., Rizvi, A., Gaffey, M.F., Walker, N., Horton, S., Webb, P., Lartey, A. & Black, R.E. 2013. Evidence-based interventions for improvement of maternal and child nutrition: what can be done and at what cost? *The Lancet*, 382(9890), June:452-477. [https://doi.org/10.1016/S0140-6736(13)60996-4].

27 MENA. 2018. *United States: UN-Habitat and GGGI Collaborate to Promote Cooperation on Sustainable and Green Urban Development*. MENA Report. London: Albawaba.

28 Barros, A.J. & Ewerling, F. 2016. Early childhood development: a new challenge for the SDG era. *Lancet Global Health*, 4(12), December:873-874. [https://doi.org/10.1016/S2214-109X(16)30298-4].

29 United Nations Secretary-General. 2013. Secretary-General’s remarks at a G20 working dinner. See also Kajee, N., Sobngwi, E., Macnab, A. & Daar, A.S. 2018. The Developmental Origins of Health and Disease and Sustainable Development Goals: mapping the way forward. *Journal of Developmental Origins of Health and Disease*, 9(1), August:5-9. [https://doi.org/10.1017/S2040174417000630].

30 Pentecost, M., Macnab, A.J., Mayekiso, A. & Ross, F. 2018. Beyond the dyad: making Developmental Origins of Health and Disease (DOHaD) interventions more inclusive. *Journal of Developmental Origins of Health and Disease*, 9(1), August:10-14. [https://doi.org/10.1017/S2040174417000629]; Richardson, S.S. 2014. Don’t blame the mothers: careless discussion of epigenetic research on how early life affects health across generations could harm women, warn Sarah S. Richardson and colleagues. *Nature*, 512(7513):131-133. [https://bit.ly/35k8r1U].

31 Macnab, A.J. & Mukisa, R. 2017. Priorities for African youth to engage in the DOHaD agenda. *Journal of Developmental Origins of Health and Disease*, 9(1), June:15-19. [https://doi.org/10.1017/S2040174417000423].

32 Henry Doubleday Research Association. 2012. Food Growing in Schools – Taskforce Report. *Garden Organic*. Full Report. 1-66. [https://bit.ly/3aLNy0S].

33 Conde-Agudelo, A., Belizán, J.M. & Diaz-Rossello, J. 2012. Kangaroo mother care to reduce morbidity and mortality in low birth weight infants. *Cochrane Systematic Review*, 3(2), February:CD002771. [https://doi.org/10.1002/14651858.CD002771].

is improved in low-birth-weight newborns and even beneficial effects as a pain-relieving strategy and on long-term survival occur.³⁴ As evident in developing settings that this approach offers multiple benefits, the probability is that in the long term, Kangaroo Mother Care optimises human potential by up-scaling factors such as performance at school and long-term employment income. Discussion among the STIAS long-term theme group on DOHaD has advocated exploring the potential benefits of including 30 minutes of Kangaroo Mother Care for fathers after the birth of their child, another important opportunity to be inclusive in the context of DOHaD, and underscore that there are opportunities for both genders to contribute to an infant's future health and emotional and social wellbeing. Again, neuroendocrine arguments support this concept. Beneficial changes in paternal behaviour appear to occur; there is preliminary data based on differences in pre/post-Kangaroo Mother Care prolactin levels that such changes may reflect dopamine release. Certainly, many fathers who experience Kangaroo Mother Care are more attentive to their infant's needs in the first weeks of life and appear to bond better with their offspring. Some fathers have reported feeling more love for their infants after Kangaroo Mother Care. Hence, it is a feasible hypothesis related to the recognised need for greater support within households for mothers to breastfeed, that Kangaroo Mother Care by fathers may translate into improved nutrition and more desirable patterns of weight gain for infants during at least part of the first 1 000 days.

Such approaches are especially important, given that today approximately 200 million children residing in developing countries will never reach their inherent developmental potential. We argue that now is the time to change this harrowing statistic, and suggest that measures to improve maternal and infant nutrition and engage fathers to contribute to this end have a scientific basis, and should be made a priority in educational and care strategies aimed at addressing the DOHaD agenda.

However, we recognise that governments, policymakers and non-governmental organisations must unite to use evidence relating to Africa to effect such change, support DOHaD-related initiatives, and in turn, advance towards the national achievement of the Sustainable Development Goals.

Public health implications in Africa

The Sustainable Development Goal targets for 2030 require substantial vision, political commitment and well-planned and well-articulated measures to address these public health challenges, particularly in Africa where communities' lives are

34 Moore, E.R., Anderson, G.C., Bergman, N. & Dowswell, T. 2016. Early skin-to-skin contact for mothers and their healthy newborn infants. *Cochrane Systematic Review – Intervention*. [<https://doi.org/10.1002/14651858.CD003519.pub4>].

reliant on the changes we need to effect. Our proposed Sustainable Development Goals-DOHaD-linked strategy lends itself to joint problem identification and problem-solving. In this effort, advancing ideas that tackle root causes and result in high-impact positive changes will be essential.

Joint action to advance the DOHaD message of health promotion and the challenge of meeting specific Sustainable Development Goals requires the engagement of multiple agencies and groups in society to address core issues of both DOHaD and the goals and assess where interests overlap. Similarly, parallel dialogue can explore strategies required to advance the agendas, and identify the processes for effective engagement of all contributing agencies – many of which may well not have worked together previously.

In terms of governments, there is a compelling economic case to be made for DOHaD. The costs and the benefits of prevention via DOHaD-informed early-life intervention versus the reality of spiralling costs of care for managing the same preventable diseases in later life is convincing. There are benefits of scale and reduction of duplication that can be obtained by combining the DOHaD and Sustainable Development Goals agendas. Ministries tend to work in silos in many situations, often asking for budgets without considering potential cost-savings achievable through the development of national-level cross-cutting programmes. An example of such a national-level programme could quite easily be based on a joint Sustainable Development Goals-DOHaD strategy.

Involving non-governmental organisations and agencies in an early-advocacy approach through 'Calls for Action' which argument for the DOHaD-approach based on several different types of evidence, is a useful tool to effect change on a grass-root level.

Further, curricula changes are fundamentally important to promote research going forward, and to fuel social development, especially in the African context. With this in mind, the STIAS and the African Academy of Sciences are jointly helping to build a network of young research scholars to advance DOHaD science in Africa.

There is a remarkable variance between African countries in terms of health statistics, and research output aimed at improving these statistics. Healthcare professionals and the media represent key role players in terms of developing health promotion surrounding DOHaD-Sustainable Development Goals initiatives. The current lifestyle change healthcare focus, particularly in adult life, to address known chronic non-communicable disease risk factors such as diet, physical activity, tobacco smoking and abuse of alcohol is relatively unsuccessful.³⁵ On the whole,

35 Walker, S.P., Wachs, T.D., Gardner, J.M. & Lozoff, B. 2007. Child development:

conditions such as type 2 diabetes, cardiovascular disease, chronic lung diseases and certain cancers are on the rise in many parts of the world.

Upstream medical thinking is crucial for medical practitioners, and yet many medical doctors have not heard of the evidence supporting the DOHaD paradigm. There must be a shift in the knowledge and awareness of this group, for the constituency could play a crucial role in implementing and disseminating the message through contact with their patients, and by acting as champions advocating for change for both the DOHaD agenda and progress towards achieving Sustainable Development Goals.

Educators have a role to play. An innovative approach to doing this in Africa could be to use the WHO's 'Health-Promoting School' model to effect change and engage youth in DOHaD-related health promotion. In some African countries, notably Uganda and Tanzania, school-based programmes show promise, and an advantage is that they principally require a change in mindset and the energy of a local champion to make them happen, rather than the provision of large budgets and major policy change.³⁶ However, in many countries in sub-Saharan Africa, and South Africa, in particular, there is currently a problem with morale amongst teachers, and even the delivery of conventional curriculum and provision of basic educational services to children break down regularly. Consequently, without fundamental changes throughout the system, making a move to initiate even something as relatively straightforward as the WHO Health-Promoting School programme model is simply not feasible.

What is encouraging within the realm of education is that pilot studies indicate that school children can be engaged through in-class debates on matters related to DOHaD. In these sessions, once introduced to basic facts about DOHaD, school children can articulate where they see issues that are relevant to them and choose from options on how to learn about them, the ones which they see as most interesting and potentially engaging. A big advantage of the school setting is the vast number of children within sub-Saharan Africa who could receive health promotion education if innovative, evidence-based, and practical programmes were developed and made widely available. In addition to the pilot work in Africa, an excellent programme model exists in New Zealand called LENSscience, a school-based programme that primarily targets children in secondary schools and

risk factors for adverse outcomes in developing countries. *The Lancet*, 369(9556), February:145-157. [https://doi.org/10.1016/S0140-6736(07)60076-2].

36 Macnab, A.J., Stewart, D. & Gagnon, F. 2014. Health Promoting Schools: Initiatives in Africa. *Health Education*, 114(4), May:246-259. [https://doi.org/10.1108/HE-11-2013-0057].

one that has addressed the prevention of transgenerational conditioning of non-communicable diseases.³⁷ Participants, as in the African pilots, are guided through discussion where they consider with the help of tools related to DOHaD-based evidence how their diet and lifestyle choices impact their health and wellbeing. A key outcome is that they come to learn that their choices have long-term health effects as well as an impact on their immediate wellbeing. The hope (and initial impression from evaluation) is that this improvement in 'health literacy' (the ability to make sense of evidence related to health), imbues a lasting 'self-efficacy' (the confidence to exert control over one's behaviour and life and social environment). Both health and science literacy and ability over self-efficacy are independent predictors of better health and greater capacity for positive behavioural change, and the 'essence' and 'lifeblood' of what is required in initiatives to drive change related to DOHaD and progress towards attainment of the Sustainable Development Goals.³⁸

Conclusion

Of the 17 Sustainable Development Goals, at least eight can be mapped directly to the DOHaD approach, and DOHaD mapping to the relevant goal demonstrates the synergistic potential for avenues to implementation.

Currently, the DOHaD interventions being proposed within Africa represent an opportunity to focus on early childhood development and must include a call to policymakers, governance bodies, and researchers to prioritise opportunities for disease prevention.

"Children are every nation's future", and Africa's youth have most to gain from all and any success in reducing the burden of non-communicable diseases and achieving the Sustainable Development Goals, and most to lose from not being engaged effectively in the DOHaD and Sustainable Development Goal agendas.³⁹

Dissemination of DOHaD science and health promotion could be the catalyst that helps many of the Sustainable Development Goals to become achievable. Increasing global recognition of the importance of DOHaD may be the driver for

37 Bay, J.L., Mora, H.A., Sloboda, D.M., Morton, S.M., Vickers, M.H. & Gluckman, P.D. 2012. Adolescent understanding of DOHaD concepts: a school-based intervention to support knowledge translation and behaviour change. *Journal of Developmental Origins of Health and Disease*, 3(6), December:469-482. [https://doi.org/10.1017/S2040174412000505].

38 Carbone, E. & Zoellner, J. 2012. Nutrition and health literacy: a systematic review to inform nutrition research and practice. *Journal of the Academy of Nutrition and Dietetics*, 112(2), February:254-265. 2012. [https://doi.org/10.1016/j.jada.2011.08.042].

39 Meds & Food for Kids. 2020. *Anemia & malnutrition*. [https://mfkhaiti.org/anemia/].

change required to advance the Sustainable Development Goal agenda, and taking action to address both DOHaD and the Sustainable Development Goals will be central to whether sustainable public health solutions are found for many of the most pressing societal issues facing Africa.



5

RELATION BETWEEN FAMINE AND HEALTH IN FUTURE GENERATIONS: POTENTIAL KNOWLEDGE TRANSLATION TO AFRICA

Tessa J Roseboom¹

Nutrition provides the essential building blocks for human health. Although there is enough food on the planet to feed all its inhabitants, inequality in access to food poses serious threats to humanity. Poor nutrition, especially during critical periods of human development, permanently affects the structure and function of organs with lasting adverse consequences for an individual's susceptibility to disease, not only affecting the individual but society as a whole with considerable loss of human capital.

This chapter summarises the evidence from studies investigating the effects of prenatal exposure to the Dutch famine on later mental and physical health.

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The Dutch famine of 1944-1945 was remarkable in several ways, and its unique features have contributed to the fact that the Dutch famine has most often been used in studies examining the long-term consequences of prenatal undernutrition. The Dutch famine was an acute period of undernutrition that was circumscribed in time and place; it had an abrupt beginning and end and struck a population that was previously and subsequently well nourished. Also, the administration was well organised, and records were kept allowing researchers to investigate the consequences of starvation in the decades that followed.

While the acute effects of famine are devastatingly apparent in most cases, the effects of famine for those as yet unborn may not become apparent until decades later. Prenatal famine exposure increases the risk of chronic degenerative diseases and mental health problems. It not only increases health care costs but also puts an extra burden on the economy by decreasing human capital. In this way, famine leaves lasting marks on populations – even for generations to come, highlighting the importance of securing access to food for all, with particular relevance for Africa – with a rapidly growing population and intense urbanisation. Food security for all should remain a priority, as food is essential for the health and wealth of the population today and generations of the future.

Famine and its occurrence in time and place

Food is of fundamental importance to human health. The availability of food has varied in time and place. Throughout history, famines have plagued society. Every inhabited continent in the world has experienced a period of famine in the past. Famines were commonplace across the world, but in the last decades, Africa has been struck by famine more than other continents. Since 2010, Africa has been the most affected continent in the world. Despite tremendous efforts in combatting hunger as part of the Millennium Development Goals, in 2017, the UN officially declared famine had returned to Africa, with about 20 million people at risk of death from starvation in Nigeria, in South Sudan, in Yemen, and Somalia.²

There are several complex and interrelated factors contributing to Africa's vulnerability to food insecurity. The majority of Africans are directly dependent on subsistence farming on a continent that is prone to extreme natural disasters, including severe drought and floods. These natural disasters lead to failed crops, as well as insufficient pasture feed and water for livestock. In addition, the majority of African countries facing food insecurity are experiencing internal conflict, impeding both access to food and food production. Moreover, the African region also has the lowest per capita income in the world and the highest poverty levels,

² Wikipedia. 2020. Famine. [<https://en.wikipedia.org/wiki/Famine>].

meaning that a high dependence on food imports increases their vulnerability to fluctuations in food prices. The vicious cycle of poverty and undernutrition has proven to be difficult to break.

Hunger in an age of plenty

Poor diets, due to insufficient, imbalanced or excessive intakes of nutrients, can impair growth and development and induce disease. Today the world faces a double burden of malnutrition that includes both under-nutrition and over-nutrition.³ Counterintuitive as it may seem, both undernutrition and overnutrition are reducing the health of millions of individuals around the globe. Hunger and inadequate nutrition contribute to early deaths for mothers, infants and young children, and account for more losses of life than Aids, malaria and tuberculosis combined.⁴ Deficiencies in the diets of children can impair growth and development and lead to stunting and wasting in childhood while deficiencies in adulthood can lead to blindness, scurvy or anaemia. Such cases are most often seen in developing countries, while in developed countries, the consequences of imbalanced or excessive diets lead to obesity, diabetes and cardiovascular diseases.

The evidence presented in this chapter shows that the consequences of undernutrition may not be limited to the individuals suffering from undernutrition. Undernutrition before birth profoundly affects fetal growth, development and health. Those most affected by undernutrition may indeed be those as yet unborn during a famine. The consequences are apparent throughout the life-course and might even extend into the following generation. Similarly, imbalances in prenatal nutrition caused by maternal obesity and gestational diabetes can also negatively affect offspring's health.

The Dutch famine as a model to test the DOHaD hypothesis

Every living creature is plastic and able to adapt to its environment. Adaptations to the environment during the earliest stages of development have profound implications for further development, growth and health of the individual. The notion that maternal diet, metabolism and stress during pregnancy have lasting effects on the health of the offspring has been supported by a strong solid scientific evidence base from various scientific disciplines.⁵ The hypothesis that

³ World Health Organization (WHO). 2020. Nutrition: Challenges. *WHO Health Topics*. [<https://www.who.int/nutrition/challenges/en/>].

⁴ Ibid.

⁵ Barker, D., Barker, M., Fleming, T. & Lampl, M. 2013. Developmental biology: Support

undernutrition in utero permanently changes the body's structure, function and metabolism in ways that lead to chronic degenerative disease in later life was formulated based on epidemiological studies consistently showing small size at birth was linked to higher disease risk in later life.⁶ Small size at birth was taken as an indication of reduced fetal growth due to limited supply of nutrients to the fetus.⁷ Animal studies have experimentally shown that restricted fetal nutrition indeed induces adaptations that lead to altered structure and function of organs, increased rates of disease and shortened lifespan.⁸ However, the experimental evidence for the hypothesis in humans is impossible to obtain.

While famine is sadly not uncommon in many parts of the world, studying effects of undernutrition during pregnancy is hampered by the fact that undernutrition is usually not restricted to pregnancy alone, and effects of chronic undernutrition and accompanying problems of infection complicate the situation. The tragic circumstances of the Dutch famine of 1944-1945 created a unique opportunity to assess the effects of prenatal famine exposure on health in later life. The Dutch famine has been used by various investigators as an equivalent to an experimental set-up to investigate the effects of prenatal undernutrition in humans. What is unusual about the Dutch famine is:

- that the famine was imposed on a previously well-nourished population;
- there were sudden onset and relief from the famine; and
- despite the adversities of the war, midwives and doctors continued to offer professional obstetric care and kept detailed records of the course of pregnancy, the delivery and the size and health of the baby at birth.⁹

Furthermore, detailed information is available on the weekly rations provided during the famine, and in several inflicted cities birth records were kept which

mothers to secure future public health. *Nature*, 504(7479), December:209-211. [<https://doi.org/10.1038/504209a>].

6 Barker, D.J. 2007. The origins of the developmental origins theory. *Journal of Internal Medicine*, 261(5), June:412-417. [<https://doi.org/10.1111/j.1365-2796.2007.01809.x>].

7 Ibid.

8 Ozanne, S.E. & Constância, M. 2007. Mechanisms of disease: the developmental origins of disease and the role of the epigenotype. *Nature Clinical Practice Endocrinology & Metabolism*, 3(7), August:539-546. [<https://doi.org/10.1038/ncpendmet0531>].

9 Roseboom, T.J. 2019. Epidemiological evidence for the developmental origins of health and disease: effects of prenatal undernutrition in humans. *Journal of Endocrinology*, 242(1), July: T135-T144. [<https://doi.org/10.1530/JOE-18-0683>].

allowed researchers to trace those born around the time of the famine and thus to study the long-term effects of prenatal famine exposure.¹⁰

The historical course of events that led to the Dutch famine 1944-1945

After the invasion of the Allied forces on June 6, 1944, a few weeks of heavy fights followed. Then, the Allied forces finally broke through German lines. Quickly, the Allied troops took possession of France, Luxembourg and Belgium. By September 4, 1944, the Allies had the strategic city of Antwerp in their hands, and on the 14th they entered the Netherlands.¹¹ The Dutch expected that the German occupation would soon be over, and so did the commanders of the Allied forces. Hoping to capture strategic bridges across the river Rhine to open a pathway for rapid invasion into Germany, the Allied forces launched a parachute attack behind the Nazi forces near the city of Arnhem.¹² However, the operation failed with significant losses. Operation Market Garden had failed. Subsequently, the Dutch government called for a strike of the Dutch railways to support the Allied offensive. As a reprisal, the Germans banned all food transports. The food situation in the western part of the Netherlands worsened dramatically. Food stocks ran out rapidly, and soon rations for adults dropped to below 1 000 calories a day.¹³ The embargo on food transports was lifted in early November 1944, when food transport across the water was permitted again. Because most canals and waterways were frozen due to the early and extremely severe winter, it had become impossible to bring in food from the rural east to the urban west of the Netherlands.¹⁴ Food rations declined to extremely low levels between February and May 1945, with daily rations varying between 400 and 800 calories a day. During the famine, infants were relatively protected, because their official daily rations never fell below 1 000 calories. Pregnant and lactating women were entitled to an extra amount of food, but at the peak of the famine, these extra supplies could not be provided anymore. Also, extra food came from the black market, central kitchens, church organisations and foraging trips to the countryside. The period of famine ceased in early May 1945 immediately after the

10 Ibid.

11 Roseboom, T.J., De Rooij, S. & Painter, R. 2006. The Dutch famine and its long-term consequences for adult health. *Science Direct: Early Human Development*, 82(8), August:485-491. [<https://doi.org/10.1016/j.earlhumdev.2006.07.001>].

12 Roseboom, 2019.

13 Ibid.

14 Ibid.

final surrender of the Germans. The food situation quickly improved, and within a month, rations were above 2 000 calories.¹⁵

In addition to the immediate provision of food after the war, medical aid was a top priority for the Netherlands. The famine had a profound effect on the general health of the population. In Amsterdam, the mortality rate in 1945 had more than doubled compared to 1939, and most of this increase in mortality was likely attributable to undernutrition.¹⁶ Doctors from the UK and the US were sent to survey medical needs. Clement Smith from Harvard Medical School was among the first to witness the effects of the famine on the health of the Dutch population. He immediately saw the opportunity to obtain information that would help resolve important questions on how poor maternal nutrition affects pregnancy and the development of the fetus before birth.¹⁷ Using obstetric records from Rotterdam and The Hague, he studied effects of prenatal exposure to famine on pregnancy and the fetus which he described in his paper, *The effect of famine on pregnancy and its product*.¹⁸ This paper describes that babies born during the famine were lighter at birth.

Since the Dutch famine lasted five-six months, investigators have been able to not only assess effects of prenatal undernutrition per se but also to differentiate between effects of undernutrition according to its timing during gestation and the organs and tissues developing at that time. Although the exact definitions differ between studies, all studies assessing the effects of prenatal famine exposure have differentiated between the effects of famine in early, mid or late gestation.¹⁹

Consequences of prenatal famine exposure

Overall, studies of individuals born around the time of the Dutch famine studies have shown that prenatal undernutrition increased disease susceptibility. The effects of famine exposure appeared to depend on its timing during gestation and the organs and tissues developing at that time.

15 Ibid.

16 Roseboom et al., 2006.

17 Ibid.

18 Smith, C. 1947. The effects of wartime starvation in Holland on pregnancy and its product. *American Journal of Obstetrics & Gynecology*, 53(4):599-608. [https://doi.org/10.1016/0002-9378(47)90277-9].

19 Roseboom, 2019.

Early gestation

The landmark studies of Stein and Susser performed in the early seventies initially found no effect of undernutrition during gestation on the adult mental performance.²⁰ However, they subsequently showed that those exposed in early gestation had a two-fold increase in the risk of schizophrenia and anti-social personality disorder.²¹ Later studies also found increased rates of addiction.²² Some studies have found indications of effects of exposure to famine in early gestation on cognition though other studies did not detect such effects.²³ Imaging studies of the brain have shown lasting effects of famine exposure on brain size and structure.²⁴ Men who had been exposed to famine in early gestation had smaller intracortical volumes and total brain volumes than unexposed men. They also had smaller volumes of total cortical grey matter, white matter cerebellar grey matter, thalamus, caudate nuclear and accumbens area and a large number of more specific cortical

20 Stein, Z., Susser, M., Saenger, G. & Morolla, F. 1975. Famine and Human Development. *The Dutch Hunger Winter of 1944-45*. New York: Oxford University Press.

21 Hoek, H.W., Susser, E.Z., Buck, K., Lumey, L.H., Lin, S.P. & Gorman, J.M. 1996. Schizoid personality disorder after prenatal exposure to famine. *American Journal of Psychiatry*, 153(12), December:1637-1639. [https://doi.org/10.1176/ajp.153.12.1637]; Neugebauer, R., Hoek, H.W. & Susser, E. 1999. Prenatal exposure to wartime famine and development of antisocial personality disorder in early adulthood. *The Journal of the American Medical Association*, 282(5), Augustus:455-462. [https://doi.org/10.1001/jama.282.5.455].

22 Franzek, E.J., Spranger, N., Janssens, A.C., Van Duijn, C.M. & Van de Wetering, B.J.M. 2008. Prenatal exposure to the 1944-45 Dutch 'hunger winter' and addiction later in life. *Addiction*, 103(3), March:433-438. [https://doi.org/10.1111/j.1360-0443.2007.02084.xx].

23 De Rooij, S.R., Wouters, H., Yonker, J.E., Painter, R.C. & Roseboom, T.J. 2010. Prenatal undernutrition and cognitive function in late adulthood. *Proceedings of the National Academy of Sciences of the United States of America*, 107(39), September:16881-16886. [https://doi.org/10.1073/pnas.1009459107]; De Groot, R.H., Stein, A.D., Jolles, J., Van Boxtel, M.P., Blauw, G.J., Van de Bor, M. & Lumey, L.H. 2011. Prenatal famine exposure and cognition at 59 years. *International Journal of Epidemiology*, 40(2), March:327-337. [https://doi.org/10.1093/ije/dyq261]; Stein, M., Susser, G., Saenger, F. & Marolla F. 1972. Nutrition and mental performance. *Science*, 178(4062):708-713. [https://doi.org/10.1126/science.178.4062.708].

24 Hulshoff Pol, H.E., Hoek, H.W., Susser, E., Brown, A.S., Dingemans, A. & Schnack, H.G. 2000. Prenatal exposure to famine and brain mortality in schizophrenia. *American Journal of Psychiatry*, 157(7), July:1170-1172. [https://doi.org/10.1176/appi.ajp.157.7.1170]. De Rooij, S.R., Caan, M.W., Swaab, D.F., Nederveen, A.J., Majoie, C.B., Schwab, M., Painter, R.C. & Roseboom, T.J. 2016. Prenatal famine exposure has sex-specific effects on brain size. *Brain*, 139(8), July:2136-2142. [https://doi.org/10.1093/brain/aww132].

white and grey matter areas. The overall reduction in brain size after prenatal famine exposure was ~five per cent.²⁵

Stein and Sussers' landmark study found that 19-year old conscripts exposed to famine in early gestation were more likely to be obese.²⁶ These effects on obesity were also found in two other studies which examined effects on anthropometry in adulthood with the effects being more pronounced among women than men.²⁷ Women who had been exposed to famine in early gestation had higher BMI and appeared to be more centrally obese than those who had not been exposed to famine prenatally. These differences in adiposity could at least in part be mediated by differences in food preferences and food intake as there are indications that those exposed to famine in early gestation higher energy intakes, higher protein intakes and higher intakes of fat.²⁸ They also had more atherogenic lipid profiles, with higher LDL and lower HDL cholesterol levels, again the effects being more pronounced in women than in men.²⁹ There were indications that those exposed to famine in early gestation more often had disturbed blood coagulation, and were

more responsive to stress.³⁰ Exposure to famine in early gestation was furthermore associated with increased rates of cardiovascular disease at a younger age.³¹

Although based on small numbers, there is evidence to suggest that women exposed to famine in early gestation have increased rates of breast cancer.³² Analyses of mortality data suggest that those exposed to famine in early gestation have increased mortality, which is mainly found in women and mostly due to cardiovascular causes and cancer.³³ Uniquely, Ekamper used a large national birth cohort to assess effects on mortality up to age 63 years and found a 12 per cent increase in mortality among those who had been exposed to famine in early gestation.

The effects of famine exposure in early gestation are not limited to health but appear to have economic consequences too. The most striking finding was the significantly lower probability of being employed among those who had been exposed to famine in early gestation.³⁴ This result fits with findings of poorer

25 Roseboom, 2019.

26 Ravelli, G.P., Stein, Z.A. & Susser, M.W. 1976. Obesity in young men after famine exposure in utero and early infancy. *The New England Journal of Medicine*, 295(7), August:349-353. [https://doi.org/10.1056/NEJM197608122950701].

27 Stein, A.D., Kahn, H.S., Rundle, A., Zybert, P.A., Van der Pal-de Bruin & K., Lumey, L.H. 2007. Anthropometric measures in middle age after exposure to famine during gestation: evidence from the Dutch famine. *American Journal of Clinical Nutrition*, 85(3), March:869-876. [https://doi.org/10.1093/ajcn/85.3.869]; Ravelli, A.C., Van Der Meulen, J.H., Osmond, C., Barker, D.J. & Bleker, O.P. 1999. Obesity at the age of 50 y in men and women exposed to famine prenatally. *American Journal of Clinical Nutrition*, 70(5):811-816. [https://doi.org/10.1093/ajcn/70.5.811].

28 Stein, A.D., Rundle, A., Wada, N., Goldbohm, R.A. & Lumey, L.H. 2009. Associations of gestational exposure to famine with energy balance and macronutrient density of the diet at age 58 years differ according to the reference population used. *Journal of Nutrition*, 139(8), June:1555-1561. [https://doi.org/10.3945/jn.109.105536]; Lussana, F., Painter, R.C., Ocke, M.C., Buller, H.R., Bossuyt, P.M. & Roseboom, T.J. 2008. Prenatal exposure to the Dutch famine is associated with a preference for fatty foods and a more atherogenic lipid profile. *American Journal of Clinical Nutrition*, 88(6), January:1648-1652. [https://doi.org/10.3945/ajcn.2008.26140].

29 Roseboom, T.J., Van der Meulen, J.H., Osmond, C., Barker, D.J., Ravelli, A.C. & Bleker, O.P. 2000a. Plasma lipid profile in adults after prenatal exposure to the Dutch famine. *American Journal of Clinical Nutrition*, 72(5), November:1101-1106. [https://doi.org/10.1093/ajcn/72.5.1101]; Lumey, L.H., Stein, A.D., Kahn, H.S. & Romijn, J.A. 2009. Lipid profiles in middle-aged men and women after famine exposure during gestation: the Dutch Hunger Winter Families Study. *American Journal of Clinical Nutrition*, 89(6), May:1737-1743. [https://doi.org/10.3945/ajcn.2008.27038].

30 Roseboom, T.J., Van der Meulen, J.H., Ravelli, A.C., Osmond, C., Barker, D.J. & Bleker, O.P. 2000b. Plasma fibrinogen and factor VII concentrations in adults after prenatal exposure to famine. *British Journal of Haematology*, 111(1), November:112-117. [https://doi.org/10.1111/j.1365-2141.2000.02268.x]; Painter, R.C., De Rooij SR, Bossuyt PM, Phillips DI, Osmond C, Barker DJ, Bleker OP, Roseboom TJ. 2006. Blood pressure response to psychological stressors in adults after prenatal exposure to the Dutch famine. *Journal of Hypertension*, 24(9), September:1771-1778. [https://doi.org/10.1097/01.hjh.0000242401.45591.e7].

31 Roseboom, T.J., Van der Meulen, J.H., Osmond, C., Barker, D.J., Ravelli, A.C., Schroeder-Tanka, J.M., Van Montfrans, G.A., Michels, P.P. & Bleker, O.P. 2000c. Coronary heart disease after prenatal exposure to the Dutch famine 1944-45. *Obstetrical and Gynecological Survey*, 84(6), December:595-598. [https://doi.org/10.1136/heart.84.6.595]; Painter, R.C., De Rooij, S.R., Bossuyt, P.M., Simmers, T.A., Osmond, C., Barker, D.J., Bleker, O.P. & Roseboom, T.J. 2006. Early onset of coronary heart disease after prenatal exposure to the Dutch famine. *American Journal of Clinical Nutrition*, 84(2), September:322-327. [https://doi.org/10.1093/ajcn/84.1.322].

32 Painter, R.C., De Rooij, S.R., Bossuyt, P.M., Osmond, C., Barker, D.J., Bleker, O.P. & Roseboom, T.J. 2006. A possible link between prenatal exposure to famine and breast cancer: a preliminary study. *American Journal of Human Biology*, 18(6), November:853-856. [https://doi.org/10.1002/ajhb.20564].

33 Ekamper, P., Van Poppel, F., Stein, A.D. & Lumey, L.H. 2014. Independent and additive association of prenatal famine exposure and intermediary life conditions with adult mortality between age 18-63 years. *Social Science and Medicine*, 119, October:232-239. [https://doi.org/10.1016/j.socscimed.2013.10.027]; Van Abeelen, A.F., Veenendaal, M.V., Painter, R.C., De Rooij, S.R., Dijkgraaf, M.G., Bossuyt, P.M., Elias, S.G., Grobbee, D.E., Uiterwaal, C.S. & Roseboom, T.J. 2012. Survival effects of prenatal famine exposure. *American Journal of Clinical Nutrition*, 95(1), December:179-83. [https://doi.org/10.3945/ajcn.111.022038].

34 Scholte, R.S., Van den Berg, G.J. & Lindeboom, M. 2015. Long-run effects of

performance on cognitive tasks in men who had been exposed to famine in early gestation.³⁵ It seems that the effects of famine on employment are at least partly explained by effects on cognition. Mental disorders such as schizophrenia and anti-social personality disorders, more common after exposure to famine in early gestation, may contribute to this, as well as physical health.³⁶ It could be argued that the effects of famine exposure on health reduced individual productivity and hence employability.

Mid-gestation

Mid-gestation exposure to famine was linked to an increase in the occurrence of microalbuminuria in adulthood and a decrease in creatinine clearance.³⁷ It may be that mid-gestational exposure to famine – the period of the rapid increase in nephron number – may prevent the formation of sufficient glomeruli and thus increase the risk for microalbuminuria and deteriorating renal function in adulthood. This finding supports the concept that intrauterine conditions during distinct, organ-specific periods of sensitivity may permanently determine health outcome in later life.³⁸ Another example of this phenomenon is the finding in the same study that people who had been exposed to famine in mid-gestation had an increased prevalence of obstructive airways disease.³⁹ These observations were not paralleled by reduced lung function or increased serum concentrations of Immunoglobulin E, suggesting that the increased prevalence of symptoms and disease may be attributable to increased bronchial reactivity rather than to irreversible airflow obstruction or atopic disease. Because the bronchial tree grows most rapidly in mid-gestation, these findings support the hypothesis that fetal undernutrition

permanently affects the structure and physiology of the airways during ‘critical periods’ of development that coincide with periods of rapid growth.⁴⁰

Late gestation

Different studies have shown exposure to the Dutch famine during any stage of gestation were found to have raised glucose and insulin levels as adults.⁴¹ The effects being most pronounced among those exposed to famine in late gestation, seemingly reflecting an insulin secretion defect.⁴² It may suggest the effects of prenatal exposure to famine on beta-cell development with lasting adverse consequences for its function.

What do these historic studies teach us about population health today?

Findings from studies of people born around periods of famine suggest that maternal nutrition before and during pregnancy play an important role in later disease susceptibility. They have shown that maternal undernutrition during gestation has lasting adverse consequences for the offspring’s health.⁴³ Many chronic diseases that plague our society may originate in the womb. The effects seem to be large and depend on the timing during gestation and the organs and tissues developing at that time.⁴⁴ Also, the effects are independent of the size of the baby at birth. Most notably, those exposed to famine in early gestation did not have lower birth weights than those who were not exposed to famine prenatally but did

gestation during the Dutch Hunger Winter Famine on labor market and hospitalization outcomes. *Journal of Health Economics*, 39, January:17-30. [https://doi.org/10.1016/j.jhealeco.2014.10.002].

35 De Rooij et al., 2010.

36 Roseboom, 2019.

37 Painter, R.C., Roseboom, T.J., Van Montfrans, G.A., Bossuyt, P.M., Krediet, R.T., Osmond, C., Barker, D.J. & Bleker, O.P. 2005. Microalbuminuria in adults after prenatal exposure to the Dutch famine. *Journal of the American Society of Nephrology*, 16(1), February:189-194. [https://doi.org/10.1681/ASN.2004060474].

38 Roseboom, 2019.

39 Lopuhaä, C.E., Roseboom, T.J., Osmond, C., Barker, D.J., Ravelli, A.C., Bleker, O.P., Van der Zee, J.S. & Van der Meulen, J.H. 2000. Atopy, lung function and obstructive airways disease after prenatal exposure to famine. *Thorax*, 55(7), July:555-561. [https://doi.org/10.1136/thorax.55.7.555].

40 Roseboom, 2019.

41 Ravelli, A.C., Van der Meulen, J.H., Michels, R.P., Osmond, C., Barker, D.J., Hales, C.N. & Bleker, O.P. 1998. Glucose tolerance in adults after in utero exposure to the Dutch famine. *The Lancet*, 351(9097), January:173-177. [https://doi.org/10.1016/s0140-6736(97)07244-9]; Lumey, L.H., Stein, A.D. & Kahn, H.S. 2009. Food restriction during gestation and impaired fasting glucose or glucose tolerance and type 2 diabetes mellitus in adulthood: evidence from the Dutch Hunger Winter Families Study. *Journal of Developmental Origins of Health and Disease*, 1, January:S164; De Rooij, S.R., Painter, R.C., Roseboom, T.J., Phillips, D.I., Osmond, C., Barker, D.J., Tanck, M.W., Michels, R.P., Bossuyt, P.M. & Bleker, O.P. 2006. Glucose tolerance at age 58 and the decline of glucose tolerance in comparison with age 50 in people prenatally exposed to the Dutch famine. *Diabetologia*, 49(4), April:637-643. [https://doi.org/10.1007/s00125-005-0136-9]; De Rooij, S.R., Painter, R.C., Phillips, D.I., Osmond, C., Michels, R.P., Godsland, I.F., Bossuyt, P.M., Bleker, O.P. & Roseboom, T.J. 2006. Impaired insulin secretion after prenatal exposure to the Dutch famine. *Diabetes Care*, 29(8), September:1897-1901. [https://doi.org/10.2337/dc06-0460].

42 De Rooij et al., 2006.

43 Roseboom, 2019.

44 Ibid.

have the worst health outcomes as adults, possibly implying that adaptations that enable the fetus to continue to grow may nevertheless have adverse consequences for health in later life.⁴⁵ The chronic degenerative disease may be viewed as the price paid for adaptations made to an adverse intrauterine environment.

These findings confirm experimental evidence from studies in animals that show undernutrition during gestation permanently affecting the structure and function of organs, thereby affecting behaviour as well as disease risk, and ultimately shortening lifespan.⁴⁶ Findings from studies of the Dutch famine's long-term consequences were replicated or examined in other settings to study the effects of famines. Studies in other settings, of famines with different durations and severity affecting different populations, support these findings and suggest that the results of studies on the Dutch famine are not uniquely linked to the characteristics and setting of the Dutch famine, but rather reflect biologically fundamental processes that describe human plasticity.⁴⁷

A study in Nigeria showed that prenatal undernutrition also affects later health in African populations.⁴⁸ People exposed to the Biafran famine during the Nigerian civil war (1967-1970) in utero were found that have increased rates of hypertension and type 2 diabetes at the age of 40 compared to those who had not been exposed to the Biafran famine in utero.

Similarly, studies of people exposed to the Great Leap Forward famine in China have shown similar effects of prenatal famine exposure in later life risk of diabetes, hypertension and schizophrenia.⁴⁹ Undernutrition in early life contributes significantly to the increasing prevalence of hypertension and glucose intolerance. Therefore, prevention of fetal and infant undernutrition should be given high priority in national health, education, and economic agendas to limit the increase of non-communicable diseases in many developing countries.

Evidence for the importance of early nutrition for later health has come from many cohort studies across the globe. Pooled analyses of several cohorts from

45 Ibid.

46 Ozanne & Constância, 2007.

47 Gluckman, P.D. & Hanson, M.A. 2004. Living with the past: evolution, development, and patterns of disease. *Science*, 305(5691), September:1733-1736. [https://doi.org/10.1126/science.1095292].

48 Hult, M., Tornhammar, P., Ueda, P., Chima, C., Bonamy, A.K., Ozumba, B. & Norman, M. 2010. Hypertension, diabetes and overweight: looming legacies of the Biafran Famine. *PLoS One*, 5(10), November:e13582. [https://doi.org/10.1371/journal.pone.0013582].

49 Chen, Y. & Zhou, L.A. 2007. The long-term health and economic consequences of the 1959-1961 famine in China. *Journal of Health Economics*, 26(4):659-681. [https://doi.org/10.1016/j.jhealeco.2006.12.006].

low and middle-income countries has shown that not only are babies who were larger at birth more likely to be healthy. They are also more likely to complete secondary school.⁵⁰ These findings have implications for public health policy and nutrition interventions. An analysis of evidence-based interventions and focus on improvement in nutrition in pregnancy and linear growth in the first two years after birth could lead to substantial reductions in stunting and improved survival.⁵¹ These improvements form the basis for the emphasis on the first 1 000 days of life.⁵² The 1 000 days between a woman's pregnancy and her child's second birthday offer a unique window of opportunity to shape healthier and more prosperous future. The right nutrition and care during this 1 000-day window can have a profound impact on a child's ability to grow, learn, and rise out of poverty. It can also shape a society's long-term health, stability and prosperity.⁵³

Conclusion

Hunger is caused by poverty and inequality, not scarcity. For the past two decades, the rate of global food production has increased faster than the rate of global population growth. The world already produces more than enough food to feed everyone on the planet. We should prioritise an equal distribution of food across the world so that both the consequences of poor diets due to undernutrition and overnutrition will be prevented. Priority should be given to women of reproductive age. Adequately feeding women before and during pregnancy will allow future generations to reach their potential and lead to healthier and more productive lives, ultimately leading to healthier and more equitable future. Breaking the vicious cycle of poverty and undernutrition will most likely succeed if we provide women with sufficient food to provide their children with a good start in life.⁵⁴

50 Adair, L.S., Fall, C.H., Osmond, C., Stein, A.D., Martorell, R., Ramirez-Zea, M., Sachdev, H.S., Dahly, D.L., Bas, I., Norris, S.A. & Micklesfield, L. 2013. Associations of linear growth and relative weight gain during early life with adult health and human capital in countries of low middle income: findings from five birth cohort studies. *The Lancet*, 382(9891), August:525-534. [https://doi.org/10.1016/S0140-6736(13)60103-8].

51 Bhutta, Z.A., Ahmed, T., Black, R.E., Cousens, S., Dewey, K., Giugliani, E., Haider, B.A., Kirkwood, B., Morris, S.S., Sachdev, H.P. & Shekar, M. 2008. What works? Interventions for maternal and child undernutrition and survival. *The Lancet*, 371(9610), March:417-440. [https://doi.org/10.1016/S0140-6736(07)61693-6].

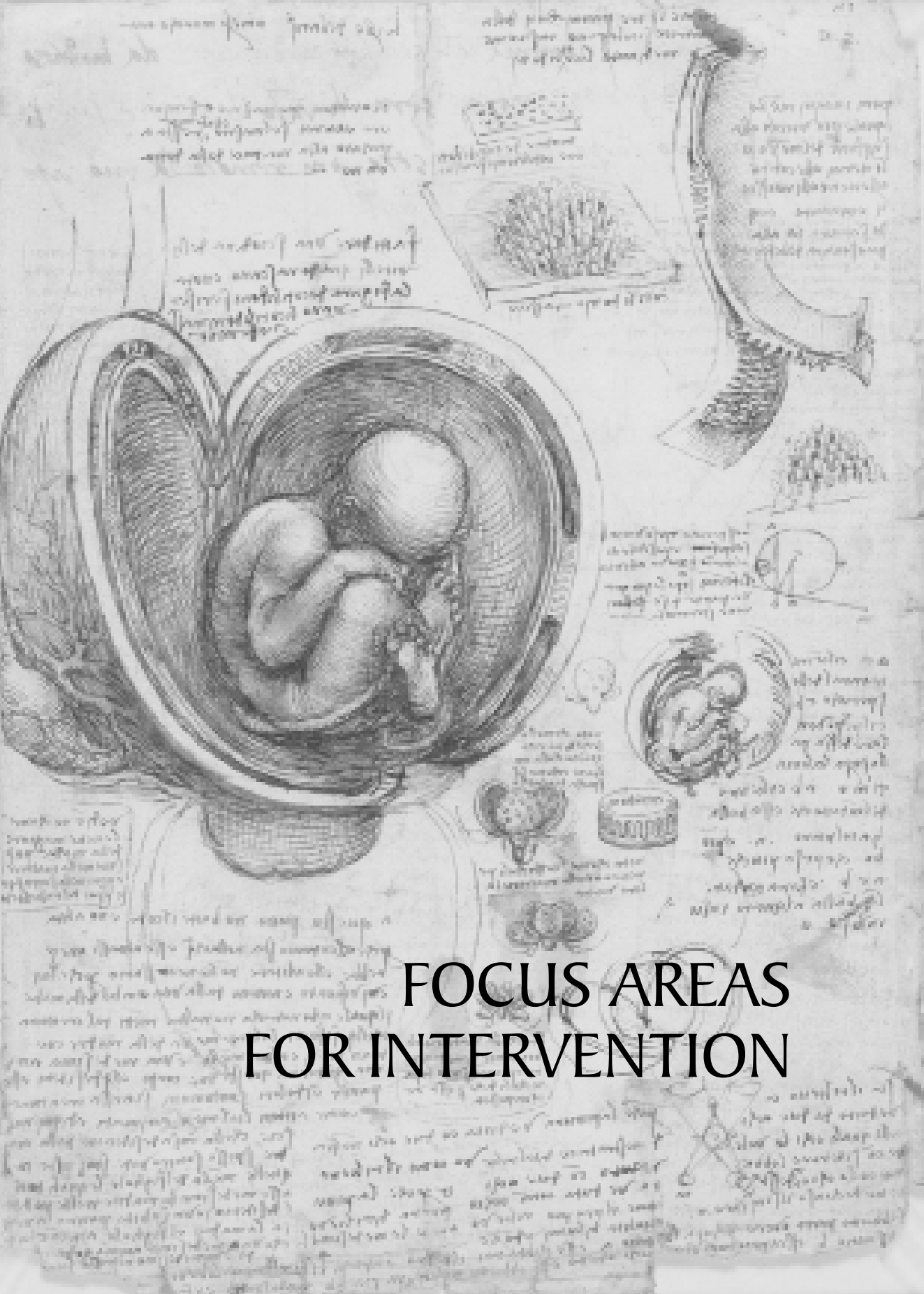
52 Save the Children. 2012. Nutrition in the first 1 000 days. *State of the World's Mothers*, 13th Edition. [https://bit.ly/2IIIIG8x].

53 Food Security Initiative (FSI) Nepal. 2020. *Golden 1000 Days Awareness Program*. [http://fsinepal.org.np/nutrition-awareness/].

54 Roseboom, 2019.



Figure 5.1 The effects of prenatal exposure to famine depend on its timing during gestation and the organs and tissues developing at that time.



FOCUS AREAS FOR INTERVENTION



6

THE FUNDAMENTAL IMPORTANCE OF BREASTFEEDING FOR HEALTH AND DEVELOPMENT

Robert D. Martin¹

How an infant is nourished in early life is central to the DOHaD hypothesis regarding the later onset of chronic non-communicable diseases, especially where feeding practices result in either stunting of growth or excessive weight gain. This chapter reviews the evolutionary history of the origins of breastfeeding and summarises studies evaluating its benefits.

Mammals take their name from the Latin word *mamma* for the teat. This root also gave rise to the term mammary gland, which, along with the associated behaviour of suckling offspring, is a universal feature of all mammals alive today. Human cultural practices over the past 5 000 years or so, notably including the exploitation of milk from other mammals and eventual development of milk formulae, have exerted a major impact on breastfeeding. The greatest effects have occurred in industrialised

¹ Science & Education, The Field Museum, Chicago; Institute of Evolutionary Medicine, University of Zürich; Stellenbosch Institute for Advanced Study, Wallenberg Research Centre at Stellenbosch University, Stellenbosch, South Africa.

nations, where many mothers breastfeed for only a few months, if at all, and breastfeeding beyond a year is rare. Because of pervasive cultural influences, it is difficult to establish a 'natural' period for human breastfeeding that would include an initial period of exclusive breastfeeding, followed by a phase of supplementary feeding. Information from modern hunting-and-gathering populations and other non-industrialised societies indicate an average total duration of at least two-and-a-half years, with a wide range of variation extending up to around five years.

Whenever tested, the benefits of breastfeeding for infants have been found to show a dose-response relationship, with the greatest benefits shown with breastfeeding for two to three years. Breastfeeding is also beneficial for mothers. There have been recent claims that over-enthusiastic promotion of breastfeeding, given the label 'activism' is both unkind and unwarranted. While it is true that women who, for whatever reason, are unable to breastfeed, need support and not bullying, it is both unjustifiable and irresponsible to dismiss the very substantial scientific evidence that now exists for the undoubted benefits of breastfeeding.

Ancient origins of breastfeeding

For a biologist, humans are mammals – not simply an arcane statement about our place in the animal classification, but the implication is far more profound: We possess all the key biological features that distinguish mammals from other members of the animal kingdom. Two of those features – the presence of hair and suckling (called breastfeeding or nursing in humans) – are easily recognised. Less obvious is the fact that they have linked evolutionary origins.

Hair is a feature that distinguishes mammals from all other vertebrates (animals with backbones). Whereas fish, amphibians and reptiles lack hair and may have scales instead, birds have feathers. By contrast, mammals typically have a coat of hair covering most of the body surface, although in some cases a secondary development has led to reduction or loss. Aquatic mammals such as dolphins and manatees, for instance, are often virtually bare, and burrowing mole-rats have also lost most of their hair. Humans also count among the special cases, as famously proclaimed in the title of Desmond Morris's 1967 bestseller, *The Naked Ape*.² Because hair is confined to mammals and is present in some form in virtually all species, it seems most likely that a covering of body fur emerged early in their evolution and then underwent a secondary reduction in a few lineages. However, it is theoretically possible that hair evolved separately in several different lineages. Evolutionary

² Morris, D. 1967. *The Naked Ape: A Zoologist's Study of the Human Animal*. London: Jonathan Cape.

biologists have recognised many cases of the independent evolutionary origin of features – known as *convergent evolution*.

In reconstructing evolutionary history, a crucial source of information is the fossil record. At first sight, it might seem highly unlikely that we could ever find fossil evidence for the evolutionary origin of hair, given that preservation of remains is mostly limited to hard structures such as teeth and bones. However, under certain conditions, traces of body hair may be found with mammal fossils, for example when a shadow-like outline of the body is preserved, and sometimes actual carbonized filaments provide direct indications of hair. Such direct evidence has been found with well-preserved fossil specimens of very early mammals. Hair has been reported for several different Cretaceous mammals from China dating back about 125 million years, and the earliest evidence comes from mammals that lived 165 million years ago.³ It is generally accepted that mammals originated from mammal-like reptiles some 200 million years ago, and indirect evidence suggests that hair may have evolved even earlier. Before the first appearance of mammals in the fossil record, some advanced mammal-like reptiles had pits on their snouts interpreted as having an association with whiskers, which are tactile hairs.

Because living mammals typically have hair, some classifications once used the name *Pilosa* (from the Latin word, *pilus* for hair) for the entire group. So at one point biologists could have ended up calling mammals 'pilosans', but the other striking feature of mammals, suckling, is even more fundamental. It is truly universal, without a single exception. Whereas some mammals have virtually lost their hair, not one species has secondarily lost the possession of milk-producing *mammary glands* and suckling. All female mammals produce milk to feed their infants by suckling. Modern classifications began with Linnaeus, who introduced stability into a rather chaotic free-for-all. Writing a century before Darwin (and hence

³ Ji, Q., Luo, Z.X., Yuan, C.X., Wible, J.R., Zhang, J.P. & Georgi, J.A. 2002. The earliest known eutherian mammal. *Nature*, 416, April:816-822. [https://doi.org/10.1038/416816a]; Luo, Z.X., Ji, Q., Wible, J.R. & Yuan, C.X. 2003. An early Cretaceous tribosphenic mammal and metatherian evolution. *Science*, 302(5652), December:1934-1940. [https://10.1126/science.1090718]. Rougier, G.W., Ji, Q. & Novacek, M.J. 2003. A new symmetrodont mammal with fur impressions from the Mesozoic of China. *Acta Geologica Sinica*, 77(1), March:7-14. [https://doi.org/10.1111/j.1755-6724.2003.tb00104.x]; Martin, T., Marugán-Lobón, J., Vulllo, R., Martín-Abad, L.Z.X. & Buscalioni, A.D. 2015. A Cretaceous eutriconodont and integument evolution of early mammals. *Nature*, 526:380-384. [https://doi.org/10.1038/nature14905]; Ji, Q., Luo, Z.X., Yuan, C.X. & Tabrum, A.R. 2006. A swimming mammaliaform from the Middle Jurassic and ecomorphological diversification of early mammals. *Science*, 311(5764), February:1123-1112. [https://doi.org/10.1126/science.1123026].

well before the advent of evolutionary theory), Linnaeus chose to use the label Mammalia rather than Pilosa. It has now emerged that his emphasis on suckling rather than hair in his influential classification was more political than biological. Science historian Londa Schiebinger discovered that Linnaeus actively campaigned to encourage Swedish women to breastfeed their babies, and distributed a pamphlet about the topic.⁴

It is important to note that both hair and suckling are more basic and ancient than live birth (*vivipary*). Among modern mammals, a few unusual representatives in Australasia known as monotremes – platypuses and spiny anteaters – have retained the ancient pattern of laying eggs; but they have hair and provide milk for their infants. However, monotremes do not possess teats, and the milk simply oozes from pores on the mother’s belly. Nonetheless, because all modern mammals provide milk for their infants, it seems very likely that their common ancestor already did so. Live birth doubtless evolved later, after the monotremes had branched away, originating somewhere between the origin of all mammals and the common ancestor that gave rise to marsupials and placentals, around 150 million years ago.⁵

Hair and suckling, however, share more than just their ancient origins. Different kinds of skin glands evolved along with the hair. Biologists recognise three basic types: sweat-producing *eccrine glands*, scent-producing *apocrine glands*, and oil-producing *sebaceous glands*.⁶ The most likely explanation is that milk-producing glands of ancestral mammals evolved from sebaceous glands. Because the oily secretions of these glands help maintain fur condition, they have a direct connection to hair follicles. Comparative evidence indicates that milk-producing glands were also connected originally with hair follicles, providing a clue to their origin. Accordingly, in ancestral mammals, skin glands producing moist secretions underwent gradual conversion to mammary glands that yielded milk containing a mixture of nutrients and antibiotics.⁷ Milk is often seen simply as a source of infant nourishment, and that can lead to the mistaken belief that artificial kinds of milk

only need to deliver the appropriate nutrients. Antibiotics contained in a mother’s milk provide the baby’s first line of defence against disease agents.⁸

As already indicated, it is reasonable to infer that in the common ancestry of all mammals, mothers suckled their offspring. However, we cannot be sure of this because similar functional requirements often lead to similar adaptations through convergent evolution. Even a complex feature such as suckling could have evolved separately in different lineages. When the ancestors of dolphins and whales returned to life in water, for instance, they eventually developed a streamlined body form that convergently resembles that of a fish.⁹ Similarly, suckling might not have evolved just once, so how can we go about checking this? In this case, there is not even a remote possibility that we might be able to test the inference with fossil evidence as we were able to do with hair.

It so happens that this is a truly remarkable case in which genetic evidence – considerably reinforced by complete genome sequences generated for an increasingly large and diverse sample of mammals – has yielded a valuable new perspective in recent years. A distinctive universal feature of mammal milk is the presence of special proteins known as *caseins*, which are unique to mammals. Genes that produce caseins are active only in mammary glands. Complete genomes have already been sequenced for an egg-laying monotreme (platypus), a marsupial (opossum), and several placental mammals (e.g. cow, dog, mice, rat, human). An evolutionary tree based on deoxyribonucleic acid (DNA) sequences of casein genes reveals that the most plausible explanation is that there was only a single origin in the common ancestor that gave rise to monotremes, marsupials, and placentals. At the outset, only a single copy of the casein gene was present, but subsequent gene duplications have generated additional copies. The genome of humans, like that of other primates, rabbits and rodents, includes five copies of the casein gene. Reconstruction of the evolutionary history of the casein gene family has resoundingly confirmed the interpretation that suckling evolved only once in or before the common ancestor of all mammals alive today.¹⁰

4 Schiebinger, L. 1993. Why mammals are called mammals: Gender politics in eighteenth-century natural history. *American Historical Review*, 98(2), April:382-411. [https://doi.org/10.2307/2166840].

5 Martin, R. 2020. How We Do It: The evolution and future of human reproduction. *Psychology Today*. [https://www.psychologytoday.com/intl/blog/how-we-do-it].

6 Ibid.

7 Oftedal, O.T. 2002. The mammary gland and its origin during synapsid evolution. *Journal of Mammary Gland Biology & Neoplasia*, 7(3), August:225-252. [https://doi.org/10.1023/A:1022896515287].

8 Lönnerdal, B. 1995. Breast milk: a truly functional food. *Nutrition*, 16(7-8), July-August:509-511. [https://doi.org/10.1016/s0899-9007(00)00363-4]; Newman, J. 1995. How breast milk protects newborns. *Scientific American*, 273(6), December:76-79. [https://doi.org/10.1038/scientificamerican1295-76].

9 Martin, 2020.

10 Rijnkels, M., Le, T. & Thomas, J. 2005. Evolution and regulation of the casein gene cluster region: a genomics approach. *Journal of Dairy Science*, 88(Supplement 1):76-77; Lemay, D.G., Lynn, D.J., Martin, W.F., Neville, M.C., Casey, T.M., Rincon, G., Krivenseva, E.V., Barri, W.C., Hinrichs, A.S., Molenaar, A.J., Pollard, K.S., Maqbool, N.J., Singh, K., Murney, R., Zdobnov, E.M., Tellam, R.L., Medrano, J.F., German, J.B. & Rijnkels, M. 2009. The bovine lactation genome: insights into the

Additional, albeit less striking, evidence is available from milk sugars regarding the evolution of suckling in the earliest mammals. Comparisons across mammals indicate that milk-specific sugars were already present in the common ancestor of extant mammals more than 200 million years ago. At that stage, however, the sugars present in milk were still quite diverse because different kinds have come to dominate in modern monotremes, marsupials and placentals, respectively. In placental mammals, including humans, lactose is universally the principal milk sugar, so it can be concluded with some confidence that this sugar was dominant in their common ancestor over 100 million years ago.

Babies' brains develop better with breastfeeding

The extensive evolutionary history of milk production and suckling, beginning with the first mammals some 200 million years ago, demands our attention and respect. Natural selection throughout that significant fraction of the history of life on earth – about a third of the total period for which multicellular organisms have existed – has surely deeply embedded the physiology of milk production (lactation) in mammals and honed the adaptations of individual species. It is therefore only to be expected that both mothers and infants must possess fine-tuned adaptations for suckling and sucking, respectively. The biological starting-point for considering breastfeeding under current living conditions worldwide must surely be the expectation that any departure from the natural pattern for which we are adapted is likely to have adverse effects. It is, therefore, crucial to try to establish what the natural pattern was for pre-agricultural societies over 10 000 years ago when the ancient lifestyle of gathering-and-hunting was still ubiquitous. Moreover, we need to determine what changes have been brought about by social modification of infant rearing. Perhaps the most obvious and influential change that has occurred is the switch from exclusive breastfeeding to bottle-feeding with infant formula.

Numerous advantages of breastfeeding over bottle-feeding have been reported in an extensive literature. One predominant theme has been the oft-repeated finding that breastfed babies consistently show significant advantages over bottle-fed babies in a variety of mental tests. It must be emphasised that the observed differences are generally quite small and that there is considerable overlap in test scores between breastfed and bottle-fed babies. Indeed, some studies have failed to find a significant difference, and there is a systematic problem in that studies depend on correlations without any kind of experimental confirmation. Accordingly, the evidence has often been disparaged as 'only circumstantial'.

evolution of mammalian milk. *Genome Biology*, 10(4):1-18. [<https://doi.org/10.1186/gb-2009-10-4-r43>].

Moreover, correlational studies are subject to the ever-present danger that observed effects might be influenced by confounding factors that have not been taken into account by the investigator. It has, for instance, often been reported that mothers from higher-income brackets are more likely to breastfeed. Babies reared in wealthier homes are, however, likely to benefit from many advantages that can positively influence mental test results. Hence, an apparent correlation between breastfeeding and mental test scores may be driven by the confounding factor of socio-economic status. Statistical studies that examine correlations between mental test scores and breastfeeding must, therefore, use appropriate methods to detect and remove the effects of confounding variables.

Reports indicating small but significant deficits in brain development in bottle-fed infants began to emerge in the 1970s. A landmark 1978 paper by Bryan Rodgers assessed a 1946 birth cohort of children monitored by the National Survey of Health and Development in the UK.¹¹ This study stands out because particular care was taken to control for confounding factors. Rodgers conducted attainment tests with over 2 000 children in the cohort when they were eight to 15 years old. One thousand one hundred and thirty-three children were entirely bottle-fed, and 1 291 were never bottle-fed. Low scores were generally more likely for bottle-fed than for breastfed children. In the bottle-fed group, 14.4 per cent (128 of 890) scored 39 points or less on the 15-year reading test, compared with only 8.4 per cent (90 out of 1 071) in the breastfed group. After taking differences in the family background into account, attainment scores for the bottle-fed group were found to be still statistically significant ($p < 0.001$). However, on average bottle-fed children scored only one to two points less than breastfed children over a range extending from 25 to 75 points. Many subsequent studies reported similar small differences, with bottle-fed children showing somewhat lower average scores on intelligence tests and a somewhat higher incidence of learning deficits.

In the meantime, sophisticated statistical techniques have become available to control for confounding factors in epidemiological studies. Appropriate analyses of survey data by numerous investigators now leave little doubt that mental development is linked to breastfeeding. There has also been increasing uses of meta-analyses in which results from several published studies are examined together to identify consistent findings. By 1999, James Anderson and colleagues

11 Rodgers, B. 1978. Feeding in infancy and later ability and attainment: a longitudinal study. *Developmental Medicine and Child Neurology*, 20(4), August:421-426. [<https://doi.org/10.1111/j.1469-8749.1978.tb15242.x>].

were able to conduct a judicious combined analysis of 20 previous studies.¹² They took particular care to control for confounding factors in testing for a convincing relationship between mental test scores and breastfeeding effects. The overall outcome was this: Breastfed babies tested between six months and two years of age consistently showed significantly higher levels of mental function than bottle-fed babies. Moreover, the benefits of breastfeeding proved to be particularly pronounced for premature babies.

Key components of milk

Mammalian milk contains so many individual constituents that it is a challenging task to identify those that are important and should, therefore, be appropriately replicated in any artificial milk formula. Indeed, much research is still needed to recognize crucial components. Milk fats (lipids) alone show a bewildering diversity. However, the study of human milk ingredients has yielded considerable evidence for the special importance of a particular class of complex lipids: long-chain polyunsaturated fatty acids. Simply stated, polyunsaturated fatty acids can form multiple additional chemical bonds, whereas saturated fatty acids do not. This basic structural distinction has practical significance: polyunsaturated fatty acids, including long-chain polyunsaturated fatty acids, have a lower melting point and remain liquid at body temperature. One reflection of this is that long-chain polyunsaturated fatty acids are important structural components of cell membranes. They are especially well represented in nerve cells, so an adequate supply is essential for optimal development and function of the nervous system. Nutritional researchers Susan Carlson, Michael Crawford, and Stephen Cunnane have particularly emphasized the importance of long-chain polyunsaturated fatty acids for normal development of the brain during pregnancy and breastfeeding.¹³ Two prominent examples are arachidonic acid (AA) and docosahexaenoic acid (DHA). AA and DHA are major ingredients of nutritional supplements containing

12 Anderson, J.W., Johnstone, B.M. & Remley, D.T. 1999. Breast-feeding and cognitive development: a meta-analysis. *American Journal of Clinical Nutrition*, 70(4), October:525-535. [https://doi.org/10.1093/ajcn/70.4.525].

13 Carlson, S.E. 1999. Long-chain polyunsaturated fatty acids and development of human infants. *Acta Paediatrica*, 88(430), August:72-77; Carlson, S.E. 2001. Docosahexaenoic acid and arachidonic acid in infant development. *Seminars in Neonatology*, 6(5), October:437-449. [https://doi.org/10.1053/siny.2001.0093]; Cunnane, S.C. & Crawford, M.A. 2003. Survival of the fattest: Fat babies were the key to evolution of the large human brain. *Comparative Biochemistry & Physiology A*, 136(1), September:17-26. [https://doi.org/10.1016/S1095-6433(03)00048-5]; Cunnane, S.C. 2005. *Survival of the Fattest: The Key to Human Brain Evolution*. Hackensack, NJ: World Scientific.

omega-6 and omega-3 fatty acids. Both are key components of nerve cells, and DHA is also crucial for light-sensitive cells in the retina of the eye.

It is unclear whether a growing human baby can manufacture all the long-chain polyunsaturated fatty acids it needs or whether some degree of supply from the mother is essential. Given the unique developmental demands of the unusually large human brain after birth, these unsaturated fatty acids are in all likelihood crucial ingredients of human milk. It is certainly true that long-chain polyunsaturated fatty acids are well represented in human milk. However, as Lauren Milligan and Richard Bazinet showed in a 2008 paper, they are well represented in primate milk in general, and the increased demands of the enlarged human brain are not reflected by a distinctively higher level of long-chain polyunsaturated fatty acids in human milk.¹⁴ Perhaps the special needs of the growing human brain are met by providing enough milk to meet the overall need for long-chain polyunsaturated fatty acids. Regardless of the findings for non-human primates, cow's milk contains only trace amounts of long-chain polyunsaturated fatty acids, a cause for concern if these unsaturated fatty acids play a key role in brain development, as milk formulas are commonly based on cow's milk.

It is highly likely that long-chain polyunsaturated fatty acids stored during fetal development contribute to human brain growth after birth. Rapid brain growth during the first year of life is connected with an unusual feature of human neonates: their striking plumpness. In an average human newborn weighing around seven-and-a-half pounds, fat tissue accounts for over a pound, around 14 per cent of the total. Human babies at birth are among the plumpest found among mammals and look markedly different from the scrawny newborns of other primates, such as chimpanzees and rhesus monkeys. The proportion of fat tissue in newborn human matches that in mammals living under arctic conditions, and exceeds the level found in baby seals. Stephen Cunnane and Michael Crawford suggested a connection between the unusual plumpness of newborn human infants and long-chain polyunsaturated fatty acids: Stored fat may contain a reserve supply to support brain development.¹⁵ It is also possible that early provision of suitable complementary foods rich in these fatty acids could boost availability for brain development in human infants.

14 Milligan, L.A. & Bazinet, R.P. 2008. Evolutionary modifications of human milk composition: evidence from long-chain polyunsaturated fatty acid composition of anthropoid milks. *Journal of Human Evolution*, 55(6): September:1086-1095. [https://doi.org/10.1016/j.jhevol.2008.07.010].

15 Cunnane & Crawford, 2003; Cunnane, 2005.

Because cow's milk has only trace amounts of long-chain polyunsaturated fatty acids, there is a possibility that bottle-feeding could lead to deficient development of an infant's nervous system. It is known that blood concentrations of long-chain polyunsaturated fatty acids are higher in breastfed than bottle-fed infants. Circumstantial evidence reported in various studies also indicates that development of the nervous system may suffer deficits in bottle-fed infants. Results reported for infants born after full-term pregnancies have been mixed, but for preterm infants born after an unusually short pregnancy, there is convincing evidence that a shortage of long-chain polyunsaturated fatty acids in artificial milk is detrimental. Several meta-analyses have failed to find a significant difference between breastfed and bottle-fed infants born at term, so the jury is out regarding a general need to supplement milk formulae with these unsaturated fatty acids.¹⁶ By contrast, there is convincing evidence that any milk given to premature babies should contain adequate quantities of these important fatty acids.

The key point is that the fetus only stores fat during the last three months of pregnancy. Accordingly, infants born well before the due date have unusually limited fat reserves and lack the customary plumpness; their need for long-chain polyunsaturated fatty acids supplied in milk is hence considerably greater. Because of mounting evidence that long-chain polyunsaturated fatty acids in milk may be important for normal development of the nervous system, especially in premature babies, AA and DHA have been gradually added to artificial milk in various countries. In 2002, the USA Food and Drug Administration belatedly approved the addition of AA and DHA to milk formula. Artificial milk enhanced in this way was, however, not approved for preterm infants, despite this group having the greatest need for supplementation with long-chain polyunsaturated fatty acids. The basic problem has been that evidence indicating the vital importance of AA and DHA in human milk has generally been indirect. That evidence, however, is a smoking gun and an urgent topic for targeted medical investigation.

Almost all evidence indicating that breastfeeding is advantageous for a baby's mental development is circumstantial, inevitably because ethical considerations

generally rule out experiments of any kind. One key experimental study, however, does provide convincing evidence that supplementation of milk formula with the polyunsaturated fatty acids DHA and AA enhances mental development. In 2000, a team of researchers led by Eileen Birch assessed the effects of adding DHA and AA for four months to a commercial milk formula fed to infants.¹⁷ This experimental approach eliminated many of the confounding factors that bedevil comparisons between breastfeeding and bottle-feeding. Infants in the study were assessed with standard developmental tests at four, 12, and 18 months of age. For 18-month-old infants, adding both DHA and AA to formula resulted in an average increase of seven points on a standard scale of mental development. By contrast, no significant effects were found for muscle activity or general behavioural performance. This study convincingly establishes a causal connection between DHA and AA in human milk and brain development.

While breastfed infants have been shown to perform better on mental tests than bottle-fed babies, it has rarely been asked whether this advantage persists into adulthood. Filling this gap, in 2002, epidemiologist Erik Mortensen and colleagues published results from a long-term study of breastfeeding and IQ in more than 3 000 cases.¹⁸ In the study, the duration of breastfeeding was divided into five categories (less than one month, two to three months, four to six months, seven to nine months, and more than nine months), using information the mothers provided when their babies were one year old. Intelligence tests were conducted when those babies had become adults. Mortensen and colleagues took no fewer than thirteen potential confounding factors into account:

- social status and education of parents;
- marital status;
- mother's height, age, and weight gain during pregnancy;
- cigarette consumption during the last third of pregnancy;
- the number of pregnancies;
- estimated gestational age;

16 Simmer, K., Patole, S. & Rao, S.C. 2008. Longchain polyunsaturated fatty acid supplementation in infants born at term. *Cochrane Database of Systematic Reviews*, 3(CD000376):1-28; Alshweki, A., Muñuzuri, A.P., Baña, A.M., De Castro, M.J., Andrade, F., Aldamiz-Echevarría, L., Sáenz de Pipaón, M., Fraga, J.M. & Couce, M.L. 2015. Effects of different arachidonic acid supplementation on psychomotor development in very preterm infants; a randomized controlled trial. *Nutrition Journal*, 14(1), September:1-11. [<https://doi.org/10.1186/s12937-015-0091-3>]; Jasani, B., Simmer, K., Patole, S.K. & Rao, S.C. 2017. Long chain polyunsaturated fatty acid supplementation in infants born at term. *Cochrane Database of Systematic Reviews*, 3(CD000376):1-52. [<https://doi.org/10.1002/14651858.CD000376>].

17 Birch, E.E., Garfield, S., Hoffman, D.R., Uauy, R. & Birch, D.G. 2000. A randomized controlled trial of early dietary supply of long-chain polyunsaturated fatty acids and mental development in term infants. *Developmental Medicine and Child Neurology*, 42(3), March:174-181. [<https://doi.org/10.1017/s0012162200000311>].

18 Mortensen, E.L., Michaelson, K.F., Sanders, S.A. & Reinisch, J.M. 2002. The association between duration of breastfeeding and adult intelligence. *Journal of the American Medical Association*, 28(18), May:2365-2371. [<https://doi.org/10.1001/jama.287.18.2365>].

- birth length and weight; and
- indicators of complications during pregnancy and birth.

Even after allowing for all of these factors, the duration of breastfeeding was found to be significantly associated with higher adult scores in various intelligence tests.

Influence of breastfeeding duration

Although numerous studies have revealed a consistent relationship between breastfeeding and mental function, some studies have reported no significant effect. However, it is notable that no study has ever reported a *negative* relationship between breastfeeding and mental test scores, which would surely be expected if the discrepancy between studies were solely attributable to chance variation. One reason for continuing doubts about a connection between breastfeeding and mental function is that the results, although usually significant with adequate sample sizes, are typically relatively small. Even more important, however, is general vagueness about the *duration* of breastfeeding in published studies. Although the category of exclusive bottle-feeding is easily defined and applied, the category ‘breastfeeding’ may mean anything between mothers nursing a baby for only a few weeks and mothers that do so for three years or more. In modern industrialised countries, mothers commonly stop breastfeeding after a few weeks or months. Numerous investigators did not attempt to determine the duration of breastfeeding and compared exclusively bottle-fed babies with babies in the catch-all category ‘ever breastfed’. If mental test scores are compared between never breastfed babies and infants that have been breastfed for only a few weeks or months, it is hardly surprising that any differences found are marginal.

Given the very extensive evolutionary history of suckling, one key question that must be asked is how long breastfeeding would have lasted on average in early human societies before the advent of settled communities and agriculture some 10 000 years ago. Although the fossil record provides no clues to suckling behaviour in the past, we can draw some instructive conclusions from comparative studies, starting with a survey of mammals in general.

Beginning with birth and ending with weaning, every mammal mother suckles her infants for a certain amount of time, called the *lactation period*. In many species, the suckling duration is remarkably constant. A house-mouse mother typically suckles her pups for 22 days, a rat for 31 days, and a tree-shrew for 35 days. In other species, particularly in large-bodied mammals with single infants, the lactation period is quite variable. As humans are large-bodied mammals, appreciable variation in the lactation period is only to be expected. In all modern human societies, culture has,

however, greatly influenced mothering. Consequently, it is no easy task to decide what is ‘natural’ for our species.

In search of clues, an instrumental first step is to survey mammals in general – with a special focus on primates – to identify general principles as a background to human origins.¹⁹ Mice, rats, tree-shrews, and other similar mammals have a primitive breeding pattern, with short pregnancies and poorly developed (altricial) offspring. Suckling stops sharply at a standard interval after birth, and there is an abrupt shift to solid foods. Primates, by contrast, give birth to well-developed (precocial) offspring after long pregnancies. In many cases, particularly with larger-bodied species, suckling periods are rather variable and associated with a gradual transfer to solid foods. Suckling duration varies from species to species among primates, from a fairly constant 45 days in a two-ounce mouse lemur to a variable period averaging around six-and-a-half years in a 90-pound Bornean orangutan. The maximum duration of over seven-and-a-half years reported for a Bornean orangutan is seemingly the longest recorded among mammals.²⁰

As is the case for many other features, suckling durations are scaled to body size across mammals: the larger the mammal, the longer the average lactation period. Primates, however, generally suckle infants for a comparatively long time even in comparison to mammals of similar body size. There is also a marked disjunction between groups (grade shift) in the scaling relationship among primates. At any given body size, higher primates (monkeys and apes) generally suckle longer than lower primates (lemurs, lorises and tarsiers). It seems difficult to decide on an average weaning age for which humans are biologically adapted, confronted with such complexity. Seeking a biological clue to human weaning age, in a 2004 paper anthropologist Katherine Dettwyler examined the fairly consistent overall relationship between suckling duration and body weight for monkeys and apes.²¹ The average value expected for a woman weighing about 120 pounds calculated from that relationship is close to three years.

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- 19 Martin, R.D. 1990. *Primate Origins and Evolution: A Phylogenetic Reconstruction*. New Jersey: Princeton University Press; Martin, R.D. 2007. The evolution of human reproduction: A primatological perspective. *Yearbook of Physical Anthropology*, 135(45):59-84 [https://doi.org/10.1002/ajpa.20734]; Martin, R.D. 2013. *How We Do It: The Evolution and Future of Human Reproduction*. New York: Basic Books.
- 20 Van Noordwijk, M.A. & Van Schaik, C.P. 2005. Development of ecological competence in Sumatran orangutans. *American Journal of Physical Anthropology*, 127(1), May:79-94. [https://doi.org/10.1002/ajpa.10426].
- 21 Dettwyler, K.A. 1995. A time to wean: The hominid blueprint for a natural age of weaning in modern human populations. In: Stuart-Macadam, P. & Dettwyler, K.A. (eds). 1995. *Breastfeeding: Biocultural Perspectives*. New York: Aldine de Gruyter. 39-73.

There are also several other ways of estimating a natural duration for human breastfeeding by conducting comparisons of life-history milestones across primates. The underlying assumption here is that life-history patterns generally show coordination of individual phases, such that the overall tempo is either fast or slow. One simple approach is to start at the beginning of individual development and take the length of human pregnancy – the interval between conception and birth – to calculate expected weaning age from the duration of suckling in relation to gestation period in non-human primates. Dettwyler noted that the average duration of breastfeeding among large-bodied primates far exceeds the average length of gestation.²² In our closest relatives – chimpanzees and gorillas – the duration of breastfeeding is more than six times the length of gestation. On that basis, she estimated that the natural age at weaning for humans would at least four-and-a-half years. Following birth, another important developmental milestone is the eruption of the first permanent molar teeth. Anthropologist Holly Smith has examined the relationship between the timing of dental eruption and age at weaning in primates and other mammals.²³ In primates, these events coincide closely in time. In modern humans, the first permanent molars erupt at about six years (range: 5.5 to 6.5).

Another rule of thumb can be derived from the weight the offspring reaches by the time of weaning. In a 1991 paper, Phyllis Lee and colleagues examined the attainment of a threshold body weight by weaning age in offspring of three groups of large-bodied mammals: higher primates, ungulates (hoofed mammals) and pinnipeds (seals and sea-lions).²⁴ It emerged that offspring in these mammals have approximately quadrupled their birth weight by the time they are weaned. Taking an average human birth weight of 3.5 kilograms (7.7 pounds), quadrupling it to 14 kilograms (31 pounds) would be expected to happen by an age close to three years in a well-nourished, healthy population and somewhere between three and four years of age in a population with marginal nourishment exposed to elevated environmental stress levels. The weaning age is also indicated by the age at which a child reaches a third of adult body weight. A 1993 paper by Eric Charnov and David Berrigan indicates that primates, on average, resemble other mammals in weaning

an offspring when it reaches this stage of development.²⁵ Applying this criterion to humans yields a breastfeeding duration between four and seven years.

Last but not least, human weaning age can be inferred from the age at which sexual maturity is attained. In 1985, Paul Harvey and Timothy Clutton-Brock reported a close correlation between age at weaning and age at first breeding for female non-human primates.²⁶ Using the regression equation provided by Harvey and Clutton-Brock, Dettwyler calculated an expected average duration of human breastfeeding of 4.7 years taking an average female age at first reproduction of 16 years. If an average age at first reproduction of 12 years of age is taken instead, the estimated average duration of breastfeeding is 3.2 years. Accordingly, the shortest duration of breastfeeding predicted with this approach would be greater than three years.

An estimated natural human breastfeeding period of about three years may seem surprisingly long. It is actually on the short side compared to our closest relatives among primates, the great apes (chimpanzees and bonobos, gorillas, orangutans). The difference in body size between humans and great ape species is far less than across primates generally, so a direct comparison of lactation periods is reasonably informative in this case. Three months is in fact below the averages for all wild-living great apes: four-and-a-half years for common chimpanzees and bonobos, three-and-a-half years for gorillas, and six-and-a-half to seven years for orangutans.²⁷ Moreover, adult female chimpanzees weigh in at about ninety pounds, markedly less than the average woman. So, weaning in chimpanzees should be expected to occur *earlier* than in humans, not *later*. Because of an additional grade shift in the scaling relationship between weaning age and mother's body mass, apes tend to have somewhat later weaning ages, relative to body size, than monkeys. Because of this further difference, the natural suckling duration of three years inferred for humans from an examination of monkeys and apes together may be too low.

It is, however, possible that comparative evidence from non-human primates might not be entirely reliable. Following divergence of the sister lineages leading to humans and chimpanzees and bonobos, a special adaptation leading to a

22 Dettwyler, K.A. 2004. When to wean: Biological versus cultural perspectives. *Clinical Obstetrics & Gynecology*, 47(3), September:712-723. [<https://doi.org/10.1097/01.grf.0000137217.97573.01>].

23 Smith, B.H. 1989. Dental development as a measure of life history in primates. *Evolution*, 43(3), May:683-688. [<https://doi.org/10.2307/2409073>]; Smith, B.H. 1992. Life history and the evolution of human maturation. *Evolutionary Anthropology*, 1(4), June:134-142. [<https://doi.org/10.1002/evan.1360010406>].

24 Lee, P.C., Majluf, P. & Gordon, I.J. 1991. Growth, weaning and maternal investment from a comparative perspective. *Journal of Zoology*, 225(1), March:99-114. [<https://doi.org/10.1111/j.1469-7998.1991.tb03804.x>].

25 Charnov, E.L. & Berrigan, D. 1993. Why do female primates have such long lifespans and so few babies? or life in the slow lane. *Evolutionary Anthropology*, 1(6), June:191-194. [<https://doi.org/10.1002/evan.1360010604>].

26 Harvey, P.H. & Clutton-Brock, T.H. 1985. Life history variation in primates. *Evolution*, 39(3), May:559-581. [<https://doi.org/10.1111/j.1558-5646.1985.tb00395.x>].

27 Van Noordwijk, M.A., Willems, E.P., Atmoko, S.S.U. & Van Schaik, C.P. 2013. Multi-year lactation and its consequences in Bornean orangutans (*Pongo pygmaeus wurmbii*). *Behavioral Ecology & Sociobiology*, 67(5):805-814. [<https://doi.org/10.1007/s00265-013-1504-y>].

reduction in the duration of human breastfeeding could have occurred. For instance, adaptation for a nutrient-rich, high-energy diet throughout human evolution could have allowed supplementary feeding of babies at an early stage of lactation, may be facilitated by the participation of social group members other than mothers in the rearing of infants and children. Various authors have proposed that this might have allowed earlier weaning. In a 2003 paper, anthropologist Gail Kennedy specifically argued that the high energy demands of the development of the particularly large human brain and a need for more rapid reproduction could have led to a 'weanling's dilemma'.²⁸ It has since been widely accepted among anthropologists that humans are, indeed, specially adapted for earlier weaning than in great apes.

To probe deeper into this question, we can conduct a comparative survey of information for our species. One clue to the natural lactation period for humans is provided by the age at which the production of lactase (a specific enzyme for the breakdown of lactose) stops in populations that are not biologically adapted for digestion of dairy products after weaning. In most human populations, the gene for production of lactase is switched off in children when they reach an age of about five years. Unfortunately, the timing of this is too variable to provide more than a hint of the natural duration of lactation, but it does indicate a relatively late weaning age. However, social norms and individual preferences governing weaning practices differ widely between human societies and also change over time. Current practices range from nursing for up to six years or more to not breastfeeding at all, resorting either to bottle-feeding or to using wet nurses.

One comparative approach is to examine information concerning modern human societies with a hunting-and-gathering lifestyle, possibly yielding an indication of average weaning age under conditions closer to those that prevailed for some 97 per cent of human evolution along the seven-million-year lineage leading from the earliest hominids to modern *Homo sapiens*. Because genuine hunting-and-gathering societies generally lack domesticated mammals as an alternative milk source, cultural practices have considerably less impact on weaning age. We should not, however, forget that the early introduction of supplementary feeding in infant rearing can influence the duration of breastfeeding in all contemporary human societies.

It turns out that breastfeeding generally lasts an average of three years in existing gathering-and-hunting societies. In a widely influential paper published in 1980, anthropologists Melvin Konner and Carol Worthman reported weaning of children at an average age of three-and-a-half years among the !Kung-gatherer-hunters

28 Kennedy, G.E. 2005. From the ape's dilemma to the weanling's dilemma: early weaning and its evolutionary context. *Journal of Human Evolution*, 48(2), February:123-145. [https://doi.org/10.1016/j.jhevol.2004.09.005].

of Botswana and Namibia.²⁹ This pioneering two-year study became a textbook example of fieldwork in human biology. Twenty-five years later, Konner published a chapter in a book on gatherer-hunters in which he reviewed information on weaning in five different societies.³⁰ In addition to the !Kung, he included information on the Agta, Hadza, Aka, and Ache, with the Aka's average weaning age three-and-a-half years as with the !Kung. Weaning occurred earlier in the other gathering-hunting societies, at around two years in the Agta and Ache and two-and-a-half years in the Hadza. The average weaning age across all five societies was close to three years (33.2 months).

Spreading the net more widely, Daniel Sellen, an anthropologist who has devoted his career to exploring the evolutionary background to human mothering, conducted a general survey of weaning age in 112 non-industrialised societies. His results, published in 2001, revealed that the extended duration of breastfeeding reported for gatherer-hunters is generally typical in a non-industrialised context.³¹ In his sample, weaning occurred at an average age of about two-and-a-half years (29 months). However, there was considerable variation, with an overall range between one year and five-and-a-half years.

Overall, the balance of evidence, both from non-human primates and from human gathering-and-hunting societies, indicates that a natural weaning age in humans would be *at least* three years. Although many authors have concluded that the weaning age was reduced after humans diverged from great apes, they nevertheless maintained a basic pattern of relatively late weaning that is still evident in modern gatherers-and-hunters living close to nature. A weaning age of three years is less than in extant great apes, but it is still considerably longer than the average condition seen in most societies today. Moreover, the proposal that weaning age was reduced during human evolution is not entirely convincing. As a rule, in mammals, *all* life-history phases evolve in tandem, such that late attainment of sexual maturity and a lengthy lifespan are usually accompanied by a delayed age of weaning. So a reduction in the human age weaning conflicts with our very slow sexual maturation and our unusually long lifespan. The hypothesis that natural selection favoured increased reproductive output in early humans also clashes with the expectation

29 Konner, M.J. & Worthman, C. 1980. Nursing frequency, gonadal function, and birth spacing among !Kung hunter-gatherers. *Science*, 207(4432), February:788-791. [https://doi.org/10.1126/science.7352291].

30 Konner, M. 2005. Hunter-gatherer infancy and childhood: The !Kung and others. In: Hewlett, B.S. (ed). *Hunter-Gatherer Childhoods: Evolutionary, Developmental, and Cultural Perspectives*. New York: Routledge. 19-64.

31 Sellen, D.W. 2001. Comparison of infant feeding patterns reported for nonindustrial populations with current recommendations. *Journal of Nutrition*, 131(10), October:2707-2715. [https://doi.org/10.1093/jn/131.10.2707].

from our general life-history pattern. As Dettwyler has rightly emphasised, the natural (i.e. ancestral) period of breastfeeding in the human species is *at least* three years and may well be substantially longer.³²

A natural weaning age of at least three years might come as a shock to women who are accustomed to nursing their babies for three to six months, with a maximum of a year. It is therefore important to emphasise that the figure of three years is for *total duration* of breastfeeding. Cross-cultural research by Daniel Sellen and others indicates that exclusive breastfeeding usually lasts six months to a year. For the rest of the time until weaning the infant receives supplementary foods in addition to breast milk. In 2005, the Section on Breastfeeding of the American Academy of Pediatrics recommended that, wherever possible, an infant should be exclusively breastfed for six months and weaned at a year. Both the World Health Organization (WHO) and the United Nations Children's Fund have also advocated six months of exclusive breastfeeding but now recommend weaning at two years. So we are inching our way back to the timing that biological and anthropological comparisons suggest.

We can also obtain information about weaning age by looking back into the distant past. For instance, documentary sources for the Pharaonic period in Egypt (between 2686 and 332 BC) indicate that infants were breastfed up to an age of three years. Already at that time, older infants were sometimes given milk from domestic mammals as a supplement.

Fortunately, our information sources are not limited to written documents. It is possible to gain useful information from chemical analyses of bones excavated at archaeological sites by measuring isotopes (variants of a chemical element that have the same number of protons in each atom but differ in the number of neutrons). It has been known for some time that isotope ratios for certain elements, notably nitrogen and carbon, change in a consistent fashion from the bottom to the top of the food chain. When herbivores eat plants, certain isotopes are enriched, and that enrichment process is carried further when predators eat herbivores. Consequently, the greatest degree of enrichment is found in predators at the top of the food chain. Ironically, the same thing happens when mothers suckle babies. Perhaps not surprisingly, isotopes in milk are enriched in suckled infants just as if they were predators feeding on the mother's body. The nitrogen isotope ¹⁵N and the carbon isotope ¹³C are both enriched relative to maternal levels in an infant's body (including the skeleton) during breastfeeding and then return to baseline after weaning.³³

32 Dettwyler, 2004.

33 Carlson, 1999; Rodgers, 1978.

Analysing stable isotopes in skeletons of all ages, anthropologist Tosha Dupras and colleagues investigated infant feeding and weaning practices during the Roman period some 2 000 years ago at the Dakhleh Oasis in Egypt.³⁴ The study revealed that Egyptian mothers at this site probably introduced supplementary foods when their infants were around six months of age and completed weaning by three years of age. Investigation of isotopes in animal and plant remains from an ancient village nearby yielded valuable additional information. After the age of about six months, infants were fed with milk from goats or cows.

Even earlier evidence is available from studies of nitrogen isotopes in skeletons of infants and children from two Neolithic sites in Anatolia, Turkey, dating back around 10 000 years. Archaeologist Jessica Pearson and colleagues used isotope analysis to glean clues about foods eaten by past populations and the relationship between diet and health.³⁵ They also studied skeletons from archaeological sites to seek features that indicate past activities. The team reported that, in their study populations, exclusive breastfeeding lasted one to two years and weaning occurred between two and three years after birth. Both Anatolian communities were on the cusp of the shift from gathering and hunting to agriculture, harvesting a few domesticated plants and living with some not-yet-domesticated animals.

So comparative evidence from primatology, anthropology and archaeology uniformly indicates that our gathering-and-hunting ancestors 10 000 years ago would have breastfed babies for *at least* three years. Accordingly, in assessing the natural advantages and benefits of breastfeeding, it is biologically appropriate to compare bottle-fed infants with children that have been breastfed for three years or more. It is certainly barely informative to use the category 'ever breastfed' for comparison with bottle-fed infants.

In fact, in 1999, Anderson and colleagues reported another significant finding from their meta-analysis of 20 individual studies: Benefits for mental development increased with the duration of breastfeeding.³⁶ So, nursing for three years rather than just a few months can be confidently expected yield greater benefits. In 1993, developmental biologists Walter Rogan and Beth Gladen threw valuable light

34 Dupras, T.L., Schwarcz, H.P. & Fairgrieve, S.I. 2001. Infant feeding and weaning practices in Roman Egypt. *American Journal of Physical Anthropology*, 115(3), July:204-212. [https://doi.org/10.1002/ajpa.1075].

35 Pearson, J.A., Hedges, R.E.M., Molleson, T.I. & Özbek, M. 2010. Exploring the relationship between weaning and infant mortality: An isotope case study from Asikli Höyük and Cayönü Tepesi. *American Journal of Physical Anthropology*, 143(3), November:448-457. [https://doi.org/10.1002/ajpa.21335].

36 Anderson et al., 1999.

on this possibility.³⁷ In a well-designed prospective study, they tested some 800 children aged between six months and five years. Their results confirmed the oft-reported finding that average scores are significantly higher in breastfed than bottle-fed children, albeit by only a few points. More interestingly, however, they showed that scores mounted continuously as the duration of breastfeeding increased, from a few weeks to over a year.

Another, notably more recent, prospective study published in 2015 by Vasiliki Leventakou and colleagues analysed data for 540 mother-child pairs included in a cohort study in Heraklion, Crete in Greece, to examine the effect of breastfeeding duration.³⁸ The authors emphasised that few studies had addressed this issue. When children reached the age of 18 months, their cognitive, linguistic and motor development were assessed with standard tests (Bayley scales). Statistical procedures were applied to control an impressive range of potential confounding factors:

- maternal and paternal age at birth;
- the educational level at recruitment;
- Greek versus non-Greek origin;
- the mother's working status at the time of testing;
- marital status at birth;
- maternal and paternal smoking during pregnancy;
- parents' relationship when the child was aged nine months;
- postpartum depressive symptoms assessed at eight to 10 weeks after delivery;
- the child's sex;
- type of delivery;
- siblings at birth;

37 Rogan, J.W. & Gladen, B.C. 1993. Breast feeding and cognitive development. *Early Human Development*, 31(3), January:181-193. [[https://doi.org/10.1016/0378-3782\(93\)90194-y](https://doi.org/10.1016/0378-3782(93)90194-y)].

38 Leventakou, J., Roumeliotaki, T., Koutra, K., Vassilaki, M., Mantzouranis, E., Bitsios, P., Kogevinas, M., Chatzi, L. 2015. Breastfeeding duration and cognitive, language and motor development at 18 months of age: Rhea mother-child cohort in Crete, Greece. *Journal of Epidemiology and Community Health*, 69(3), March:232-239. [<https://doi.org/10.1136/jech-2013-202500>].

- birth order;
- birth weight;
- head circumference;
- body length;
- gestational age;
- preterm birth;
- neonatal intensive care and hospitalization;
- daycare attendance at 18 months of age;
- daily time spent with mother and father at 18 months of age (hours); and
- age at which solid foods were introduced.

Even after allowing for possible effects of all of these factors, a positive effect of breastfeeding duration was found with test scores for all capacities except gross motor development, namely, cognitive development, receptive communication, and expressive communication. For every month of breastfeeding, scores increased by about 0.3 points. Unfortunately, the study did not distinguish breastfeeding duration beyond six months, but a simple linear continuation in the trend would result in an improvement of more than 10 points after three years.

Of course, the underlying assumption is that development of the brain directly benefits from breastfeeding. It is therefore pertinent to obtain information on actual brain development rather using the indirect method of assessing mental capacities. In 2013 Sean Deoni and colleagues published results from a novel approach using the non-invasive technique of magnetic resonance imaging to examine brain development in human infants.³⁹ These authors examined 133 healthy children aged between 10 months and four years to estimate the total amount of white matter, which consists of the myelin-sheathed nerve fibres that convey signals in the brain. It emerged that, at any given age, breastfed children consistently had more white matter in the later-maturing frontal and association regions of the brain. Deoni and colleagues also found a positive relationship between the duration of breastfeeding and the development of white matter in

39 Deoni, S.C.L., Dean, D.C., Piryatinsky, I., O'Muircheartaigh, J., Waskiewicz, N., Lehman, K., Han, M. & Dirks, H. 2013. Breastfeeding and early white matter development: A cross-sectional study. *NeuroImage*, 82, November:77-86. [<https://doi.org/10.1016/j.neuroimage.2013.05.090>].

several brain regions that could account for higher scores in scores for cognitive and behavioural performance. The authors concluded that their findings “support the hypothesis that breast milk constituents promote healthy neural growth and white matter development”.

Additional benefits of breastfeeding

Thus far, the discussion has focused on the nutritional content of milk, but breast milk did not evolve exclusively to nourish babies. It has several additional benefits. For instance, a mammalian mother also provides her offspring with a cocktail of antibiotic ingredients in her milk. In particular, while her infant’s active defence mechanisms are developing, she temporarily provides passive protection against microbes. Such protection against infection may have been one of the earliest functions of suckling. Paediatrician Armond Goldman noted that the oily secretions of sebaceous glands (the likely precursors of mammary glands) in mammals contain immune factors similar to those present in milk.⁴⁰ In his 2000 paper reviewing several key features of human milk, nutritionist Bo Lönnerdal reported that these include various agents of immunity, such as antibodies and immune cells, and that most of the specific active ingredients are proteins.⁴¹

Beneficial bacteria also take up residence in the digestive tract. As babies are sterile at birth, however, they have to accumulate the bacteria they need from local sources, and the natural provider is the breastfeeding mother. Almost inevitably, harmless bacteria inhabiting the gut differ between breastfed and bottle-fed infants, although suitable supplements can be added to milk formula to overcome this problem. In his 1995 article, Jack Newman, a paediatrician who founded the influential breastfeeding clinic at the Hospital for Sick Children in Toronto, reviewed the protective agents against noxious microbes provided by human milk.⁴² Newman noted that in several countries mothers directly use their breast milk to treat eye infections in infants. A child’s immune response does not reach full strength until it is about five years old, so the protection provided by breastfeeding is sorely needed. Doctors have long recognised that breastfed infants contract fewer infections and suffer less than bottle-fed infants from meningitis or infections of the gut, ear, respiratory system, and urinary tract. That difference applies even when infants are fed with milk formula that has been sterilised.

40 Goldman, A.S. 2002. Evolution of the mammary gland defense system and the ontogeny of the immune system. *Journal of Mammary Gland Biology & Neoplasia*, 7(3), July:277-289. [<https://doi.org/10.1023/a:1022852700266>].

41 Lönnerdal, 1995.

42 Newman, 1995.

All human babies receive some protection from their mothers even before birth. Antibodies pass across the placenta to the fetus during pregnancy, and they continue to circulate in the infant’s blood for weeks or even months after birth. From birth onwards, breastfed infants receive extra protection from antibodies, other proteins, and immune cells in human milk. Some proteins bind to microbes inside the gut cavity, preventing them from passing through the gut wall. Others reduce the supply of certain minerals and vitamins that noxious bacteria need to survive in the gut. For instance, a special binding protein reduces the availability of vitamin B12, while lactoferrin captures iron. Bifidus factor actively promotes the growth of beneficial bacteria in the infant’s gut.

In addition to the basic types of antibodies, human milk contains numerous immune cells, including some that attack microbes directly. The most abundant type of antibody in human milk is secretory Immunoglobulin A, which includes a component that shields it against digestion in the infant’s gut. Until they begin producing their own secretory Immunoglobulin A, usually some weeks or months after birth, bottle-fed infants have only limited resources to protect them against noxious microbes. As Newman concluded: “Breast milk is truly a fascinating fluid that supplies infants with far more than nutrition. It protects them against infection until they can protect themselves.”

Around the time of birth, human mothers produce a special kind of yellowish, low-fat milk known as *colostrum*, a widespread, probably universal feature of mammals. Its primary, vital function is to transfer immunity from mother to offspring immediately after birth. Immune cells and the antiviral agent interferon are concentrated in colostrum, which also includes growth factors that promote the development of the infant’s digestive tract. It is hence particularly important for newborn baby mammals, including human infants, to receive the first batch of milk that the mother produces. Before the latter part of the 17th Century, European society did not recognise the significance of colostrum for the health of human babies. Previously, colostrum was widely believed to be harmful. This extraordinary view was seemingly widespread among preindustrial societies and persisted in medieval Europe. It dates back at least as far as claims made by the second-century Greek physician Soranus of Ephesus, offering a striking example of how cultural norms sometimes clash directly with biological reality.

It must also be mentioned that bottle-feeding may generally trigger allergic responses in susceptible individuals. Public health scientist Michael Burr and colleagues studied wheezing and allergy in almost 500 children with a family history of allergic complaints.⁴³ Wheezing occurred in just over half of children

43 Burr, M.L., Limb, E.S., Maguire, M.J., Amarah, L., Eldridge, B.A., Layzell, J.C. &

that had ever been breastfed, whereas it affected three-quarters of exclusively bottle-fed children. The difference persisted even after allowing for several possible confounding factors. Burr and colleagues concluded that breastfeeding may confer long-term protection against respiratory infection – yet another example of the benefits of natural nursing.

Benefits of breastfeeding for mothers

It is now widely accepted that breastfeeding an infant has advantages over bottle-feeding, notably concerning brain development. However, it has been far less widely reported that breastfeeding also has genuine benefits for the well-being of the mother. These range from faster recovery of the womb after birth through a reduced risk of cardiovascular disease and on to a decreased risk for certain cancers later in life.

Immediate breastfeeding after birth helps to reduce blood loss by increasing the frequency of uterine contractions. While breastfeeding an infant during the first few days after birth, women commonly experience after-pains in the womb. Taking this experience as a starting-point, Selina Chua and her colleagues studied a small sample of 11 women, who served as their own controls. Following an uncomplicated birth in all cases, the effects of breastfeeding and nipple stimulation on womb activity were compared to baseline levels.⁴⁴ Chua and her colleagues found that the tempo of uterine contractions almost doubled during breastfeeding. The rate of contraction was also boosted with nipple stimulation alone, although not to the same extent.

Breastfeeding is generally associated with faster recovery of the womb after birth and helps to restore the mother's general physical condition. This finding has important practical consequences because haemorrhage after birth is a major cause of maternal death in Third World countries.⁴⁵ In 1993, for World Breastfeeding Week the WHO sent out a press release stating that, in the absence of suitable medical facilities, breastfeeding or nipple stimulation may be a safe, effective and

Merrett, T.G. 1993. Infant feeding, wheezing, and allergy: a prospective study. *Archives of Diseases in Childhood*, 68(6), June:724-728. [https://doi.org/10.1136/adc.68.6.724].

44 Chua, S., Arulkumaran, S., Lim, I., Selamat, N. & Ratnam, S.S. 1994. Influence of breastfeeding and nipple stimulation on postpartum uterine activity. *British Journal of Obstetrics & Gynaecology*, 101(9), September:804-805. [https://doi.org/10.1111/j.1471-0528.1994.tb11950.x].

45 Abrams, E.T. & Rutherford, J.N. 2011. Framing postpartum hemorrhage as a consequence of human placental biology: An evolutionary and comparative perspective. *American Anthropologist*, 113(3):417-430. [https://doi.org/10.1111/j.1548-1433.2011.01351.x].

economical means of reducing blood loss after birth. This advice applied especially to blood loss resulting from significant bleeding during the third stage of labour.

Heart disease is the leading cause of death in women in the USA. It is therefore of some importance that, over the long term, breastfeeding reportedly reduces the risk that mothers will eventually suffer from blockages in the circulatory system notably in the arteries of the heart (cardiovascular disease). In 2009, Eleanor Schwarz and colleagues published their results from an investigation of almost 140 000 postmenopausal women with a median age of 63 years who reported having at least one live birth.⁴⁶ The women concerned had either enrolled for observational study within the Women's Health Initiative or were included in controlled trials. To examine the relationship between risk factors for cardiovascular disease and duration of breastfeeding, Schwarz and colleagues applied multivariate models that allowed for effects of a variety of possible confounding factors, including age, parity, ethnicity, education, income, age at menopause, lifestyle and family history variables. Data for obesity, hypertension (high blood pressure), self-reported diabetes, high blood fat (notably cholesterol and triglycerides) and cardiovascular disease were analysed. Compared to women who had never breastfed, it emerged that those reporting a lifetime total of more than 12 months lactation were significantly less likely to have four of those conditions, although they were not less likely to be obese. Schwarz and colleagues estimated that, among women who had given birth, those who did not breastfeed compared with those who breastfed for more than 12 months were more likely to have hypertension (42.1 per cent versus 38.6 per cent), diabetes (5.3 per cent versus 4.3 per cent), high blood fat (14.8 per cent versus 12.3 per cent) and cardiovascular disease appearing after menopause (9.9 per cent versus 9.1 per cent).

In 2015, a team led by Erica Gunderson reported on a similar study of breastfeeding concerning hardening of the arteries (atherosclerosis), which is the main cause of heart attacks, stroke, and peripheral vascular disease.⁴⁷ They examined data from a multi-centre prospective study in the USA titled, *Coronary Artery Risk Development in Young Adults*. In that study, women were initially examined for a baseline evaluation in 1985-1986 when aged 18-30 years and then re-examined

46 Schwarz, E.B., Ray, R.M., Stuebe, A.M., Allison, M.A., Ness, R.B., Freiberg, M.S. & Cauley, J.A. 2009. Duration of lactation and risk factors for maternal cardiovascular disease. *Obstetrics & Gynecology*, 113(5), May:974-982. [https://doi.org/10.1097/01.AOG.0000346884.67796.ca].

47 Gunderson, E.P., Quesenberry, C.P., Ning, X., Jacobs, D.R., Gross, M., Goff, D.C., Pletcher, M.J. & Lewis, C.E. 2015. Lactation duration and midlife atherosclerosis. *Obstetrics & Gynecology*, 126(2), August:381-390. [https://doi.org/10.1097/AOG.0000000000000919].

20 years later in 2005-2006. Gunderson and colleagues selected 846 women who had no heart disease or diabetes at baseline and subsequently had one or more births. For each woman, the total duration of breastfeeding was calculated across all births after baseline examination and allocated to one of the following categories: zero to less than one month; one to six months; six to 10 months; 10 months or more. Atherosclerosis was assessed by using ultrasound to measure the thickness of the innermost two layers of the wall of the common carotid artery. Statistical methods were applied to exclude confounding effects of pre-pregnancy obesity, cardiometabolic status, parity and other risk factors in comparisons between breastfeeding categories. Carotid wall thickness was found to have an inverse relationship with duration of breastfeeding that remained significant after exclusion of confounding effects.

Health benefits of breastfeeding for the mother extend far beyond a lower incidence of heart disease. Epidemiological evidence indicates that the benefits include protection against certain cancers, notably breast cancer. One early pointer to this came from records of mammals kept in zoos, indicating that mammary cancers were more likely to develop in females that had never suckled offspring. Reports from the 1920s reinforced this possibility and suggested that human breasts that had never been used to feed an infant were more likely to become cancerous. In one ingenious approach to this question, in a 1977 paper, Roy Ing and colleagues examined the unusual case of women inhabiting fishing villages in Hong Kong, who customarily suckled infants only from the right breast.⁴⁸ Radiotherapeutic records for the period 1958-1975 were searched, and breast cancer patients were interviewed to compile details of their lactation history. For the sample as a whole, there was no difference between frequencies of cancers on the left and right sides. Comparisons of postmenopausal patients who had nursed exclusively from one breast with those who had never given birth or had given birth but had not breastfed, however, revealed a highly significant increase in the risk of cancer for the unsuckled breast. However, the paper by Ing and colleagues met with considerable criticism at the time because of perceived shortcomings.

The topic then remained dormant for over a decade until 1989, when Peter Layde and colleagues published a paper examining the relationship between age at first full-term pregnancy, number of births, duration of breastfeeding and the risk of breast cancer.⁴⁹ By that time, it was widely accepted that a woman's reproductive

history exerts a strong influence on her risk of breast cancer, but the relationships between the individual factors involved remained unclear. The analysis was complicated by the fact that pregnancy itself is known to provide some degree of protection against breast cancer. To assess the respective contributions of different factors, Layde and colleagues used appropriate statistical techniques to analyze data from the *Cancer and Steroid Hormone Study*, a multi-centre case-control investigation. Four thousand and five hundred and ninety-nine women, identified as having an initial diagnosis of breast cancer, were compared with 4 536 randomly selected women from the same regions, serving as controls. In line with previous reports, age at first full-term pregnancy was found to exert a strong influence on breast cancer risk. However, after allowing for this influence along with the effects of several other potential confounding factors, it emerged that the number of births (parity) and duration of breastfeeding also made strong contributions to reducing the risk of breast cancer. Compared with women who had given birth only once, women who had had seven or more births showed a reduction of about 40 per cent in breast cancer risk. Similarly, compared with women who had given birth but never breastfed, women who had breastfed for a combined total exceeding two years showed a reduction of about 33 per cent.

Those findings were reinforced in a large-scale, worldwide review of available information published in 2002 by the Collaborative Group on Hormonal Factors in Breast Cancer.⁵⁰ The study examined information from 47 epidemiological studies in 30 countries, covering over 50 000 women with invasive breast cancer and almost twice as many who were cancer-free. The Collaborative Group's review confirmed the protective effects of pregnancy by showing that women with breast cancer had 15 per cent fewer births, with an average of 2.2 compared to 2.6. It also revealed that, among women who had given birth, just over 70 per cent of those who developed cancer had ever breastfed. By contrast, almost 80 per cent of women who remained cancer-free had breastfed to some extent. A further difference was detected for the average lifetime duration of breastfeeding. On average, women who developed cancer breastfed for only 9.8 months altogether, compared with a lifetime total of 15.6 months for women who remained cancer-free. The most important finding reported by the Collaborative Group was that the relative risk of breast cancer decreased by seven per cent for every birth and by more than four

48 Ing, R., Ho, J.H.C. & Petrakis, N.L. 1977. Unilateral breast-feeding and breast cancer. *Lancet*, 2(8029), July:124-127. [[https://doi.org/10.1016/s0140-6736\(77\)90131-3](https://doi.org/10.1016/s0140-6736(77)90131-3)].

49 Layde, P.M., Webster, L.A., Baughman, A.L., Wingo, P.A., Rubin, G.L. & Ory, H.W. 1989. The independent associations of parity, age at first full term pregnancy, and duration of breastfeeding with the risk of breast cancer. *Journal of Clinical Epidemiology*,

42(10):963-973. [[https://doi.org/10.1016/0895-4356\(89\)90161-3](https://doi.org/10.1016/0895-4356(89)90161-3)].

50 Collaborative Group on Hormonal Factors in Breast Cancer. 2002. Breast cancer and breastfeeding: collaborative reanalysis of individual data from 47 epidemiological studies in 30 countries, including 50 302 women with breast cancer and 96 973 women without the disease. 2002. *Lancet*, 360(9328), July:187-95. [[https://doi.org/10.1016/S0140-6736\(02\)09454-0](https://doi.org/10.1016/S0140-6736(02)09454-0)].

per cent for every year of breastfeeding. Combining all findings to estimate the cumulative incidence of breast cancer up to age 70 for developed countries, yielded the following conclusion:

If all women had the average number of births and lifetime duration of breastfeeding that characterized third world countries until recently, deaths from breast cancer could be more than halved – from one in 16 to one in 37 – the influence of breastfeeding accounts for almost two-thirds of this projected reduction.⁵¹

Breastfeeding has also been linked to a reduced risk of ovarian cancer. In the 1970s indications emerged that associated the absence of ovulation with a lower incidence of cancer of the ovaries. One notable development was a 1979 paper by John Casagrande and colleagues, who conducted a case-control study comparing 150 ovarian cancer patients under the age of 50 with individually matched controls. The aim was to assess the potential effects of fertility and oral contraceptives on ovarian cancer risk. Casagrande and colleagues found that a decreased risk was associated with increasing numbers of live births and incomplete pregnancies and also with the use of oral contraceptives. All three factors were regarded as periods free of ovulation and amalgamated into a single index termed, ‘protected time’. The residual period after subtraction of protected time from the period between menarche and diagnosis of ovarian cancer (or cessation of menses), was strongly related to ovarian cancer risk. This study did not specifically address breastfeeding, but a connection with reduced risk of ovarian cancer seems likely because of the influence of numbers of live births and the long-recognized fact that ovulation is suppressed during full-time breastfeeding.

In 1993, Kerin Rosenblatt and David Thomas published results from a direct study of the relationship between breastfeeding and the risk of ovarian cancer with data derived from a WHO multinational study of associations between cancer and steroid contraceptives in 1979-1988.⁵² Rosenblatt and Thomas compared 393 cases of ovarian cancer with 2 565 carefully matched controls. The risk of ovarian cancer was reduced by about a quarter in women who breastfed for at least two months, although this result did not reach statistical significance. No additional reduction in risk was found with longer-term lactation. Moreover, the reduction in risk associated with months of lactation was not as great as the reduction observed with months of pregnancy. Still, it is encouraging to note that breastfeeding for just

a few months after birth did seemingly provide some degree of protection against ovarian cancer.

A very useful overview of the beneficial effects of breastfeeding for the mother was provided by Miriam Lobbok in 2001.⁵³ She stated:

... a clear pattern of positive physiologic changes that lead to improved short-term and long-term health sequelae is emerging. All patients and their families should be informed fully as to the positive preventive health effects of breastfeeding not only for infants but also for mothers. Women have many difficult choices to make; it behooves physicians to ensure that they receive all of the facts on which to base these decisions.

Lobbok discussed ovarian cancer risk, referring to the 1979 paper by Casagrande and colleagues and their hypothesis that ‘incessant ovulation’ is a causal factor. She also mentioned several other studies, including one by Harvey Risch and colleagues, published in 1983, that reported a moderate reduction in the risk of ovarian cancer from interviews with patients and a random sample of women living in the same areas in Washington and Utah.⁵⁴ Logistic regression methods were applied, allowing for a range of potential confounding factors. Significant estimated relative risks of 0.88 per pregnancy, 0.82 per miscarriage, 0.79 per year of breastfeeding and 0.89 per year of oral contraception were determined. These diminished risks’ magnitude greatly exceeded those expected solely based on the inhibition of ovulation. Taking into account the 1993 study by Kerin Rosenblatt and David Thomas, Lobbok concluded that that breastfeeding for two to seven months after birth is associated with a significant decrease in the risk of ovarian cancer, at a level averaging 20 per cent.⁵⁵ However, available data did not support a dose-response relationship with increased duration of breastfeeding, so some alternative explanation to that proposed by Casagrande and colleagues is seemingly needed.

A more recent case-control study by Dada Su and colleagues, published in 2013, referred to growing evidence indicating a protective effect of breastfeeding on the

53 Lobbok, M.H. 2001. Effects of breastfeeding on the mother [review]. *Pediatric Clinics of North America*, 48(1), February:143-158. [https://doi.org/10.1016/s0031-3955(05)70290-x].

54 Risch, H.A., Weiss, N.S., Lyon, J.L., Daling, J.R. & Liff, J.M. 1983. Events of reproductive life and the incidence of epithelial ovarian cancer. *American Journal of Epidemiology*, 117(2), February:128-139. [https://doi.org/10.1093/oxfordjournals.aje.a113523].

55 Rosenblatt, K.A. & Thomas, D.B. 1993. Lactation and the risk of epithelial ovarian cancer. The WHO Collaborative Study of Neoplasia and Steroid Contraceptives. *International Journal of Epidemiology*, 22(2), April:192-197. [https://doi.org/10.1093/ije/22.2.192].

51 Collaborative Group on Hormonal Factors in Breast Cancer, 2002.

52 Casagrande, J.T., Pike, M.C., Ross, R.K., Louie, E.W., Roy, S., Henderson, B.E. 1979. ‘Incessant ovulation’ and ovarian cancer. *Lancet*, 2(8135), July:170-173. [https://doi.org/10.1016/s0140-6736(79)91435-1].

risk of ovarian cancer.⁵⁶ Their study, conducted in southern China in 2006-2008, used a questionnaire to obtain information on the number of children breastfed and total months of lactation for 493 ovarian cancer patients and 472 hospital-based controls. Logistic regressions were performed to assess the association between breastfeeding and the risk of ovarian cancer. Other independent variables included in the models as potential confounders were age at interview, parity, oral contraceptive use, ovarian or breast cancer in a first-degree relative, educational level, menopausal status, alcohol consumption, and smoking status. After allowing for these factors, significant inverse dose-response relationships were found for both the number of children breastfed and the total duration of lactation. Women with a total lactation greater than 31 months had only a tenth of the risk of ovarian cancer compared to women with less than ten months. Women who had breastfed more than three children had less than 40 per cent of the risk of ovarian cancer for women who had breastfed only one child.

Opposition to campaigns to encourage breastfeeding

Accumulated evidence surely indicates that breastfeeding has distinct benefits for both mothers and infants. Although the evidence comes largely from epidemiological surveys and is therefore predominantly circumstantial, breastfeeding is associated with improved development of the infant's brain, reflected by higher scores on mental tests in breastfed children that are admittedly limited in scope but statistically significant. As far as mothers are concerned, breastfeeding heals the womb and wards off heart disease and protects against breast cancer. Various studies have indicated a dose-response relationship between duration of breastfeeding and health benefits for mothers and infants, vitally important because modern mothers living in industrialised societies very rarely breastfeed their infants for the minimum period of three years that has been inferred for early members of our species leading a gathering-hunting existence. As a result, many studies that have compared bottle-feeding with breastfeeding have analysed data from mothers who have commonly stopped nursing within a few months after birth, with a maximum of one year in rare cases. This behaviour may well explain why the differences between bottle-feeding and breastfeeding mothers have generally been quite small and why some studies have yielded inconclusive results. Indeed, studies that have used the category 'ever breastfed' in comparisons with bottle-feeding are virtually doomed from the outset. It is not at all reasonable to expect that babies that have been breastfed for less than a month after birth will

56 Su, D., Patalich, M., Lee, A.H. & Binns, C.W. 2013. Ovarian cancer risk is reduced by prolonged lactation: a case-control study in southern China. *American Journal of Clinical Nutrition*, 97:354-359. [<https://doi.org/10.3945/ajcn.112.044719>].

show significant differences in brain development or associated scores of mental function. It is unreasonable to expect that mothers who have breastfed their infants for just a few weeks will show a significantly reduced risk of breast cancer.

Under ideal conditions, then, it would be in a woman's best interests – both for optimal development of her infant and for her well-being – to breastfeed her infant for at least three years. National and international agencies have progressively recognised this fact and have increasingly issued recommendations to encourage breastfeeding and to augment its duration. At the same time, however, it is important to acknowledge that, for medical and other reasons, many women are unable or unwilling to breastfeed, and campaigns that promote breastfeeding should avoid overt or implied criticism. Women who, for whatever reason, cannot breastfeed should certainly not be made to feel guilty.

So it should be made abundantly clear that the take-home message from this review of the natural history of breastfeeding is not that we all need to return to our gathering-and-hunting lifestyles, nor even that women should always try to breastfeed their babies. Instead, the appropriate message is that we should investigate in-depth the evolutionary background to human breastfeeding to ensure that any modifications resulting from current lifestyles fit all natural requirements as closely as possible. In particular, any formula provided as a substitute for breast milk should be optimised to provide everything that a baby needs. Moreover, we need to explore the benefits of breastfeeding for mothers in detail to develop treatments that will replicate the natural provided, especially relevant to devise ways of reducing risks of cancer to the level normally associated with several pregnancies and extended breastfeeding of the infants during a woman's lifetime.

We still have much to do, particularly in designing more appropriate milk formulae. Both women and babies are biologically adapted for at least three years of breastfeeding, so mothers who nurse their babies for just a few months are not much better off than mothers who do not nurse at all. Moreover, the general trend to reduced family size in industrialised nations is, in itself, diminishing the protective effect provided by pregnancies and extended breastfeeding of each infant. The simplest approach is for a woman to breastfeed every infant as long as possible, but what all mothers need and deserve is an appropriate formula to use whenever bottle-feeding is the only option.

The bottom line is that female mammals adapted not only for milk secretion and suckling but also for close mother-infant contact. In recent decades, health authorities have increasingly acted on evidence for natural advantages of breastfeeding by encouraging mothers to nurse babies as far as possible. Still, the widely used slogan, *Breast is Best*, has raised hackles in some quarters. Official

promotion of breastfeeding has not been universally welcomed and has triggered some quite strident opposition. One milestone was Hanna Rosin's 2009 article, *The case against breastfeeding*, in *The Atlantic*, feeding fairly directly on to the 2015 book, *Lactivism*, by Courtney Jung, Professor of Political Science at the University of Toronto.⁵⁷

Lactivism has two main themes, one commendable and the other reprehensible. The first, praiseworthy, theme is that women who do not breastfeed – for whatever reason – should never be bullied. Many women try hard without success to nurse their babies, and they do not need over-zealous breastfeeding advocates to deepen their disappointment. Many other mothers cannot breastfeed for financial or medical reasons. The HI-virus is an oft-cited example, although it is unclear whether breastfeeding increases or decreases transmission risk. Regardless, slogans like *Breast is Best* are no excuse for demeaning women for not breastfeeding. What we need instead is scientifically-based replication of benefits when women cannot breastfeed.

Jung's second theme, though, is the systematic belittlement of the scientific evidence for benefits of breastfeeding, which are portrayed as minimal to non-existent. Enthusiastic advocates of breastfeeding do sometimes overstate benefits. Formula-reared babies fare remarkably well on an artificial substitute for human milk, especially because of manufacturers' feeble attempts to approximate human milk composition.

Jung's discussion of scientific findings though – essentially Chapter 3 of *Lactivism* – is patchy and selective. A key feature is her focus on paediatrician Michael Kramer as the prime source of expert opinion. It must be noted at once that Jung misrepresents his findings. Tom Bartlett sought comments from Kramer when reviewing *Lactivism* for *The Chronicle of Higher Education*. Kramer told him: "I think she chose to ignore some of the science ... I don't think it's a balanced summary of the evidence, and I do think it sends the wrong message."

The fundamental point here is that Kramer led the Promotion of Breastfeeding Intervention Trial (Probit, 1996-1997), described by Jung as "the largest and most authoritative study of the effects of breastfeeding to date".⁵⁸ Kramer was concerned

because previous studies that had provided evidence for breastfeeding benefits were largely observational with no possibility for testing, meaning that interpretations depended on correlations and their reliability depended on the degree to which effective exclusion of confounding factors could be achieved by statistical means. With great inspiration, Kramer designed a prospective procedure that would avoid ethical problems of actual experiments – taking 31 hospitals, half were randomly selected for specific promotion of breastfeeding (intervention group), while the other half continued existing practices (control group). For logistic reasons, the Republic of Belarus was chosen as the location for the project.

Over the past two decades, the Probit study has generated a steady flow of publications. Before it started, although most mothers initiated breastfeeding after birth, many introduced bottle-feeding soon afterwards and ceased breastfeeding entirely within three months. Strikingly, in the intervention group, exclusive breastfeeding of babies at three months of age proved to be more than seven times more likely than in the control group. Moreover, a year after birth, intervention mothers were twice as likely as control mothers to be still breastfeeding. It is vital to note, however, that the Probit study must necessarily *underestimate* breastfeeding benefits, because of its ingenious design to comply with ethical standards. The fundamental design of Probit does not permit comparison between breastfeeding and exclusive bottle-feeding; it only allows comparison of babies receiving a limited amount of breastfeeding with others whose mothers are encouraged to breastfeed for a longer period.

Encouragingly, despite its constraints, Probit neatly confirmed several findings from previous observational studies. The 2001 paper by Kramer and colleagues reported a significantly reduced risk of gastrointestinal tract infections (about a third lower) and atopic eczema (down by half) for intervention group babies.⁵⁹ On the other hand, respiratory tract infection showed no significant difference. Furthermore, various other Probit papers reported no significant positive effects of increased breastfeeding on height, weight, adiposity, Body Mass Index, blood pressure, diabetes, asthma or atopic eczema. For these conditions, confounding factors may have skewed previous observational studies. So, the spectrum of breastfeeding benefits may not be as broad as sometimes claimed.⁶⁰

57 Rosin, H. 2009. The case against breast-feeding. *The Atlantic*, April issue. [<https://www.theatlantic.com/magazine/archive/2009/04/the-case-against-breast-feeding/307311/>]; Jung, C. 2015. *Lactivism: How Feminists and Fundamentalists, Hippies and Yuppies, and Physicians and Politicians Made Breastfeeding Big Business and Bad Policy*. New York: Basic Books.

58 Kramer, M.S., Chalmers, B., Hodnett, E.D. & Helsing, E. 2001. Promotion of Breastfeeding Intervention Trial (PROBIT): A randomized trial in the Republic of Belarus.

Journal of the American Medical Association, 285(4), January:413-420. [<https://doi.org/10.1001/jama.285.4.413>].

59 Ibid.

60 Kramer, M.S., Matush, L., Vanilovich, I., Platt, R.W., Bogdanovich, N., Sevkovskaya, Z., Dzikovich, I., Shishko, G., Collet, J.P., Martin, R.M., Smith, G.D., Gillman, M.W., Chalmers, B., Hodnett, E. & Shapiro, S. 2007. Effects of prolonged and exclusive breastfeeding on child height, weight, adiposity, and blood pressure at age 6.5 y:

Another major breastfeeding benefit indicated by many other studies is protection against Sudden Infant Death Syndrome. Unfortunately, Probit yielded insufficient data for statistical tests of this widely accepted benefit. However, in 2011 Fern Hauck and colleagues published a meta-analysis of results from many previous studies that yielded convincing evidence of risk reduction.⁶¹ Sudden infant death syndrome rates were lower with infants that received any breastfeeding at all and by almost three quarters with exclusive breastfeeding of any duration. These findings, incidentally, suggest that an extended period of breastfeeding may not be necessary to provide a significant degree of protection against sudden infant death syndrome. It also indicates that the Probit investigation would not have provided an adequate test of protection against sudden infant death syndrome, because infants in that study were generally breastfed to some extent.

Importantly, a 2008 paper by Kramer and colleagues from the Probit study reported that, when assessed with various intelligence tests at six-and-a-half years of age, intervention group children scored significantly higher – by up to 7.5 points (depending on test type) – than control group children.⁶² Teachers' academic ratings for both reading and writing were also significantly higher. The team concluded: "These results, based on the largest randomized trial ever conducted in the area of human lactation, provide strong evidence that prolonged and exclusive breastfeeding improves children's cognitive development."

The core weakness of *Lactivism* is that Jung fails to mention evolution and indeed ignores biology almost completely.⁶³ This omission is encapsulated in her sweeping

statement that "there has never been a time when *all* women breastfed", surely only referring to recent recorded history. Our species would have ceased to exist if, for a substantial evolutionary period, breastfeeding had been eliminated to the extent seen around the world today. Suckling is universal in mammals and has that 200-million-year evolutionary history behind it that cannot simply be ignored.

The fundamental issue is still this: Few people today breastfeed to the extent that prevailed for hundreds of thousands of years before our species domesticated milk-yielding mammals around ten millennia ago. Multiple lines of evidence indicate that our hunting-and-gathering ancestors breastfed babies for 'at least' three years, exclusively for the first six months or so and then combined with complementary feeding until weaning. Few mothers today come anywhere near that original pattern. As already noted, studies of 'breastfeeding' often fail to distinguish between 'ever breastfed' (perhaps for just a few days after birth) and breastfeeding for a year or more. We have only very limited information about breastfeeding lasting for three years or more. The few studies about the duration of breastfeeding have consistently reported accumulating beneficial increases over time for mothers and infants.

Lactivism rightly censures bullying of mothers who do not breastfeed. On the other hand, its seriously misleading disparagement of breastfeeding benefits is downright dangerous. It may reduce pressure to develop effective solutions for mothers who cannot breastfeed. Right now, the best advice to new mothers is that they should breastfeed if they can and for as long as possible. Benefits are not huge, but any mother surely wants her infant to have fewer early infections, to have a lower probability of cot death, and to grow up to be as smart as possible. She will surely prefer decreased risks of cancer of the breast and ovaries. However, if for any reason breastfeeding is not an option, every attempt should be made to replicate its benefits. For working mothers, breastpumping remains a useful (not necessarily easy) option, despite all the negative comments in *Lactivism*. If the formula has to be used, then it should be optimised. For instance, the jury is still out regarding a requirement for omega-3 and omega-6 fatty acids. However, they are known to be important for brain development, and human milk contains them, whereas cow's milk does not. So, it is wise to opt for a formula that contains them. Any formula used should, in any case, be closely scrutinised to see how effectively it matches human milk. Over the long term, pressure should be applied to oblige formula manufacturers to work harder to maximize the resemblance to human milk.

evidence from a large randomized trial. *American Journal of Clinical Nutrition*, 86(6), December:1717-1721. [<https://doi.org/10.1093/ajcn/86.5.1717>]; Patel, R., Oken, E., Bogdanovich, N., Matush, L., Sevkovskaya, Z., Chalmers, B., Hodnett, E.D., Vilchuck, K., Kramer, M.S. & Martin, R.M. 2014. Cohort profile: The Promotion of Breastfeeding Intervention Trial (PROBIT). *International Journal of Epidemiology*, 43(3), June:679-690. [<https://doi.org/10.1093/ije/dyt003>].

61 Hauck, F.R., Thompson, J.M.D., Tanabe, K.O., Moon, R.Y. & Vennemann, M.M. 2011. Breastfeeding and reduced risk of Sudden Infant Death Syndrome: A meta-analysis. *Pediatrics*, 128(1), July:103-110. [<https://doi.org/10.1542/peds.2010-3000>].

62 Kramer, M.S., Aboud, F., Mironova, E., Vanilovich, I., Platt, R.W., Matush, L., Igumnov, S., Fombonne, E., Bogdanovich, N., Ducruet, T., Collet, J.P., Chalmers, B., Hodnett, E., Davidovsky, S., Skugarevsky, O., Trofimovich, O., Kozlova, L. & Shapiro, S. 2008. Promotion of Breastfeeding Intervention Trial (PROBIT) Study Group. Breastfeeding and child cognitive development: New evidence from a large randomized trial. *Archives of General Psychiatry*, 65(5), May:578-584. [<https://doi.org/10.1001/archpsyc.65.5.578>].

63 Bartlett, T. 2015. Has mother's milk gone sour? *The Chronicle of Higher Education*. [<https://www.chronicle.com/article/Has-Mother-s-Milk-Gone-Sour-/234060>].



7

THE CHALLENGES OF BREASTFEEDING IN POOR URBAN AREAS IN SUB-SAHARAN AFRICA

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Optimal breastfeeding has the potential to prevent more than 800 000 deaths in children younger than five years; 500 000 neonatal deaths; and 20 000 deaths in women every year. Despite these benefits, evidence from Sub-Saharan Africa shows that breastfeeding practices remain sub-optimal with only 25 per cent of children exclusively breastfed for the first six months, while six per cent of infants in these countries are never breastfed. For example, although the proportion of children who were exclusively breastfed in Kenya improved from 32 per cent in 2008 to 61 per cent in 2014, pockets of suboptimal breastfeeding practices are documented in urban slums. Exclusive breastfeeding in some of the urban slums in Kenya is as low as two per cent, with the age of introducing complementary foods being one-month post-delivery, while about a third of children are not breastfed within one hour of delivery as recommended by the World Health Organization (WHO).

Urban slums are faced by unique social and structural factors that hinder optimal breastfeeding including poverty and non-conducive livelihood opportunities, poor living conditions, food insecurity, poor professional and social support to breastfeeding mothers and knowledge deficit coupled with negative cultural beliefs and misconceptions about breastfeeding. This situation calls for macro-level policies and interventions that consider the ecological setting. Promising interventions may include global initiatives such as the Baby-Friendly Hospital Initiative, the Baby-Friendly Community Initiative, Human Milk Banking and the Baby-Friendly Workplace Initiative. However, innovations in their implementation need to take consideration for the contextual complexities.

This chapter explores breastfeeding practices, associated challenges and interventions that could promote breastfeeding in urban slums.

Introduction

Nutrition is one of the most important factors influencing a child's health, growth and development, especially during the first years of life when neuro-psychomotor development is rapid.⁷ Consequently, poor nutrition in the first 1 000 days can cause irreversible long-term health consequences on the child's mental, physical and social development.⁸ Despite the remarkable progress in the health care delivery systems all over the world, child malnutrition continues to be one of the

7 Rosales, F.J., Reznick, J.S. & Zeisel, S.H. 2009. Understanding the Role of Nutrition in the Brain & Behavioral Development of Toddlers and Preschool Children: Identifying and Overcoming Methodological Barriers. *Nutritional Neuroscience*, 12(5), October:190-202. [<https://doi.org/10.1179/147683009X423454>].

8 Martorell, R. 1999. The nature of child malnutrition and its long-term implications. *Food and Nutrition Bulletin*, 20(3), January:288-292. [<https://doi.org/10.1177/156482659902000304>].

major public health problems in the low- and middle-income countries.⁹ Globally, child malnutrition plays a role in almost half of the reported cases of infant and young child morbidity and mortality. In sub-Saharan Africa, approximately one child in 13 dies before his or her fifth birthday, unlike the world's high-income countries experiencing a mortality ratio of one child in 189.¹⁰

There are various forms of infant and young child undernutrition such as intrauterine growth restriction, micronutrient deficiencies, protein-energy malnutrition which is associated with stunting, underweight, and wasting. Globally in 2016, the United Nations Children's Fund (UNICEF) estimated that a total of 159 million children younger than five years were stunted (too short for age): a ratio of one in every four children. Approximately 52 million were estimated to be wasted (too thin for height), and 41 million were overweight or obese. The majority (80 per cent) of these malnourished children lived in developing countries.¹¹ In Kenya, as of 2014, 26 per cent of children younger than five years were stunted with eight per cent severely stunted, 11 per cent underweight and four per cent wasted.¹²

Child undernutrition is estimated to cause annual child mortality of 3.1 million or 45 per cent of all child deaths, 35 per cent of the disease burden among children younger than five years, and 11 per cent of the total global Disability Adjusted Years.¹³ Whereas, severe wasting, stunting, and intrauterine growth restriction are estimated to constitute the largest percentage of any risk factors causing global deaths, and Disability-Adjusted Years among children younger than five years.¹⁴ Acute malnutrition is associated with high mortality risk and attributed to causing 14.6 per cent of all child deaths under five years old.¹⁵ Undernutrition

9 United Nations Children's Fund (UNICEF). 2013. *Improving child nutrition: the achievable imperative for global progress*. New York: UNICEF.

10 UNICEF, World Health Organization (WHO) and World Bank Group. 2014. Joint child malnutrition estimates – Levels and trends. *Global Database on Child Growth and Malnutrition*. [<http://www.who.int/nutgrowthdb/estimates2014/en/>].

11 Ibid.

12 Kenya National Bureau of Statistics (KNBS). 2015. *Kenya demographic and health surveys, 2014: Key indicators*. Nairobi, Kenya: KNBS. 76. [<https://bit.ly/3kh70pf>].

13 Black, R.E., Allen, L.H., Bhutta, Z.A., Caulfield, L.E., De Onis, M., Ezzati, M., Mathers, C. & Rivera, J. 2008. Maternal and child undernutrition: global and regional exposures and health consequences. *The Lancet*, 371(9608), January:243-260. [[https://doi.org/10.1016/S0140-6736\(07\)61690-0](https://doi.org/10.1016/S0140-6736(07)61690-0)].

14 Black, R.E., Allen, L.H., Bhutta, Z.A., Caulfield, L.E., De Onis, M., Ezzati, M., Mathers, C. & Rivera, J. 2008. Maternal and child undernutrition: global and regional exposures and health consequences. *The Lancet*, 371(9608), January:243-260. [[https://doi.org/10.1016/S0140-6736\(07\)61690-0](https://doi.org/10.1016/S0140-6736(07)61690-0)].

15 Ibid.

is highly correlated with short-term and long-term adverse health effects on the affected children, and increased risk of metabolic diseases and obesity later in their life course.¹⁶

Inadequate breastfeeding and complementary feeding practices have been widely documented in developing countries. For example, about 37 per cent of infants younger than six months are exclusively breastfed in low- and middle-income countries, which is below the targeted global universal coverage of 90 per cent.¹⁷ In particular, evidence from sub-Saharan Africa shows that breastfeeding practices remain sub-optimal with only 25 per cent exclusively breastfed for the first six months. Additionally, six per cent of infants in these countries are never breastfed.¹⁸ This inadequate infant and young child feeding practices in the first two years of life is highly associated with the high burden of child undernutrition.¹⁹ Particularly, suboptimum breastfeeding and complementary feeding practices, together with high rates of morbidity from infectious diseases such as pneumonia, diarrhoea and malaria, are the immediate causes of malnutrition in this age group.²⁰ To address these challenges, the WHO recommends optimal breastfeeding and complementary feeding practices, involving early initiation of breastfeeding, beginning from the first hour of life, exclusive breastfeeding of the infant for the first six months and continued breastfeeding up to two years of age in combination with adequate and safe complementary feeding to meet the evolving needs of the growing infant.²¹ Evidence shows that scaling up of breastfeeding promotes child

survival by preventing an estimated 823 000 child deaths, and it has the potential to prevent 500 000 neonatal deaths annually.²²

In Kenya, the proportion of exclusively breastfed children improved from 32 per cent in 2008 to 61 per cent in 2014 according to the Kenya Demographic and Health Survey.²³ However, the poor urban populations still present a higher burden of multiple nutrition-related health risks, which have been closely linked to inadequate poor infant and young child feeding practices, primarily including low breastfeeding rates.²⁴ In Africa, over half of the urban population (61.7 per cent) lives in slums. While in Kenya, 60-80 per cent of its urban population lives in slums. For example, in Nairobi, informal settlements cover just six per cent of the total residential land area, yet accommodates 60 per cent of the city's population.²⁵ Consequently, there is a need to focus on addressing challenges hindering optimal breastfeeding in vulnerable urban populations.

This chapter explores breastfeeding practices in poor urban settings with an emphasis on Nairobi's urban informal settlements where the African Population and Health Research Center conduct most of their research. The chapter is structured into four sections: In the first section, we discuss the importance of breastfeeding regarding early breastfeeding initiation, exclusive for the first six months and continued breastfeeding. We later discuss breastfeeding practices across sub-Saharan Africa and poor urban settings in sub-Saharan Africa in our second section of the book chapter. The third section explores challenges to optimal breastfeeding in poor urban settings which includes optimal exclusive breastfeeding for the first six months and continued breastfeeding. Most of the challenges discussed in this chapter are based on previous studies conducted by the African Population and Health Research Center in poor urban settlements in Kenya. The last part of this

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- 16 Lanigan, J. & Singhal, A. 2009. Early nutrition and long-term health: a practical approach. *Proceedings of the Nutrition Society*, 68(4), November:422-429. [https://doi.org/10.1017/S002966510999019X]; Victora, C.G., Adair, L., Fall, C., Hallal, P.C., Martorell, R., Richter, L. & Sachdev, H.S. 2008. Human capital. Maternal and Child Undernutrition Study G: Maternal and child undernutrition: consequences for adult health and human capital. *The Lancet*, 371(9609), January:340-357. [https://doi.org/10.1016/S0140-6736(07)61692-4].
- 17 Victora, C.G., Bahl, R., Barros, A.J., Franca, G.V., Horton, S., Krasevec, J., Murch, S., Sankar, M.J., Walker, N., Rollins, N.C. 2016. Breastfeeding in the 21st century: epidemiology, mechanisms, and lifelong effect. *The Lancet*, 387(10017), January:475-490. [https://doi.org/10.1016/S0140-6736(15)01024-7].
- 18 Ogbo, F.A., Nguyen, H., Naz, S., Agho, K.E. 2018. Page A: The association between infant and young child feeding practices and diarrhoea in Tanzanian children. *Tropical Medicine and Health*, 46(1), December:2. [https://doi.org/10.1186/s41182-018-0084-y].
- 19 Victora et al., 2016.
- 20 UNICEF, 2013.
- 21 WHO. 2001. *The optimal duration of exclusive breastfeeding*. Report of an Expert Consultation, Geneva, Switzerland, 28-30 March. [https://bit.ly/3pizGlr].

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- 22 Victora et al., 2016.
- 23 KNBS, 2014.
- 24 Kimani-Murage, E.W., Schofield, L., Wekesah, F.M., Mohamed, S., Mberu, B., Ettarh, R., Egondi, T., Kyobutungi, C. & Ezech, A. 2014. Vulnerability to food insecurity in urban slums: experiences from Nairobi, Kenya. *Journal of Urban Health: Bulletin of the New York Academy of Medicine*, 91(6), December:1098-1113. [https://doi.org/10.1007/s11524-014-9894-3]; Kimani-Murage, E.W., Wekesah, F.M., Wanjohi, M., Kyobutungi, C., Ezech, A.C., Musoke, R.N., Norris, S.A., Madise, N.J. & Griffiths, P. 2015. Factors affecting actualisation of the WHO breastfeeding recommendations in urban poor settings in Kenya. *Maternal & Child Nutrition*, 11(3), July:314-332. [https://doi.org/10.1111/mcn.12161].
- 25 United Nations Human Settlement Programme (UN-Habitat). 2014. *The State of African Cities 2014 – A Framework for Addressing Urban Challenges in Africa*. Nairobi. [https://bit.ly/3eW9PeA].

book chapter reflects on interventions to improve exclusive breastfeeding and support breastfeeding mothers.

Importance and benefits of breastfeeding

The WHO describes breastfeeding as the normal way of providing infants with the needed nutrients for healthy growth and development.²⁶ Human milk is uniquely engineered for human infants and is the biologically 'natural' way to feed infants.²⁷ Optimal breastfeeding encompasses immediate initiation within one hour of birth, followed by exclusive breastfeeding (where no additional foods or liquids, including water, are added to breast milk) for the first six months of life, and after that continued breastfeeding along with appropriate complementary foods for two years or longer.²⁸ Under normal circumstances, when women are provided with accurate information, and with the support of their family, the health care system and society at large, all mothers may be able to breastfeed.

There are many health benefits and advantages of breastfeeding at all stages of life. Breast milk promotes the survival, healthy growth, and development of the child by offering a source of crucial food, vitamins, minerals, enzymes and antibodies that children require.²⁹ Additionally, breastfeeding confers benefits to the mother and the society at large.

Benefits of breastfeeding to the child

Extant research shows that optimal breastfeeding has the potential to prevent more than 800 000 deaths in children younger than age five and 20 000 deaths in women every year in developing countries.³⁰ Breastfeeding supports healthy brain development, higher educational achievement, and lowers the risk of obesity and other chronic diseases.³¹

26 WHO. 2020. Breastfeeding. *Health Topics*. [https://bit.ly/3pm0nWm].

27 Allen, J. & Hector, D. 2005. Benefits of breastfeeding. *New South Wales Public Health Bulletin*, 16(3-4), March-April:42-46. [https://doi.org/10.1071/nb05011].

28 WHO, 2020.

29 Busch, D.W., Logan, K. & Wilkinson, A. 2014. Clinical practice breastfeeding recommendations for primary care: applying a tri-core breastfeeding conceptual model. *Journal of Pediatric Health Care*, 28(6), November-December:486-496. [https://doi.org/10.1016/j.pedhc.2014.02.007].

30 Victora et al., 2016.

31 WHO. 2018. Taking Action on Childhood Obesity. *World Obesity*. [https://bit.ly/2JSBFwB].

Breastfeeding protects against a wide range of immediate and longer-term adverse health outcomes. Breast milk is protective against infectious diseases such as upper and lower respiratory tract infections, gastrointestinal illnesses, and otitis media, during the infant period and beyond.³² Breastfeeding also enhances intellectual and motor development and protects against sudden infant death syndrome,³³ asthma and atopy.³⁴

There exists a link between breastfeeding and lower prevalence of childhood obesity and overweight/obesity later in life.³⁵ In a Canadian child cohort, breastfeeding was inversely associated with weight gain velocity and body mass index. These associations are dose-dependent, partially diminished when breast milk is fed from a bottle, and substantially weakened by formula supplementation after the neonatal period.³⁶ Breastfeeding is also a protective effect against type 2 diabetes, particularly among adolescents. Breastfeeding is associated with increased performance in intelligence tests in childhood and adolescence.³⁷

Benefits of breastfeeding initiation within the first one hour of birth

Early initiation to breastfeeding is associated with a decrease in neonatal death in infants. Research findings have shown that there is a marked dose-response of increasing risk of neonatal mortality with increasing delay in initiation of

32 Heinig, M.J. & Dewey, K.G. 1996. Health advantages of breast feeding for infants: a critical review. *Nutrition Research Reviews*, 9(1), January:89-110. [https://doi.org/10.1079/NRR19960007].

33 McVea, K.L., Turner, P.D. & Pepler, D.K. 2000. The role of breastfeeding in sudden infant death syndrome. *Journal of Human Lactation*, 16(1), February:13-20. [https://doi.org/10.1177/089033440001600104].

34 Eigenmann, P. 2004. Breastfeeding and atopic eczema dermatitis syndrome: protective or harmful? *Allergy*, 59(Supplement 78), August:42-44. [https://doi.org/10.1111/j.1398-9995.2004.00564.x]; Kemp, A. & Kakakios, A. 2004. Asthma prevention: Breast is best? *Journal of Paediatrics and Child Health*, 40(7), July:337-339. [https://doi.org/10.1111/j.1440-1754.2004.00397.x].

35 Arenz, S., Ruckerl, R., Koletzko, B. & Von Kries, R. 2004. Breast-feeding and childhood obesity: a systematic review. *International Journal of Obesity*, 28(10), October:1247. [https://doi.org/10.1038/sj.ijo.0802758]; WHO, 2018.

36 Azad, M.B., Vehling, L., Chan, D., Klopp, A., Nickel, N.C., McGavock, J.M., Becker, A.B., Mandhane, P.J., Turvey, S.E., Moraes, T.J., Taylor, M., Lefebvre, D.L., Sears, M.R., Subbarao, & CHILd Study Investigators. 2018. Infant Feeding and Weight Gain: Separating Breast Milk From Breastfeeding and Formula From Food. *Pediatrics*, 142(4), October. [https://doi.org/10.1542/peds.2018-1092].

37 Horta, B.L., Bahl, R., Martinés, J.C., Victora, C.G. & WHO 2007. Evidence on the long-term effects of breastfeeding. *WHO Systematic Reviews and Meta-Analyses*. [https://bit.ly/3klRI2z].

breastfeeding from the first hour to the seventh day; with overall late initiation (after day one) being associated with a two-fold increase in risk.³⁸

Benefits of exclusive breastfeeding

Results from a Cochrane review to assess the effects of exclusive breastfeeding for six months on child health, growth, and development showed that breastfeeding, both in duration or exclusivity, played a role in reducing infant morbidity and mortality.³⁹ Infants that were exclusively breastfed for six months experienced less morbidity from gastrointestinal infections compared to those who were partially breastfed.⁴⁰ Evidence suggests that exclusively breastfed children are less susceptible to diarrhoea and pneumonia and are more likely to survive than non-breastfed children.⁴¹

Benefits of breastfeeding to the mother

Mothers that breastfeed their infants are less likely to experience postpartum haemorrhage and are at a reduced risk of premenopausal breast and ovarian cancers.⁴² Hormonal changes associated with breastfeeding help recovery after childbirth and suppress maternal fertility.⁴³

38 Edmond, K.M., Zandoh, C., Quigley, M.A., Amenga-Etego, S., Owusu-Agyei, S. & Kirkwood, B.R. 2006. Delayed Breastfeeding Initiation Increases Risk of Neonatal Mortality. *Pediatrics*, 117(3), March:e380. [https://doi.org/10.1542/peds.2005-1496].

39 Kramer, M.S. & Kakuma, R. 2012. Optimal duration of exclusive breastfeeding. *Cochrane Database of Systematic Reviews (CDoSr)*, 8, August:CD003517. [https://doi.org/10.1002/14651858.CD003517.pub2].

40 Ibid.

41 Black, R.E., Victora, C.G., Walker, S.P., Bhutta, Z.A., Christian, P., De Onis, M., Ezzati, M., Grantham-McGregor, S., Katz, J., Martorell, R., Uauy, R. & Maternal and Child Nutrition Study Group. 2013. Maternal and child undernutrition and overweight in low-income and middle-income countries. *The Lancet*, 382(9890), August:427-451. [https://doi.org/10.1016/S0140-6736(13)60937-X].

42 Collaborative Group on Hormonal Factors in Breast Cancer. 2002. Breast cancer and breastfeeding: collaborative reanalysis of individual data from 47 epidemiological studies in 30 countries, including 50 302 women with breast cancer and 96 973 women without the disease. *The Lancet*, 360(9328), July:187-195. [https://doi.org/10.1016/S0140-6736(02)09454-0]; León-Cava, N., Lutter, C., Ross, J. & Martin, L. 2002. *Quantifying the benefits of breastfeeding: a summary of the evidence*. Pan American Health Organization, LINKAGES Project & Academy for Educational Development. [https://bit.ly/3510hXl]; Tung, K., Goodman, M.T., Wu, A.H., McDuffie, K., Wilkens, L.R., Kolonel, L.N., Nomura, A.M., Terada, K.Y., Carney, M.E. & Sobin, L.H. 2003. Reproductive factors and epithelial ovarian cancer risk by histologic type: a multiethnic case-control study. *American Journal of Epidemiology*, 158(7), October:629-638. [https://doi.org/10.1093/aje/kwg177].

43 Rea, M.F. 2004. Benefits of breastfeeding and women's health. *Journal de Pediatria* 2004,

Initiation of breastfeeding immediately after delivery stimulates the release of oxytocin, a hormone that helps to contract the uterus, expel the placenta, and reduce postpartum bleeding.⁴⁴ Exclusive breastfeeding through six months was associated with delayed resumption of menses and more rapid postpartum weight loss in the mother in studies conducted in Honduras, Bangladesh and Senegal.⁴⁵ Breastfeeding also allows women to space their pregnancies better.⁴⁶ Mothers who exclusively breastfed for six months had prolonged lactational amenorrhoea, and consequently decreased exposure to the maternal health risks associated with short birth intervals.⁴⁷

Breastfeeding has also been linked with decreases in maternal depression and improves mother-infant bonding.⁴⁸

Economic benefits of improved breastfeeding

Breast milk is safe (being the right temperature, requires no preparation, and is available even in environments with poor sanitation), and healthier, and also inexpensive. One can argue that breast milk is universally available, low-tech, of high impact in child survival and development. A novel analysis on the contribution of breastfeeding to the economy in Australia showed that breast milk yielded a net economic benefit (after adjustment for a small increase in maternal food consumption) of a minimum of 2.2 billion dollars each year.⁴⁹ With respect to the protective nature of breast milk, there are potential cost savings associated with the

80(Supplement 5), November:142-146. [https://doi.org/10.2223/1247]; Labbok, M.H. 2001. Effects of breastfeeding on the mother. *Pediatric Clinics of North America*, 48(1), February:143-158. [https://doi.org/10.1016/s0031-3955(05)70290-x].

44 Kantrowitz-Gordon, I. 2005. The Oxytocin Factor: Tapping the Hormone of Calm, Love and Healing: Kerstin Uvnäs Moberg, MD, PhD. *Journal of Midwifery & Women's Health*, 50(1), December:e6-e6. [https://doi.org/10.1016/j.jmwh.2004.07.002].

45 Kramer et al., 2012.

46 UNICEF. 2018. Improving breastfeeding, complementary foods and feeding practices. *Nutrition*. [https://www.unicef.org/nutrition/index_breastfeeding.html].

47 Kramer et al., 2012.

48 Mezzacappa, E.S. 2004. Breastfeeding and maternal stress response and health. *Nutrition Reviews*, 62(7, Part 1), July:261-268. [https://doi.org/10.1111/j.1753-4887.2004.tb00050.x]; Hart, S., Boylan, L.M., Carroll, S., Musick, Y.A. & Lampe, R.M. 2003. Brief report: breast-fed one-week-olds demonstrate superior neurobehavioral organization. *Journal of Pediatric Psychology*, 28(8), December:529-534. [https://doi.org/10.1093/jpepsy/jsg043].

49 Smith, J. & Ingham, L.H. 2001. Breastfeeding and the measurement of economic progress. *Journal of Australian Political Economy*, 47, January:51. [https://bit.ly/2Uhk6Zc].

treatment of three childhood illnesses: otitis media, gastroenteritis, and necrotising enterocolitis which are observed among non-breastfed children.⁵⁰

Breastfeeding practices across sub-Saharan Africa countries

As previously mentioned, the WHO recommends that optimal breastfeeding practices should include early initiation of breastfeeding within one hour of life, exclusive breastfeeding for infants aged younger than six months, and continued breastfeeding for up to two years of age in combination with adequate complementary feeding. In sub-Saharan Africa, evidence shows that breastfeeding practices remain sub-optimal across the continent despite the benefits that breastfeeding would have in reducing early childhood malnutrition, and associated morbidity and mortality.⁵¹ Closely, varying patterns and trends of sub-optimal breastfeeding do exist between and within sub-Saharan Africa countries, with the poorest populations facing greater challenges.

Multiple publications using national demographic surveys, for instance, Roberts, Carnahan and Gakidou, have indeed found that very few sub-Saharan Africa countries have made noticeable improvements in breastfeeding practices, while many others have lagged.⁵² They looked at breastfeeding patterns and shifts from 1990-2010 in 137 developing countries and reported that exclusive breastfeeding increased by 47 per cent in Ghana as opposed to two per cent in Côte d'Ivoire across the studied period. The same authors reported additional disparities in 2010: prevalence of exclusive breastfeeding, for instance, was as low as 3.5 per cent in Djibouti while being as high as 77.3 per cent in Rwanda. Rates for early initiation of breastfeeding also had wide ranges, with the lowest recorded at a little above six per cent in Malawi and the highest close to 60 per cent in Chad. Prevalence of continued breastfeeding was generally seen quite high in multiple sub-Saharan Africa countries, with the highest prevalence reported closely to 95 per cent in the Gambia among children aged six to 11 months and in Burundi among children

50 Weimer, J.P. 2001. The economic benefits of breastfeeding: A review and analysis. *Food Assistance and Nutrition Research*, 13. United States Department of Agriculture: Economic Research Service. [https://www.aeped.es/sites/default/files/6-economic_benefits.pdf].

51 Ogbo, F.A., Agho, K., Ogeleka, P., Woolfenden, S., Page, A. & Eastwood, J. 2017. Infant feeding practices and diarrhoea in sub-Saharan African countries with high diarrhoea mortality. *PLoS One*, 12(2), February:e0171792. [<https://doi.org/10.1371/journal.pone.0171792>]; Black et al., 2008.

52 Roberts, T.J., Carnahan, E. & Gakidou, E. 2013. Can breastfeeding promote child health equity? A comprehensive analysis of breastfeeding patterns across the developing world and what we can learn from them. *BMC Medicine*, 11(1), December:254. [<https://bmcmmedicine.biomedcentral.com/articles/10.1186/1741-7015-11-254>].

aged 12-23 months. Recent studies still found that some countries have indeed made better progress than others (Issaka, Agho and Renzaho, 2017).⁵³

Health Surveys conducted in 29 sub-Saharan countries from 2010-2015,⁵⁴ found again that Ghana was among the few countries that have seen remarkable optimisation of breastfeeding practices, with the prevalence of early initiation of breastfeeding and exclusive breastfeeding both a little over 50 per cent. The authors also found Rwanda to have the highest prevalence for exclusive breastfeeding, which impressively neared 90 per cent from data reported in 2014-2015. Recent research has specifically included Kenya among the few countries on target to attain the WHO or UNICEF objective of having at least 50 per cent of infants under six months old being exclusively breastfed.⁵⁵ The country has seen considerable progress with exclusive breastfeeding switching from 31 per cent in 2008 to 61 per cent in 2015. A previous publication by Madise, Matthews and Margetts had interestingly found that the prevalence of exclusive breastfeeding was worrisome across all sub-Saharan Africa countries, with prevalence ranging from two per cent in Nigeria to 34 per cent in Tanzania.⁵⁶ Thus, disparities in breastfeeding practices consistently reported have certainly widened in the last few years across nations. In turn, these differences have heightened further among the poorest communities.

Breastfeeding practices among sub-Saharan Africa poor urban communities

Health and nutrition inequities within countries have been widely linked to poverty.⁵⁷ In other words, the poorest populations have been found to have more

53 Issaka, A.I., Agho, K.E. & Renzaho, A.M. 2017. Prevalence of key breastfeeding indicators in 29 sub-Saharan African countries: a meta-analysis of demographic and health surveys (2010-2015). *BMJ Open*, 7(10), October:e014145. [<https://doi.org/10.1136/bmjopen-2016-014145>].

54 Issaka AI, Agho KE, Renzaho AM: Prevalence of key breastfeeding indicators in 29 sub-Saharan African countries: a meta-analysis of demographic and health surveys (2010-2015). *BMJ Open* 2017, 7(10):e014145.

55 Wanjohi, M., Griffiths, P., Wekesah, F.M, Muriuki, P., Muhia, N., Musoke, R.N., Fouts, H.N., Madise, N.J. & Kimani-Murage, E.W. 2016. Sociocultural factors influencing breastfeeding practices in two slums in Nairobi, Kenya. *International Breastfeeding Journal*, 12:5. [<https://doi.org/10.1186%2Fs13006-016-0092-7>].

56 Madise, N.J., Matthews, Z. & Margetts, B. 1999. Heterogeneity of Child Nutritional Status between Households: A Comparison of Six Sub-Saharan African Countries. *Population Studies*, 53(3):331-343. [<https://doi.org/10.1080/00324720308092>].

57 Fotso, J. 2006. Child health inequities in developing countries: differences across urban and rural areas. *International Journal for Equity in Health*, 5(1):9.

limited access to health and social services, and subsequently present greater burdens of health and nutritional issues. The poorest populations comprise immensely urban communities that live in informal settlements. As a result, it becomes even more challenging for these communities to practice optimal health and nutrition care, especially among mothers, infants, and children.⁵⁸ In parallel, breastfeeding practices have been reported to be more problematic among urban sub-Saharan Africa poor communities. Kimani-Murage and colleagues (Madise, Fotso, Kyobutungi, Mutua, Gitau and Yatich, 2011) indeed found exclusive breastfeeding in Nairobi slums to be less than two per cent even though universal breastfeeding was high at 99 per cent and 85 per cent at 11 months old.⁵⁹ The authors reported that 37 per cent of children were not breastfed within one hour of delivery despite well-evidenced highly nutritious components and health benefits of colostrum (breast milk produced in the first hours after delivery). In addition, 40% of infants were fed something else than breast milk within 3 days after delivery, with a mean of introducing complementary feeding being one month after delivery." Introduction of complementary feeding within one month of birth is not recommended - it is the practice - which is an untoward practice. Briefly, reasons for such poor practices included, among others, unfounded beliefs of low production of breast milk due to food insecurity; and other cultural beliefs such as that colostrum is 'dirty'.

Unfounded beliefs of not having enough breast milk were again said to be the main reason for giving newborns other fluids before breast milk. Similarly, Engebretsen and colleagues (Wamani, Karamagi, Semiyaga, Tumwine and Tylleskär, 2007) found a high prevalence, 99 per cent, of breastfeeding among low-income households living in the Ugandan urban area.⁶⁰ However, exclusive breastfeeding was low, being practised in seven per cent and zero per cent of infants by three and six months of age, respectively. Predominant breastfeeding was also very sub-

optimal, with prevalence at 30 per cent and three per cent by the age of three and six months respectively.

In short, urban sub-Saharan Africa poor populations need interventions to optimise breastfeeding practices and consequently tackle multiple nutrition-related health and social issues.

Challenges to (and facilitators of) optimal breastfeeding in poor urban settings in sub-Saharan Africa

Research findings from the urban slums in Nairobi demonstrate various challenges and barriers that hinder mothers from breastfeeding their children optimally.⁶¹ In a conceptual framework on factors affecting breastfeeding in these settings, adapted from Hector, King, Webb and Heywood (2005), Kimani-Murage and colleagues (Wekesah et al., 2015) categorise these barriers and challenges into individual, group and societal level factors, as shown in Figure 7.1.⁶²

Individual-level barriers relate to the mother, child, and the 'mother-child dyad'. Relating to the child, studies in the slums highlighted 'baby crying' as a reason for early introduction of complementary feeding, mainly due to the perception that the child is hungry and unsatisfied by breast milk. It is also documented in this setting that boys are likely to be introduced to complementary feeds earlier than girls.⁶³ A qualitative study on the cultural beliefs in the slums highlighted the fact that baby boys are thought to be strong, needing early introduction of foods to support their growth and that breastfeeding them for long may weaken the mothers, hence early cessation of breastfeeding.⁶⁴ Boys and small-sized babies are perceived to have higher nutritional needs, which breast milk alone cannot solely satisfy. They are thus more likely to be given complementary foods at earlier ages.⁶⁵ Relating to the mother, maternal age, marital status, health and nutrition

[<https://doi.org/10.1186%2F1475-9276-5-9>]; Ziraba, A.K., Fotso, J.C. & Ochako, R. 2009. Overweight and obesity in urban Africa: a problem of the rich or the poor? *BMC Public Health*, 9(1), December:465. [<https://doi.org/10.1186/1471-2458-9-465>].

58 Black et al., 2008.

59 Kimani-Murage, E.W., Madise, N.J., Fotso, J., Kyobutungi, C., Mutua, M.K., Gitau, T.M. & Yatich, N. 2011. Patterns and determinants of breastfeeding and complementary feeding practices in urban informal settlements, Nairobi Kenya. *BMC Public Health*, 11, May:396. [<https://doi.org/10.1186/1471-2458-11-396>].

60 Engebretsen, I.M.S., Wamani, H., Karamagi, C., Semiyaga, N., Tumwine, J. & Tylleskär, T. 2007. Low adherence to exclusive breastfeeding in Eastern Uganda: a community-based cross-sectional study comparing dietary recall since birth with 24-hour recall. *BMC Pediatrics*, 7(1), March:10. [<https://doi.org/10.1186/1471-2431-7-10>].

61 Goudet, S.M., Kimani-Murage, E.W., Wekesah, F.M., Wanjohi, M., Griffiths, P.L., Bogin, B. & Madise, N.J. 2017. How does poverty affect children's nutritional status in Nairobi slums? A qualitative study of the root causes of undernutrition. *Public Health Nutrition*, 20(4), March:608-619. [<https://doi.org/10.1017%2FS1368980016002445>]; Kimani-Murage et al., 2015; Wanjohi et al., 2016; Kimani-Murage et al., 2011.

62 Hector, D., King, L., Webb, K. & Heywood, P. 2005. Factors affecting breastfeeding practices. Applying a conceptual framework. *New South Wales Public Health Bulletin*, 16(3-4), March-April:52-55. [<https://doi.org/10.1071/nb05013>]; Kimani-Murage et al., 2015.

63 Kimani-Murage, 2011.

64 Wanjohi et al., 2016.

65 Kimani-Murage et al., 2015.

status are documented to have some influence on breastfeeding practices, with poorer practices among young and single mothers.⁶⁶ Qualitative studies in these settings indicate that young mothers are less knowledgeable on breastfeeding and care and have several competing issues that hinder them from breastfeeding optimally, including perceptions on their body image, peer influence and school. The multiple responsibilities of having to breastfeed, work and care for the family solely, is cited as a key constraint to optimal breastfeeding among single mothers.⁶⁷ A qualitative study in poor urban settings in Kenya indicates that stress, poor nutrition and health status of the mother are perceived causes of insufficient breast milk production. These are consequently barriers to exclusive breastfeeding, hence the early introduction of complementary feeding and cessation of breastfeeding.⁶⁸ Poor maternal nutritional status and perceived associations is a major barrier to optimal breastfeeding.⁶⁹ Concerns of mother to child transmission of HIV/Aids and misperceptions regarding breastfeeding while living with HIV/Aids are also considered an important barrier to optimal breastfeeding practices.⁷⁰ Important, given the high prevalence of HIV/Aids in poor urban settings, at about twice the national prevalence.⁷¹ There is also reportedly highly unsettled advice regarding the current breastfeeding recommendations for HIV positive women which further confounds their decision on breastfeeding.⁷²

Although some studies have shown fair knowledge of breastfeeding recommendations among mothers living in the slums, pockets of knowledge deficits on breastfeeding and child feeding are still documented as a cause for suboptimal breastfeeding practices. This is especially among young and teenage mothers who are said to rely heavily on the information from their parents, which may not be necessarily correct as relatives and peers are highlighted as key channels for breastfeeding myths and misconceptions in the same setting.⁷³

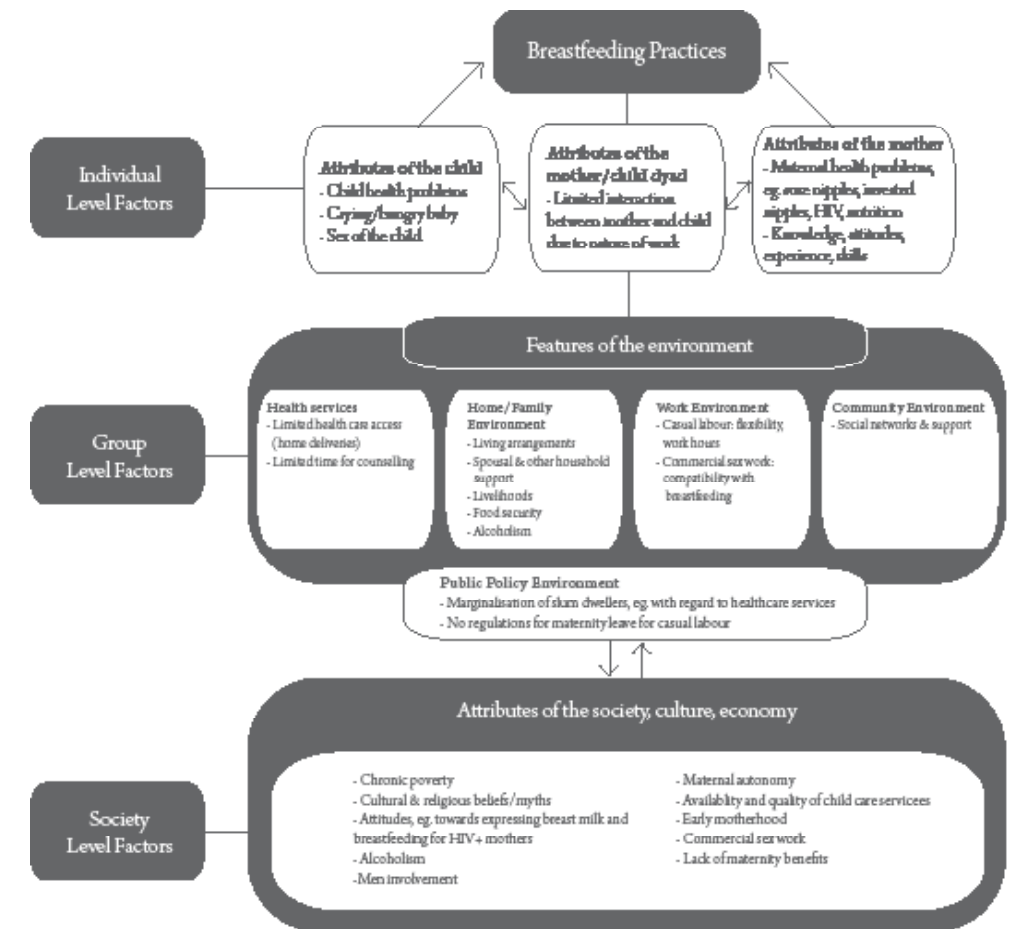


Figure 7.1 Conceptual framework of factors affecting breastfeeding practices in poor urban settings.⁷⁴

Group level factors, constituting the attributes of the environments where the mother and the child live, including the home, work and community where they live and the accessibility and availability of services to promote optimal breastfeeding. Since they are not recognised as legal settlements, the two informal settlements are characterised by poor access to basic services and amenities, health and education.⁷⁵

⁷⁴ Kimani-Murage et al., 2015.

⁷⁵ Emina, J., Beguy, D., Zulu, E., Ezech, A., Muindi, K. & Elung'ata, P. 2011. Monitoring of health and demographic outcomes in poor urban settlements: evidence from the Nairobi Urban Health and Demographic Surveillance System. *Journal of Urban Health*, 88(Supplement 2), June:200-218. [https://doi.org/10.1007/s11524-011-9594-1].

⁶⁶ Kimani-Murage et al., 2011.

⁶⁷ Kimani-Murage et al., 2015; Wanjohi et al., 2016; Goudet et al., 2017.

⁶⁸ Ibid.

⁶⁹ Kimani-Murage et al., 2015; Kimani-Murage et al., 2014.

⁷⁰ Ibid.; Wanjohi et al., 2016.

⁷¹ Madise, N.J., Ziraba, A.K., Inungu, J., Khamadi, S.A., Ezech, A., Zulu, E.M., Kebaso, J., Okoth, V., Mwau, M. 2012. Are slum dwellers at heightened risk of HIV infection than other urban residents? Evidence from population-based HIV prevalence surveys in Kenya. *Health & Place*, 18(5), September:1144-1152. [https://doi.org/10.1016/j.healthplace.2012.04.003].

⁷² Kimani-Murage et al., 2015.

⁷³ Ibid.; Goudet et al., 2017; Wanjohi et al., 2016.

There are high levels of poverty, unemployment and deprived livelihoods.⁷⁶ Such deprivations include poor housing: dwellings are usually made of mud, with roofs often made of iron sheets. All these poor living conditions and livelihoods in the slums are highlighted as major barriers to optimal infant and young child feeding.⁷⁷ In some cases, the structures within which the families live are too small which works against breastfeeding as cited by Kimani-Murage and colleagues (Schofield, Wekesah, Mohamed, Mberu, Ettarh, Egondi, Kyobutungi and Ezeh, 2014).⁷⁸

Further, poverty, lack of stable employment and insufficient family income forces some women too soon after delivery to seek employment and work for long hours, a major constraint to breastfeeding, which translates to the early introduction of complementary feeding and cessation of breastfeeding.⁷⁹ Majority of women in the slums work in the informal sector, mainly as casual labourers or petty traders, meaning that they do not have access to maternity leave, which further constrains their ability to combine work and optimal breastfeeding coupled with lack of workplace support for breastfeeding for those who are in employment.⁸⁰ There are also cultural beliefs against expressing breast milk which is a strategy to facilitate continued breastfeeding even when mothers are separated from their children.⁸¹ Poor women, often living in food-insecure households, are said to have inadequate food, and this is perceived to affect breast milk production and flow, leading to the early introduction of complementary foods or cessation of breastfeeding altogether.⁸²

Society level factors which influence the acceptability and expectations regarding breastfeeding and provide the context for breastfeeding, including poverty, myths and misconceptions about breastfeeding in the community, as well as the support available in the community for the mothers to breastfeed optimally. Since childcare and nutrition are socially and culturally a responsibility of women, male involvement is suboptimal. Evidence also indicates that some men go as far as

76 Beguy, D., Ndugwa, R. & Kabiru, C.W. 2013. Entry into motherhood among adolescent girls in two informal settlements in Nairobi, Kenya. *Journal of Biosocial Science*, 45(6), November:721-742. [<https://doi.org/10.1017/S0021932013000199>]; Kabiru, C.W., Beguy, D., Undie, C., Zulu, E.M., Ezeh, A.C. 2010. Transition into first sex among adolescents in slum and non-slum communities in Nairobi, Kenya. *Journal of youth studies*, 13(4), August:453-471. [<https://doi.org/10.1080%2F13676261003801754>].

77 Kimani-Murage et al., 2015.

78 Kimani-Murage et al., 2014.

79 Ibid.; Goudet et al., 2017.

80 Emina et al. 2011.

81 Kimani-Murage et al., 2015; Wanjohi et al., 2016.

82 Kimani-Murage et al., 2015; Kimani-Murage, 2011; Goudet et al., 2017.

complaining about reduced attention they get from their spouses who take time to breastfeed. Moreover, women in poor urban settings do most domestic chores in their households, even after delivery, unlike in urban wealthier groups who engage house helps or those in rural areas which are normally supported by relatives. This impacts on optimal child feeding, thereby affecting the duration of exclusive breastfeeding or any breastfeeding.⁸³ Further, poor access to health services is documented in this setting, including antenatal and postnatal services and hence inadequate professional support on breastfeeding, which may contribute to poor breastfeeding knowledge and skills among mothers in this setting.⁸⁴

Delinquent behaviour, including alcoholism and sex trade, are common in the slum, more so among the young population.⁸⁵ These are also highlighted as key constraints for optimal breastfeeding. According to studies in this setting alcoholic mothers neglect their children and have no time to breastfeed, while, alcoholism among men leads to family neglect, driving the family into poverty and forcing the women to look for work even when they have young babies.⁸⁶ Similarly, sex workers are said to neglect their children often as they go to work while cultural beliefs against breastfeeding when engaging in the sex trade further contribute to sub-optimal breastfeeding in such cases.⁸⁷

Cultural beliefs and practices are also highlighted as important factors influencing breastfeeding and complementary feeding practices.⁸⁸ Wanjohi, Griffiths, Wekesah, Muriuki, Muhia, Musoke, Fouts, Madise, and Kimani-Murage (2017) documented some negative cultural beliefs in poor urban settings that hinder optimal breastfeeding practices. For instance, some of the mothers considered colostrum as dirty; others believed that breastfeeding while engaging in extramarital affairs was a bad omen or a curse; fear of the evil eye (malevolent glare that is believed to be a curse associated with witchcraft) when breastfeeding in public.⁸⁹

Interventions to improve breastfeeding and support mothers in breastfeeding

It is estimated that interventions that promote optimal breastfeeding and complementary feeding could prevent about a fifth of the deaths of children

83 Kimani-Murage et al., 2015.

84 Ibid.

85 Beguy et al., 2013; Kabiru et al., 2010.

86 Kimani-Murage et al., 2015; Goudet et al., 2017.

87 Wanjohi et al., 2016.

88 Ibid.

89 Ibid.

younger than five years in countries with high mortality rates.⁹⁰ In recognition of the importance of nutrition in the first 1 000 days of life, the WHO and UNICEF jointly developed the global strategy for infant and young child nutrition in 2002, aiming to revitalise efforts to protect, promote and support appropriate infant and young child feeding.⁹¹ The promotion of breastfeeding and providing supportive strategies was listed by Bhutta and colleagues (Das, Rizvi, Gaffey, Walker, Horton, Webb, Lartey and Black, 2013) as one of the ten evidence-based high impact interventions for improvement of infant and child nutrition and survival.⁹² To further support interventions towards the promotion of breastfeeding, it is estimated that interventions that promote optimal breastfeeding and complementary feeding could prevent about a fifth of deaths in children younger than five years in countries with high child mortality rates.⁹³ Additionally, interventions to increase maternal knowledge of breastfeeding benefits and family and clinician support of breastfeeding in the prenatal period may help increase breastfeeding rates.⁹⁴ Some of the interventions to support breastfeeding are highlighted below.

The Baby-Friendly Hospital Initiative

The Baby-Friendly Hospital Initiative was launched by the WHO and UNICEF in 1991, following the Innocenti Declaration of 1990.⁹⁵ The Initiative is a global effort to implement practices that protect, promote and support breastfeeding and is supported by the fact that hospitals and maternity units set a powerful example

- 90 Kramer, M.S. & Kakuma, R. 2004. The optimal duration of exclusive breastfeeding: A Systematic Review. In: Pickering, L.K., Morrow, A.L., Ruiz-Palacios, G.M. & Schanler, R.J. (eds). *Protecting Infants through Human Milk. Advances in Experimental Medicine and Biology*, 554. Boston, MA: Springer. [https://doi.org/10.1007/978-1-4757-4242-8_7]; Jones, G., Steketee, R.W., Black, R.E., Bhutta, Z.A. & Morris, S.S. 2003. How many child deaths can we prevent this year? *The Lancet*, 362(9377), July:65-71. [https://doi.org/10.1016/S0140-6736(03)13811-1].
- 91 WHO & UNICEF. 2003. Global strategy for infant and young child feeding. *Nutrition*. [https://www.who.int/nutrition/publications/infantfeeding/9241562218/en/].
- 92 Bhutta, Z.A., Das, J.K., Rizvi, A., Gaffey, M.F., Walker, N., Horton, S., Webb, P., Lartey, A. & Black, R.E. 2013. Evidence-based interventions for improvement of maternal and child nutrition: what can be done and at what cost? *The Lancet*, 382(9890), August:452-477. [https://doi.org/10.1016/S0140-6736(13)60996-4].
- 93 Jones et al., 2003; Kramer et al., 2012.
- 94 Kornides, M. & Kitsantas, P. 2013. Evaluation of breastfeeding promotion, support, and knowledge of benefits on breastfeeding outcomes. *Journal of Child Health Care*, 17(3), September:264-273. [https://doi.org/10.1177/1367493512461460].
- 95 UNICEF. 2005. The Baby-Friendly Hospital Initiative. Nutrition. [https://www.unicef.org/nutrition/index_24806.html].

for new mothers.⁹⁶ The Initiative has a measurable and proven impact, increasing the likelihood of babies being exclusively breastfed for the first six months. The strategy promotes breastfeeding in maternity wards around the time of delivery and is shown to be effective in some settings, particularly in the more developed countries.⁹⁷ For example, a study showed that the Baby-Friendly Hospital Initiative and effective implementation of the Ten Steps to Successful Breastfeeding in the USA led to breastfeeding initiation rate increasing from 58 per cent (1995) to 77.5 per cent (1998) to 86.5 per cent (1999). Infants being exclusively breastfed increased from 5.5 per cent (1995) to 28.5 per cent (1998) to 33.5 per cent (1999).⁹⁸ In less developed countries, where a significant number of deliveries do not occur in health facilities, the effectiveness of the Baby-Friendly Hospital Initiative may be limited. In sub-Saharan Africa, about 60 per cent of urban residents live in slum settlements, where social and health services are limited, and many women either deliver at home or sub-standard private health facilities, meaning that many of these women may not benefit from the counselling on infant and young child nutrition offered through the Baby-Friendly Hospital Initiative.⁹⁹

The Baby-Friendly Community Initiative

The Baby-Friendly Community Initiative is also a global initiative launched by the WHO and UNICEF and aims to protect, promote and support breastfeeding at the community level. The Baby-Friendly Community Initiative is an integrated approach that emphasises linkages between infant and maternal nutrition as well as their environment. The components of the BFCI include home based counselling which has been shown to be effective. Given difficulty of reaching majority of poor women through the Baby Friendly Hospital Initiative due to limited health care access and utilization around the time of delivery, some sub-Saharan countries such as Kenya, Gambia, Nigeria among others have explored the adoption of the BFCI which is delivered through community health volunteers (CHVs) to promote optimal

- 96 WHO. 2020. Baby-friendly Hospital Initiative. Health Topics: Nutrition. [http://www.who.int/nutrition/bfhi/en/].
- 97 Murray, C.J. & Lopez, A.D. 1997. Global mortality, disability, and the contribution of risk factors: Global Burden of Disease Study. *The Lancet*, 349(9063), May:1436-1442. [https://doi.org/10.1016/S0140-6736(96)07495-8]; WHO. 2002. *The World Health Report 2002: Reducing risks, promoting healthy life*. [https://www.who.int/whr/2002/en/].
- 98 Philipp, B.L., Merewood, A., Miller, L.W., Chawla, N., Murphy-Smith, M.M., Gomes, J.S., Cimo, S. & Cook, J.T. 2001. Baby-Friendly Hospital Initiative Improves Breastfeeding Initiation Rates in a US Hospital Setting. *Pediatrics*, 108(3), September:677. [https://doi.org/10.1542/peds.108.3.677].
- 99 Jones et al., 2003; KNBS & ICF Macro. 2010. *Kenya Demographic and Health Survey 2008-09*. Calverton, Maryland: KNBS and ICF Macro. [https://bit.ly/2IugnoG].

breastfeeding and infant and young child feeding, hence enhance health coverage. The effectiveness of community-based interventions which use community health workers to promote health, including optimal breastfeeding practices, has been documented. Through a cluster-randomised controlled trial of the key components of the Initiative (Kimani-Murage, Norris, Mutua, Wekesah, Wanjohi, Muhia, Muriuki, Egondi, Kyobutungi, Ezeh, Musoke, McGarvey, Madise and Griffiths, 2016) followed slightly over 1 000 mother-child pairs during pregnancy and for one year after birth on their breastfeeding and infant feeding practices in poor urban settings in Kenya. The study primarily tested the effectiveness of personalised, home-based nutritional counselling by community health volunteers on breastfeeding practices among women in Nairobi's urban informal settlements. The study indicated increased exclusive breastfeeding from about two per cent, before the intervention, to 55 per cent, during the intervention.¹⁰⁰ These findings depict the potential effectiveness of the implementation of the Baby-Friendly Community Initiative through the community health strategy in promoting optimal breastfeeding practices at the community level in underserved settings such as poor urban settings.

Human Milk Banks

Despite the lifesaving and other important benefits of human milk, many vulnerable infants, the majority of whom are sick, preterm, or have low birth weight, have no access to their mother's milk due to the multitude of factors that affect premature and sick infants such as maternal illness, maternal death, abandonment, or delayed lactation. In the absence of a mother's milk, the WHO recommends donated human milk as the next best evidence-based alternative.¹⁰¹ In line with this, the WHO has issued a global call to scale up the provision of safe donated human milk by the setting up of Human Milk Banks.¹⁰² Currently, an inadequate number of close to 600 Human Milk Banks exist around the world, almost half of

which are in Brazil. It is estimated that up to 40 per cent of neonates in neonatal intensive care unit settings around the world require donor human milk at some point during admission, either as a single feed or long-term. Human Milk Banks collect, pasteurise, test, and store safe, donated milk from lactating mothers and provide it to infants in need, ensuring that even if babies cannot breastfeed, they still receive human milk as soon as possible. As a pivotal component of early and essential newborn care and of protecting, promoting and supporting breastfeeding, Human Milk Banks are vital to ensure equitable access to human milk, especially sick neonates. Prematurity is currently the leading cause of death among children under five globally with one million premature babies dying every year, particularly in limited-resource settings.¹⁰³

Human Milk Banking is one of the impending implementation research which needs to be actualised in most low- and middle-income countries since different infants have specific dietary needs after delivery depending on the mother-infant dyad's health status.

The success of an established Human Milk Bank lies in government endorsement and support in breastfeeding promotion, addressing misinformation on the safety of donated milk, Kangaroo Mother Care and now the ethical provision of donated human milk for infants in need. This solution also requires addressing awareness needs of the public by education and assurance about the safety and the rigorous processes of the Human Milk Banks. Communities would accept the use of donated human milk. In Kenya, an assessment of the acceptability of human donor milk has been established.¹⁰⁴ Further, a pilot study on its operational feasibility is underway in a hospital situated in a low-income urban area in Kenya that primarily serves poor urban residents.

Workplace support for breastfeeding mothers

One of the reasons for suboptimal breastfeeding is mothers' resuming work after childbirth in workplaces that are not fully supportive of breastfeeding.¹⁰⁵ Work

- 100 Kimani-Murage, E.W., Norris, S.A., Mutua, M.K., Wekesah, F.M., Wanjohi, M., Muhia, N., Muriuki, P., Egondi, T., Kyobutungi, C., Ezeh, A.C., Musoke, R.N., McGarvey, S.T., Madise, N.J. & Griffiths, P.L. 2016. Potential effectiveness of Community Health Strategy to promote exclusive breastfeeding in urban poor settings in Nairobi, Kenya: a quasi-experimental study. *Journal of Developmental Origins of Health and Disease*, 7(2), April:172-184. [<https://doi.org/10.1017/S2040174415007941>].
- 101 Quigley, M. & McGuire, W. 2014. Formula versus donor breast milk for feeding preterm or low birth weight infants. *Cochrane Database of Systematic Reviews*, 4, April:CD002971. [<https://doi.org/10.1002/14651858.CD002971.pub3>]; Edmond, K., Bahl, R. & WHO. 2006. Optimal feeding of low-birth-weight infants: Technical review. *Maternal, newborn, child and adolescent health*. [<https://bit.ly/32wLvek>].
- 102 WHO. 2009. *Resolutions and Decisions*. Sixty-Second World Health Assembly, Geneva, 18-22 May. [<https://bit.ly/2IqxzLY>].

- 103 WHO. 2018. Fact Sheets: Preterm Birth. *Newsroom*. [<https://bit.ly/3pibBvd>].
- 104 Kimani-Murage, E. 2017. *Integrating Human Milk Banking with Breastfeeding Promotion and Newborn Care: is Kenya Ready?* Briefing Paper. African Population and Health Research Center. [<https://bit.ly/2Uhjumm>].
- 105 Food Policy Research Institute. 2016. *Global Nutrition Report 2016: From Promise to Impact: Ending Malnutrition by 2030*. Washington, DC. [<http://ebrary.ifpri.org/utills/getfile/collection/p15738coll2/id/130354/filename/130565.pdf>]; Bhutta Z.A., Salam, R.A. 2012: Global nutrition epidemiology and trends. *Annals of Nutrition Metabolism*, 61(Supplement 1):19-27. [<https://doi.org/10.1159/000345167>]. Tsai, S. 2013. Impact of a breastfeeding-friendly workplace on an employed mother's

has been cited as a major factor in suboptimal breastfeeding practices in poor urban settings in Kenya, for example.¹⁰⁶ A breastfeeding-friendly workplace for the employed mother has been found to increase the duration of breastfeeding.¹⁰⁷ Evidence from 38 low-income and middle-income countries on the association between extending the duration of legislated paid maternity leave and improved breastfeeding practices showed that a one-month increase in the legislated duration of paid maternity leave was associated with a seven percentage point increase in the prevalence of early initiation of breastfeeding, a six percentage point increase in the prevalence of exclusive breastfeeding and a 2.2-month increase in breastfeeding duration.¹⁰⁸ This study demonstrates, therefore, that extending the duration of legislated paid maternity leave can promote breastfeeding practices and reduce barriers to breastfeeding for working mothers.

The Baby-Friendly Workplace Initiative was launched during the breastfeeding week in 1993 to focus on the issue of combining women's work and breastfeeding and to complement the Baby-Friendly Hospital Initiative and the Baby-Friendly Community Initiative, taking baby-friendliness outside the hospitals and beyond the community into women's working environments. This Initiatives gave breastfeeding advocates around the world a launching pad to apply the concept to raise awareness about breastfeeding and the rights and needs of working breastfeeding women, particularly during the first week of August, which is World Breastfeeding Week. The action ideas developed for the Baby-Friendly Workplace Initiative urged working women, employers, unions and worker groups, health care workers, environments/community action groups, women's groups as well as policymakers to play their respective roles to promote breastfeeding at the workplace.

intention to continue breastfeeding after returning to work. *Breastfeeding Medicine*, 8(2):210-216. [<https://doi.org/10.1089/bfm.2012.0119>].

106 Kimani-Murage et al., 2015; Kimani-Murage et al., 2014.

107 Mills, S.P. 2009. Workplace lactation programs: A critical element for breastfeeding mothers' success. *Journal of the American Association of Occupational Health Nurses*, 57(6):227-231. [<https://doi.org/10.1177/216507990905700605>]; Wyatt, S.N. 2002. Challenges of the working breastfeeding mother: Workplace solutions. *Journal of the American Association of Occupational Health Nurses*, 50(2), February:61-66. [<https://journals.sagepub.com/doi/pdf/10.1177/216507990205000204>].

108 Chai, Y., Nandi, A. & Heymann, J. 2018. Does extending the duration of legislated paid maternity leave improve breastfeeding practices? Evidence from 38 low-income and middle-income countries. *BMJ Global Health*, 3(5): e001032. [<https://doi.org/10.1136/bmjgh-2018-001032>].

Support for breastfeeding in the workplace benefits employees if they are:

- taught about breastfeeding;
- offered professional lactation management services and support;
- provided a designated private space for breastfeeding or expressing milk;
- provided facilities for expressing breast milk including breast pumps;
- allowed flexible scheduling to support milk expression during work;
- supported by written corporate policies; and
- given options for returning to work, for example, extended maternity leave, part-time work, teleworking, and providing on-site or near-site childcare.

Kenya has enacted a law that mandates employers to provide support for breastfeeding mothers at the workplace.¹⁰⁹ Innovative ways of supporting women in poor urban settings to combine work with breastfeeding in the context of the complex realities in poor urban settings are needed.¹¹⁰

Conclusion

This chapter has explored breastfeeding practices, associated challenges and interventions that could promote breastfeeding in poor urban settings in sub-Saharan Africa, and highlighted poor breastfeeding practices in these settings. Urban slums are faced by unique social and structural factors hindering optimal breastfeeding including poverty and non-conducive livelihood opportunities, poor living conditions, food insecurity, poor professional and social support to breastfeeding mothers and a knowledge deficit coupled with negative cultural beliefs and misconceptions on breastfeeding. This situation calls for macro-level policies and interventions that consider the ecological setting. Promising interventions may include global initiatives such as the Baby-Friendly Hospital Initiative, the Baby-Friendly Community Initiative, the Human Milk Banks and the Baby-friendly Workplace Initiative. However, innovation in their implementation is necessary to take into consideration the social and structural complexities present in the settings where they are to be introduced.

109 RK (Republic of Kenya). 2017. Sections 71 & 72. *Health Act 21 of 2017*. [<https://bit.ly/2Sm7igW>].

110 Kimani-Murage et al., 2015; Kimani-Murage et al., 2014.



8

HOW ENVIRONMENTAL EXPOSURES EARLY IN LIFE MIGHT INFLUENCE PHENOTYPES OF NON-COMMUNICABLE DISEASES IN AFRICA

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Chronic non-communicable diseases, such as diabetes, cancer, cardiovascular and chronic respiratory diseases are leading causes of death and disability in the world – accounting for over 60 per cent of the nearly 60 million deaths in 2008.⁴ Importantly, 80 per cent of non-communicable disease deaths occur in low- and middle-income countries.⁵ Although Africa still has a high burden of infectious

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 - 4 WHO. 2020. Cardiovascular Diseases. *Health Topics*. [<https://bit.ly/35mrVTy>].
 - 5 Stewart, S. & Sliwa, K. 2009. Preventing CVD in resource-poor areas: perspectives from the ‘real-world’. *Nature Reviews Cardiology*, 6(7):489-492. [<https://doi.org/10.1038/nrcardio.2009.79>]; Yach, D., Kellogg, M. & Voute, J. 2005. Chronic diseases: an

diseases, the non-communicable disease epidemic is rising rapidly; it is projected that, by 2030, non-communicable diseases will account for 46 per cent of all deaths in the region.⁶ For example, although diabetes was considered a rare disease in Africa until about a century ago, it now affects up to a third of the population in some countries; the prevalence of diabetes and hypertension will have increased by nearly 80 per cent, and deaths from ischemic heart disease doubled between 2008 and 2030. This chapter discusses how environmental exposures early in life might influence phenotypes of non-communicable diseases in Africa.

Introduction

Our knowledge of non-communicable diseases in Africa is severely limited, but evidence to date suggests there are important differences between African and Western settings. The limited data available indicate that non-communicable diseases such as type 2 diabetes mellitus and hypertension occur in younger people in Africa, with the largest number of those affected aged 30-59 years old, compared to Europe where most people with diabetes are over 60 years old. Additionally, in high-income countries, these disorders are classically associated with obesity. Africans appear to be more likely to develop diabetes for the same level of body mass index and lower, than Caucasians. South Asians are also known to develop diabetes at low levels of body mass index; a presentation thought to be related to the disproportionately central distribution of fat. Thus, while only seven per cent of deaths caused by hypertension occur in people under 60 years in high-income countries, in Africa, 25 per cent of deaths occur in individuals under this age.⁷ This high burden on the economically productive population in Africa will perpetuate

increasing challenge in developing countries. *Transactions of The Royal Society of Tropical Medicine and Hygiene*, 99(5):321-324. [https://doi.org/10.1016/j.trstmh.2005.02.001].

- 6 Yach, D., Hawkes, C., Gould, C.L. & Hofman, K.J. 2004. The global burden of chronic diseases: overcoming impediments to prevention and control. *Journal of the American Medical Association*, 291(21):2616-2622. [https://doi.org/10.1001/jama.291.21.2616]; Mathers, C.D. & Loncar, D. 2006. Projections of global mortality and burden of disease from 2002 to 2030. *PLoS Medicine*, 3(11):e442. [https://doi.org/10.1371/journal.pmed.0030442]; BeLue, R., Okoror, T.A., Iwelunmor, J., Taylor, K.D., Degboe, A.N., Agyemang, C. & Ogedegbe, G. 2009. An overview of cardiovascular risk factor burden in sub-Saharan African countries: a socio-cultural perspective. *Global Health*, 5:10. [https://doi.org/10.1186%2F1744-8603-5-10].
- 7 Gaziano, T.A. 2007. Reducing the growing burden of cardiovascular disease in the developing world. *Health Affairs (Millwood)*, 26(1):13-24. [https://doi.org/10.1377/hlthaff.26.1.13]; Beaglehole, R., Ebrahim, S., Reddy, S., Voûte, J., Leeder, S. & Chronic Disease Action Group. 2007. Prevention of chronic diseases: a call to action. *The Lancet*, 370(9605):2152-2157. [https://doi.org/10.1016/S0140-6736(07)61700-0].

the vicious cycle of poverty and, if left unattended, non-communicable diseases will threaten the gains (in life expectancy and socioeconomic developments) that have been achieved in combating infectious diseases.⁸

Traditional risk factors for non-communicable diseases

The rise of non-communicable disease in low- and middle-income countries has been mainly attributed to increased life expectancy and urbanisation or globalisation, with associated changes in lifestyle behaviours (such as unhealthy diets, physical inactivity, smoking and excessive alcohol consumption).⁹ Sub-Saharan Africa, in particular, is experiencing one of the most rapid increases in urbanisation, with urban populations growing at an average annual rate of 4.5 per cent.¹⁰ These traditional risk factors such as smoking, obesity, high salt intake, sedentary lifestyle and pollution will have the same adverse health effects in Africa as they have in the developed Western countries. However, there are limited data on the distribution of these risk factors and how strongly they are associated with non-communicable diseases in sub-Saharan Africa. Recent studies suggest that the prevalence of these potential non-communicable disease risk factors is increasing in many sub-Saharan Africa countries.¹¹ Rates of risk factors

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- 8 Stewart & Sliwa, 2009; Gaziano, 2007; Reddy, K.S. 2004. Cardiovascular disease in non-Western countries. *The New England Journal of Medicine*, 350(24):2438-2440. [https://doi.org/10.1056/NEJMp048024]; Yach et al., 2004; Narayan, K.M., Ali, M.K. & Koplan, J.P. 2010. Global noncommunicable diseases--where worlds meet. *The New England Journal of Medicine*, 363(13):1196-1198. [https://doi.org/10.1056/NEJMp1002024]; Madu, E.C., Richardson, K.D., Ozigbo, O.H. & Baugh, D.S. 2003. Improving cardiovascular disease prevention and management in Africa: issues to consider for the 21st century. *Ethnicity & Disease*, 13(Supplement 2):71-76. [https://bit.ly/32asRYI].
 - 9 BeLue et al., 2009; Madu et al., 2003; Dalal, S., Beunza, J.J., Volmink, J., Adebamowo, C., Bajunirwe, F., Njelekela, M., Mozaffarian, D., Fawzi, W., Willett, W., Adami, H.O. & Holmes, M.D. 2011. Non-communicable diseases in sub-Saharan Africa: what we know now. *International Journal of Epidemiology*, 40(4):885-901. [https://doi.org/10.1093/ije/dyr050].
 - 10 Maher, D., Smeeth, L. & Sekajugo, J. 2010. Health transition in Africa: practical policy proposals for primary care. *Bulletin of the WHO*, 88(12):943-948. [https://doi.org/10.2471%2FBLT.10.077891].
 - 11 Dalal et al., 2011; Njelekela, M., Negishi, H., Nara, Y., Tomohiro, M., Kuga, S., Noguchi, T., Kanda, T., Yamori, M., Mashalla, Y., Jian Liu, L., Mtabaji, J., Ikeda, K. & Yamori, Y. 2011. Cardiovascular risk factors in Tanzania: a revisit. *Acta Tropica*, 79(3):231-239. [https://doi.org/10.1016/s0001-706x(01)00134-6]; Echouffo-Tcheugui, J.B. & Kengne, A.P. 2011. Chronic non-communicable diseases in Cameroon - burden, determinants and current policies. *Global Health*, 7(1):44.

among countries, urban-rural location and sub-populations variate considerably. While these variations may reflect the varying speed at which the communities are undergoing the epidemiological transition, they may also result from differences in study design and measurement techniques, generally not standardised in sub-Saharan Africa because of the limited amount of research on non-communicable diseases. However, it is vital though that we know the relative importance of these traditional risk factors, as well as other drivers that may have unique importance in the region, to inform control strategies and further research.

Potential contribution of genetics to risk for non-communicable diseases

Urbanisation or globalisation and associated behavioural risk factors (such as reduced food quality or increased food quantity and reduced physical activity) may not explain the epidemic of non-communicable diseases in Africa fully; other factors might contribute to the apparent increase in susceptibility. For example, the effects of these environmental factors in mediating the development of non-communicable diseases will be modulated by genetic susceptibility. Understanding the contribution of genetics is particularly important in sub-Saharan Africa because, as a region where first humans evolved, it harbours high genetic diversity and lower linkage disequilibrium (the tendency for groups of genes to be inherited together).¹² Thus, differences have been observed in the distribution of genetic

polymorphisms coding for susceptibility to communicable diseases (such as malaria, HIV, tuberculosis) and non-communicable diseases (such as breast and prostate cancer) in people of African ancestry compared to those of European descent.¹³ Recently, there have been major advances in identifying regions of the human genome that affect resistance or susceptibility to common conditions like heart disease, cancer and diabetes, using new scientific approaches such as genome-wide association analysis. For example, polymorphisms of genes associated with type 2 diabetes in the Caucasian population (e.g., of the TCF7L2 gene) have also been found in West African families.¹⁴ Moreover, most type 2 diabetes risk alleles appear to share a pattern of decreasing frequencies along with human migration from Africa, with, for example, genetic risk being consistently higher for individuals in the African populations than in the Asian ones.¹⁵ Therefore, studying the inter-

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15 Chen, R., Corona, E., Sikora, M., Dudley, J.T., Morgan, A.A., Moreno-Estrada, A., Nilsen, G.B., Ruau, D., Lincoln, S.E., Bustamante, C.D. & Butte, A.J. 2012. Type 2 diabetes risk alleles demonstrate extreme directional differentiation among human

action between environmental factors and genes in sub-Saharan Africa is likely to yield significant opportunities for scientific discovery.¹⁶

The impact of developmental origins of health and disease (DOHaD) on manifestations of non-communicable diseases in Africa

A better understanding of non-communicable diseases in sub-Saharan Africa will also require exploration of other environmental factors that may have unique importance in the region. In particular, there is compelling epidemiological and experimental evidence that early life exposures or insults play an important role in determining susceptibility to chronic degenerative diseases in adulthood. For example, many studies have shown strong associations between maternal undernutrition during pregnancy (reflected in a small size at birth) and substantially increased risk of adulthood obesity, type 2 diabetes, hypertension, coronary heart disease, as well as behavioural and neuroendocrine disorders.¹⁷ These relationships are independent of classical risk factors in adulthood, such as smoking, weight, social class, excess alcohol intake or sedentariness, which additive to the effects of birth weight.¹⁸ These observations led to the DOHaD concept, which proposes that early-life environments (periconceptual, fetal and early postnatal) have long-lasting influences in offspring to later health and disease susceptibility.¹⁹

Although initial studies linking low birth weight and later disease came from Europe and North America, the impact of ‘fetal programming’ is likely to be far greater in developing countries, where maternal and fetal malnutrition are common (approximately 95 per cent of all growth-retarded babies are born in

populations, compared to other diseases. *PLoS Genetics*, 8(4):e1002621. [https://doi.org/10.1371/journal.pgen.1002621].

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- 18 McMillen & Robinson, 2005.
- 19 Hales, C.N. & Barker, D.J. 1992. Type 2 (non-insulin-dependent) diabetes mellitus: the thrifty phenotype hypothesis. *Diabetologia*, 35(7):595-601. [https://doi.org/10.1007/bf00400248].

developing countries).²⁰ Indeed, subsequent studies in China and India have supported this notion.²¹ This concept is also likely to be important in Africa where under-nutrition, particularly during pregnancy and in early childhood, remains common, yet coexists with the global obesity epidemic.²² In the Gambia, children who were born with low birth weight and retained the ‘lean, fit and frugal’ lifestyle of the rural areas tended to maintain normal cardiovascular and metabolic health into adulthood.²³ Those who migrated to urban areas (exposed to a diet of relative energy excess and reduced physical activity), had higher susceptibility to cardiometabolic disorders, consistent with the ‘thrifty phenotype’ hypothesis.²⁴

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Thus, the combination of adverse early life influences and a demographic shift towards urbanisation might explain, at least in part, the rapidly rising burden (and early age at onset) of non-communicable diseases in sub-Saharan Africa.²⁵ However, more data from different birth cohort studies in Africa are needed to address this question and inform interventions in pregnancy or early life to reduce long-term non-communicable diseases risk. It is also noteworthy that although most epidemiological evidence on DOHaD relates to malnutrition in early life, other insults associated with poverty (such as infections, use of biomass fuel) can have similar ‘programming effects’. It is also known that early-life psychological stress (either prenatally or in the early postnatal period) can impact on later health, in part by contributing to maladaptation of the stress-response system. Indeed, the fetus is normally protected from the relatively high maternal levels of glucocorticoids (stress hormones) by the enzyme 11 β -hydroxysteroid dehydrogenase type 2 (11 β -HSD2), highly expressed in the placenta, that breaks down active glucocorticoids into inert products. Maternal undernutrition reduces placental 11 β -HSD2, increasing the load of glucocorticoids reaching the fetus via placenta transfer.²⁶ Glucocorticoids might provide a common pathway through which diverse insults exert their programming effects.

Potential mechanisms through which early insults ‘programme’ disease

In the DOHaD concept, the developing fetus, if exposed to a hostile uterine environment (caused by insults such as poor nutrition, infections, chemicals, metabolite or hormonal perturbations), responds by developing adaptations (predictive adaptive responses), that not only foster its immediate survival, but that in a similar environment later in life.²⁷ However, if the individual grows up in

implications for developing countries. *Journal of Nutrition*, 134(1):191-193. [https://doi.org/10.1093/jn/134.1.191].

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- 26 Langley-Evans, S.C., Langley-Evans, A.J. & Marchand, M.C. 2003. Nutritional programming of blood pressure and renal morphology. *Archives of Physiology and Biochemistry*, 111(1):8-16. [https://doi.org/10.1076/apab.111.1.8.15136]; Gardner, D.S., Jackson, A.A. & Langley-Evans, S.C. 1998. The effect of prenatal diet and glucocorticoids on growth and systolic blood pressure in the rat. *Proceedings of the Nutrition Society*, 57(2):235-240. [https://doi.org/10.1079/pns19980037].
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an extra-uterine environment reversed to that experienced in utero, the ‘mismatch’ would predispose them to a higher risk of specific non-communicable diseases.²⁸ This risk is further exacerbated by postnatal risk factors, such as excessive weight gain, and by the ageing process itself.²⁹ Recent study findings have, for instance, shown that postnatal weight gain rather than birth weight, maybe more important in the developmental programming of later blood pressure, with fast-growing low birth weight children at particularly higher risk.³⁰

The mechanisms mediating the programming effects of diverse environmental insults, or how this memory is stored, are not fully understood, but a few have been postulated and are described below.

Change in organ size

It is thought that during periods of insult or stimuli (such as suboptimal nutritional or hormonal levels), the fetus’ immediate aim to survive, and preserve vital functions, occurs at the expense of other ‘less critical’ functions.³¹ For example, by diverting blood supply away from organs such as the kidneys alters their normal development and may lead to permanent changes in structure (too small organs)

tree.2005.08.001]; Hales, C.N. & Barker, D.J. 2001. The thrifty phenotype hypothesis. *British Medical Bulletin*, 60(1):5-20. [https://doi.org/10.1093/bmb/60.1.5].

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and function (hormonal and metabolic).³² Indeed, at post-mortem, intrauterine growth retardation is associated with reduced nephron numbers per unit area of kidney among human stillborn infants.³³ Intrauterine growth retardation effectively reduces the long-term functional capacity of the kidney (the total number of nephrons in the kidney is set at birth).³⁴ The effects of early life insults on nephron number and kidney size have been demonstrated in several animal models, including nutritional restriction in sheep and rats, and placental insufficiency in rabbits and rats.³⁵ The small kidneys with a reduced number of nephrons will have reduced hemodynamic and excretory functional capacity (important for blood pressure regulation) and increase the risk of hypertension.³⁶ Similar changes in the size or number of beta-cell islets in the pancreas or skeletal muscle would compromise their function (insulin secretion and glucose disposal, respectively), and contribute to increased risk of diabetes in individuals who suffered insults early in life. In rats,

for example, exposure to severe starvation leads to poor development of pancreatic beta-cell mass and function, which persists into adulthood.³⁷ Similarly, poor intrauterine nutritional conditions have been shown to influence the development of skeletal mass and increase the risk of insulin resistance in later life.³⁸

Altered gene expression

Another mechanism through which early exposures might mediate their long-term effects involves epigenetics.³⁹ Epigenetic modifications, which include deoxyribonucleic acid (DNA) methylation, histone marks and non-coding ribonucleic acids, regulate gene expression independent of changing the DNA sequence and are important to normal development and differentiation.⁴⁰ DNA methylation, for example, is vital to cell differentiation, carcinogenesis and genomic imprinting.⁴¹ Several studies in animal models and humans have shown that prenatal insults such as undernutrition can change methylation levels and expression of genes in biological pathways involved in growth and metabolic function, including pancreatic beta cell functioning and insulin signalling.⁴² The offspring of mothers who were pregnant during historical famines, such as the Dutch Hunger in the winter of 1944-1945 or the Great Chinese Famine have increased risk of non-communicable diseases (including type 2 diabetes) and reduced methylation at regulatory regions for the insulin-like growth factor 2, a hormone critical to

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growth and development.⁴³ Other studies also found undernutrition in utero to alter methylation rates of important enzymes (11 β -HSD2) and hormonal receptor sites (glucocorticoid receptors), changes that perturb hormone homeostasis and can lead to adult disease.⁴⁴ Changes in non-coding ribonucleic acid and histone modifications at genes of key transcription factors such as the PPARs, Hnf4 α and Pdx1, critical to normal tissue and organ development (adipose tissue, the pancreas, liver), cellular differentiation and metabolism, have also been associated with aberrance and susceptibility to type 2 diabetes.⁴⁵

Non-human experiments have demonstrated that exposure to malnutrition in one generation can affect a range of outcomes in two subsequent generations.⁴⁶ It is thought that such transgenerational inheritance is mediated by epigenetic changes. However, with decades between generations and complex life histories, evidence of transgenerational inheritance in humans has been inconsistent. That said, many observational studies of multigenerational birthweights have found positive associations between maternal and offspring birthweights.⁴⁷ However, it is complex to quantify a causal relationship as it is confounded by shared genetic and environmental factors. Moreover, few studies have rigorously examined harder outcomes such as the occurrence of disease, beyond birth weight in subsequent generations.

Exposure of the developing fetus or infant to stressors, as mentioned above, has also been shown to alter the function of the hypothalamic-pituitary-adrenal axis, resulting in permanent overactivity.⁴⁸ The mechanisms that lead to the altered

hypothalamic-pituitary-adrenal axis are not clearly understood but are thought to include tissue-specific changes in the expression of the glucocorticoid receptor.⁴⁹ For example, studies in rodents have shown that exposure to insults in early life induces permanent downregulation of glucocorticoid receptor expression in the hippocampus and pituitary gland, resulting in attenuation of negative feedback by glucocorticoids at these centres, and therefore increased adrenocorticotropin production and stimulation of the adrenal gland.⁵⁰ Since the hypothalamic-

43 Heijmans et al., 2008.

44 Drake, A.J., McPherson, R.C., Godfrey, K.M., Cooper, C., Lillycrop, K.A., Hanson, M.A., Meehan, R.R., Seckl, J.R., Reynolds, R.M. 2012. An unbalanced maternal diet in pregnancy associates with offspring epigenetic changes in genes controlling glucocorticoid action and foetal growth. *Clinical Endocrinology*, 77(6):808-815. [https://doi.org/10.1111/j.1365-2265.2012.04453.x].

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pituitary-adrenal axis is responsible for regulating the development and function of several homeostatic systems and organs (including those involved in the regulation of blood pressure and glucose metabolism), disturbances in this system may play an important role in mediating effects that lead to fetal programming. Disruption in its development by stressors in early life not only severely affects its function, but also those of systems it regulates, leading to permanent changes in fetal physiology and behaviour.⁵¹ These changes, in turn, predispose the individuals to a plethora of cardiometabolic, neurological and neuroendocrine derangements in adulthood.⁵² The hypothalamus is also involved in appetite regulation, and animal studies have shown that obesity or undernutrition during pregnancy can programme the

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hypothalamic circuitry to influence eating behaviour and lead to later obesity and metabolic disease.⁵³

Why is this evidence important?

We must have a proper understanding of non-communicable diseases in Africa, to avoid the danger of assuming that these disorders will have similar phenotypes or approaches to prevention and treatment as those described in Western societies. For example, if obesity is currently not a major risk factor for diabetes or hypertension in Africa, prevention efforts to tackle these conditions might require going beyond simple calorie intake. Similarly, there might be implications for treatment of diabetes – is metformin, whose benefit is highest in obese people with insulin resistance, the best treatment for all phenotypes of diabetes in Africa where a significant proportion present without overweight or obesity?

Careful epidemiological and clinical studies, coupled with recent advances in technology including genomics and bioinformatics, offer vast opportunities to improve our understanding, and therefore prevention and treatment of non-communicable diseases in Africa.

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9

HYPERGLYCAEMIA IN PREGNANCY

Eugene Sobngwi¹

According to the International Diabetes Federation, the burden of diabetes is progressively rising worldwide with an expected doubling of prevalence in most low- and middle-income settings within twenty-five years. The projected surge in diabetes prevalence to epidemic proportions reflects the ongoing so-called epidemiological transition experienced across most of the fastest-growing economies. The concept of epidemiological transition is characterised by the reduction in infectious disease burden and a quasi-parallel rise in chronic non-communicable disease burden as the result of better health care, reduced fertility, lifestyle changes, increased life expectancy and changing age structure of populations.

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The specificity of epidemiological transition in most African nations is its accelerated character compared to most Western countries where the transition took place over two to three centuries. As a result, chronic non-communicable diseases frequently occur at a lower age than previously reported, including in women of childbearing age.

This chapter reviews key knowledge about the pathophysiology and consequences of hyperglycaemia in pregnancy, and their implication for screening, diagnosis and management strategy in high risk but resource-limited populations, with special emphasis on Africa.

Introduction

Hyperglycaemia in pregnancy has adverse consequences for the mother, the outcome of pregnancy, and her offspring, in turn creating challenges for care providers and the healthcare system. Underdiagnosis, and the resulting absence and sub-optimal management further increase the related burden. In developmental origins of health and disease (DOHaD) perspective, hyperglycaemia in pregnancy is an issue of major importance because it is frequent, often asymptomatic and undiagnosed, has a proven impact on the fetus and the infant after birth, and its effects then extend into adult age. Changes in the internationally accepted diagnostic criteria and strategies for management have raised concern and recognised the need for clarification. Despite the scarcity of population-based data from the most affected parts of the world, there is growing evidence from Africa to suggest a rise in early-onset diabetes and hyperglycaemia in pregnancy.

Despite progress in maternal and child health globally, adverse pregnancy outcomes remain unacceptably high in most sub-Saharan African countries, where they are mainly due to preventable causes.² One of those preventable causes, gestational diabetes, disproportionately affects women of African ethnicity.³ Diabetes mellitus

has been associated with up to eight per cent of stillbirths in developed countries against less than two per cent in other parts of the world.⁴ However, the latter figures are likely underestimated, as the true magnitude of gestational diabetes remains unknown in most low- to-middle income countries, including those in Africa.⁵ In the absence of effective and universal screening programmes, current figures suggest that close to 90 per cent of cases of gestational diabetes occur in low- to-middle income countries including Africa while less than 10 per cent of African woman undergo screening for diabetes during pregnancy.⁶

Detecting and treating gestational diabetes provides benefits in terms of reducing fetal morbidity and mortality, as well as the future maternal risk of developing type 2 diabetes mellitus.⁷ However, optimal strategies for gestational diabetes diagnosis remain elusive.⁸ Different diagnostic criteria have been proposed by different professional bodies and organisations. Recently the International Association of Diabetes and Pregnancy Study Group suggested new diagnostic criteria, informed mainly by the Hyperglycaemia and Adverse Pregnancy Outcome study. However,

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- 8 Simmons, D., McElduff, A., McIntyre H.D. & Elrishi, M. 2010. Gestational Diabetes Mellitus: NICE for the U.S.? A Comparison of the American Diabetes Association and the American College of Obstetricians and Gynecologists Guidelines With the U.K. National Institute for Health and Clinical Excellence Guidelines: Response to Holt et al. *Diabetes Care*, 33:34-37. [https://doi.org/10.2337/dc09-2335].

even these new criteria are somewhat arbitrary, as this study identified continuous associations between maternal glucose levels and several perinatal outcomes, extending the threshold for a gestational diabetes diagnosis.⁹

Because of their high risk of diabetes, women of African ethnicity are offered universal screening for gestational diabetes in most developed countries. Such universal screening is not often available in developing countries because of poor financial and health care resources, and competing health priorities. Adequate approaches should account for the overall population risk and coping capacity of the health systems. Awareness of risk factors such as a family history of diabetes is as low as 30 per cent in most sub-Saharan Africa settings.¹⁰ Moreover, diagnosing gestational diabetes requires the resource- and labour-intensive oral glucose tolerance test, seldom performed in African settings due to many constraints.¹¹ Consequently, gestational diabetes is either not screened for at all or is screened using inaccurate tests such as urine glucose.

Drivers of the risk of hyperglycaemia in pregnancy

Classification and considerations

Hyperglycaemia and hypertension are among the most common medical conditions encountered during pregnancy; estimates are that one in six live births occur in a context of maternal hyperglycaemia in pregnancy. However, because of greater prevalence of maternal and fetal complications resulting from diabetes mellitus antedating pregnancy, the International Federation of Obstetrics and Gynaecology has recommended that hyperglycaemia first detected at any time during pregnancy should be classified as either diabetes mellitus in pregnancy or gestational diabetes mellitus to account for this important fact and etiopathogenesis.

Maternal hyperglycaemia in pregnancy may thus be either due to pre-existing diabetes (type 1 or type 2) antedating pregnancy (estimated to be approximately 16 per cent of cases), or diabetes diagnosed for the first time in pregnancy where

studies meet the World Health Organization (WHO) criterion for diabetes mellitus in the non-pregnant state or due to gestational diabetes. The most commonly accepted definition of gestational diabetes is 'any degree of glucose intolerance with onset or first recognition during pregnancy'.¹² Compared to gestational diabetes, diabetes mellitus antedating pregnancy is more likely to be detected early (e.g. during the first trimester), provided appropriate testing is undertaken. While gestational diabetes is generally evident later in the course of pregnancy (often 24-28 weeks), it is diagnosed at any time when glucose levels meet the WHO criterion for the diagnosis of gestational diabetes (see Figure 9.1).

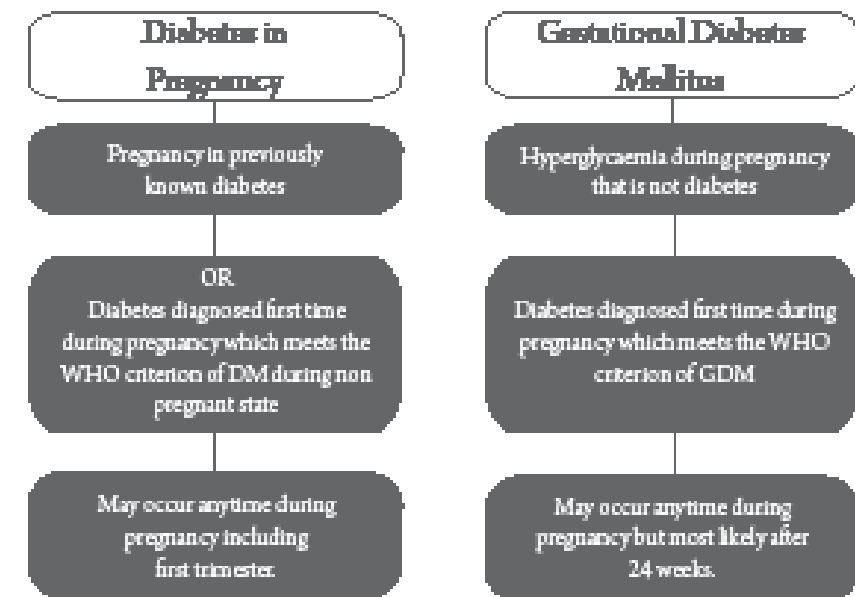


Figure 9.1 Schematic for the distinction between diabetes in pregnancy and gestational diabetes mellitus.

The role of classic factors

Due to shared risk factors, the occurrence of gestational diabetes parallels the prevalence of impaired glucose tolerance, obesity and type 2 diabetes in a given population. Worldwide, overweight and obesity are increasing in women of reproductive age, and the age of onset of diabetes is declining while the age of childbearing is increasing. Thus, in addition to family/genetic predisposition, increasing age combined with sedentary behaviour coupled with an unhealthy diet

9 Hyperglycaemia and Adverse Pregnancy Outcome (HAPO) Study Cooperative Research Group, Metzger, B.E., Lowe, L.P., Dyer, A.R., Trimble, E.R., Chaovarindr, U., Coustan, D.R., Hadden, D.R., McCance, D.R., Hod, M., McIntyre, H.D., Oats, J.J., Persson, B., Rogers, M.S., Sacks, D.A. 2008. Hyperglycemia and adverse pregnancy outcomes. *The New England Journal of Medicine*, 358(19):1991-2002. [<https://doi.org/10.1056/NEJMoa0707943>].

10 Mbanya, J.C., Motala, A.A., Sobngwi, E., Assah, F.K. & Enoru, S.T. 2010. Diabetes in sub-Saharan Africa. *The Lancet*, 375:2254-2266. [[https://doi.org/10.1016/S0140-6736\(10\)60550-8](https://doi.org/10.1016/S0140-6736(10)60550-8)].

11 Jiwani et al., 2012.

12 American Diabetes Association. 2003. Gestational Diabetes Mellitus. *Diabetes Care*, 26(Supplement 1): 103-105. [<https://doi.org/10.2337/diacare.26.2007.S103>].

and the resulting obesity, indicating more women entering pregnancy having risk factors that make them vulnerable to hyperglycaemia during pregnancy.

Other factors

Previous gestational diabetes is associated with a seven-fold lifetime risk of developing persistent type 2 diabetes. In the context of low diabetes awareness, unrecognised diabetes is, therefore, a potential additional factor. The other risk factors for gestational diabetes include ethnicity, high parity, excessive weight gain in the index pregnancy, polycystic ovarian syndrome, a history of poor pregnancy outcome (abortion, fetal loss), macrosomia in previous and/or index pregnancy, gestational diabetes in a previous pregnancy, preeclampsia and multi-fetal pregnancy.¹³

The second half of pregnancy is a diabetogenic state

Despite extensive investigation of risk factors, it is reported that none is found in about half of women diagnosed with gestational diabetes. The second half of pregnancy per se is considered a diabetogenic state for physiological reasons. During pregnancy, the fetus must be nourished continuously despite the intermittent feeding of the mother, achieved through the fetal-placental-maternal unit being under the control of placental hormonal secretions that promote maternal insulin resistance. Insulin resistance increases throughout pregnancy and is well established by the 24th week. Maternal hyperglycaemia occurs in circumstances of the failure to increase insulin secretion or additional insulin resistance in otherwise predisposed women.

Consequences of hyperglycaemia in pregnancy

Overview

Hyperglycaemia in pregnancy is associated with increased risk of adverse events affecting the mother, compromising the fetus, complicating the delivery process, and increasing morbidity in newborn infants. We now know it has long-term consequences in the offspring (see Table 9.1).

In the case of diabetes in pregnancy, as hyperglycaemia may have been present at conception and embryogenesis increases the vulnerability and risk of complications. Hyperglycaemia during the critical period of organogenesis may lead to a high risk of spontaneous abortions and congenital anomalies. Microvascular complications

13 Metzger et al., 2008.

of diabetes such as retinopathy or nephropathy, are also more likely in the mother and tend to exacerbate during pregnancy.

Gestational diabetes more commonly implies relatively milder hyperglycaemia compared to diabetes in pregnancy but is nonetheless associated with poor pregnancy outcome in the absence of appropriate management, and future risk of diabetes and cardiovascular disease.

Gestational diabetes is associated with a higher incidence of maternal morbidity, including caesarean deliveries, shoulder dystocia, birth trauma, hypertensive disorders of pregnancy (including preeclampsia) and subsequent development of type 2 diabetes. Perinatal and neonatal morbidities are also increased; the latter include macrosomia, birth injury, hypoglycaemia, polycythaemia and hyperbilirubinemia. Long-term sequelae in offspring with in utero exposure to maternal hyperglycaemia include higher risks of obesity, impaired glucose metabolism and diabetes later in life.

Relevance to DOHaD

Growth and development of the human conceptus occur within the metabolic milieu provided by the mother and the fetus and are dependent on the transfer of nutrients from the maternal circulation via the placenta. Early studies demonstrated that newborn infants of diabetic mothers suffered from hypoglycaemia.¹⁴ It was hypothesised that this was due to hyperinsulinism as a consequence of the increased transplacental transfer of sugar, and later research confirmed the presence of hyperplasia of the insulin-producing β cells in infants of diabetic mothers. Ultimately, hyperplasia could have consequences in later life; in animal experiments, Aerts and Van Assche showed that modifications in the endocrine pancreas during intrauterine life cause persistent changes in later adult life (second generation), which though not perceptible in basal conditions, become apparent in situations stressing the β cell activity, such as pregnancy.¹⁵ During pregnancy in the second-generation rats, increased non-fasting blood glucose and no adaptation of the β cells is seen. This inadequate adaptation to pregnancy causes changes in the fetal endocrine pancreas of third-generation fetuses, thereby suggesting a transgenerational transmission of risk. It is now evident that an abnormal intrauterine environment has consequences in later life mediated through

14 Jacobsen, B.B., Nielsen, F., Pedersen, V.F. & Kildeberg, P. 1988. Residual β cell function in transient neonatal diabetes mellitus (TNDM). *Pediatric Research*, 23:115. [https://doi.org/10.1203/00006450-198801000-00083].

15 Aerts, L. & Van Assche, F.A. 2006. Animal evidence for the transgenerational development of diabetes mellitus. *The International Journal of Biochemistry & Cell Biology*, 38(5-6):894-903. [https://doi.org/10.1016/j.biocel.2005.07.006].

epigenetic changes and is known as developmental programming. So, it can be concluded that fetal development in an abnormal intrauterine milieu can induce alterations in fetal metabolism, with lasting consequences for the glucose tolerance of the offspring in adult life.¹⁶ The most marked effects being the development of gestational diabetes and with it the transmitting of a diabetogenic tendency to the next generation.

Table 9.1 Adverse events associated with hyperglycaemia in pregnancy.

Maternal and Fetal morbidity associated with gestational diabetes (adapted from the International Federation of Obstetrics and Gynaecology)	
Maternal	
■ Pre-and Early Pregnancy	
-	Spontaneous abortions
■ During Pregnancy	
-	Preeclampsia
-	Gestational hypertension
-	Excessive fetal growth (macrosomia, low gestational age)
-	Hydramnios
-	Urinary tract infections
-	Preterm labour
-	Traumatic labour
-	Shoulder dystocia
-	Instrumental delivery
-	Caesarean delivery
-	Post-operative/postpartum infection
-	Post-operative/postpartum haemorrhage
-	Thromboembolism
-	Maternal mortality
■ Puerperium	
-	Failure to initiate &/or maintain breastfeeding
-	Infection
■ Long-Term Post-Partum	
-	Weight retention
-	Gestational diabetes in a subsequent pregnancy
-	Future overt diabetes
-	Future cardiovascular disease
Fetal/Neonatal	

16 Fetita, L.S., Sobngwi, E., Serradas, P., Calvo, F. & Gautier, J.F. 2006. Consequences of fetal exposure to maternal diabetes in offspring. *The Journal of Clinical Endocrinology and Metabolism*, 91(10):3718-3724. [<https://doi.org/10.1210/jc.2006-0624>].

Maternal and Fetal morbidity associated with gestational diabetes (adapted from the International Federation of Obstetrics and Gynaecology)	
-	Stillbirth
-	Neonatal death
-	Non-chromosomal congenital malformations
-	Respiratory distress syndrome
-	Cardiomyopathy
-	Neonatal hypoglycaemia
-	Neonatal polycythaemia
-	Neonatal hyperbilirubinemia
-	Neonatal hypocalcaemia
-	Erb's palsy (as a consequence of birth injury)
DOHaD	
-	Increased predictors and risk of diabetes, obesity, and hypertension in offspring at adult age

An increasing body of evidence supports the hypothesis that the abnormal metabolic environment of the mother with diabetes mellitus may affect specific developing fetal tissues, organs and control systems that will eventually lead to permanent long-term functional implications in adult life. The fetal tissues most likely to be affected are neural cells, adipocytes, muscle cells and pancreatic β cells. Freinkel & Metzger (1979) introduced the concept of pregnancy as a 'tissue culture experiment', in which the placenta and the fetus develop in an 'incubating medium' totally derived from maternal fuels. All these fuels traverse the placenta from the maternal compartment either with (e.g. glucose, lipids) or against (e.g. amino acids) concentration gradients and thus contribute to the fetal milieu. Since these constituents are regulated in part by maternal insulin, disturbances in its supply or actions influence the entire nutritional content to which the fetus is exposed; maternal hyperglycaemia leads to fetal hyperglycaemia and eventually to fetal hyperinsulinemia. According to Freinkel & Metzger (1979)'s hypothesis, the abnormal mixture of metabolites from the mother gains access to the developing fetus in utero, modifying the phenotypic expression in newly-formed cells, in turn determining permanent, short- and long-term effects in the offspring.¹⁷ Depending upon the timing of (embryonic-fetal) exposure to the aberrant fuel mixture, different events may develop. Early in the first trimester, intrauterine growth restriction and organ malformation, described by Freinkel & Metzger (1979) as

17 Freinkel, N. & Metzger, B.E. 1979. Pregnancy as a tissue culture experience: the critical implications of maternal metabolism for fetal development. *Ciba Foundation Symposium 63: Pregnancy Metabolism, Diabetes and the Fetus*, (63):3-28. [<https://doi.org/10.1002/9780470720462.ch2>].

'fuel-mediated teratogenesis' may occur.¹⁸ During the second trimester, at the time of brain development and differentiation, behavioural, intellectual or psychological damage may occur. During the third trimester, abnormal proliferation of fetal adipocytes and muscle cells, together with hyperplasia of pancreatic β cells and neuroendocrine cells may be responsible for the development of obesity, hypertension and type 2 diabetes later in life.

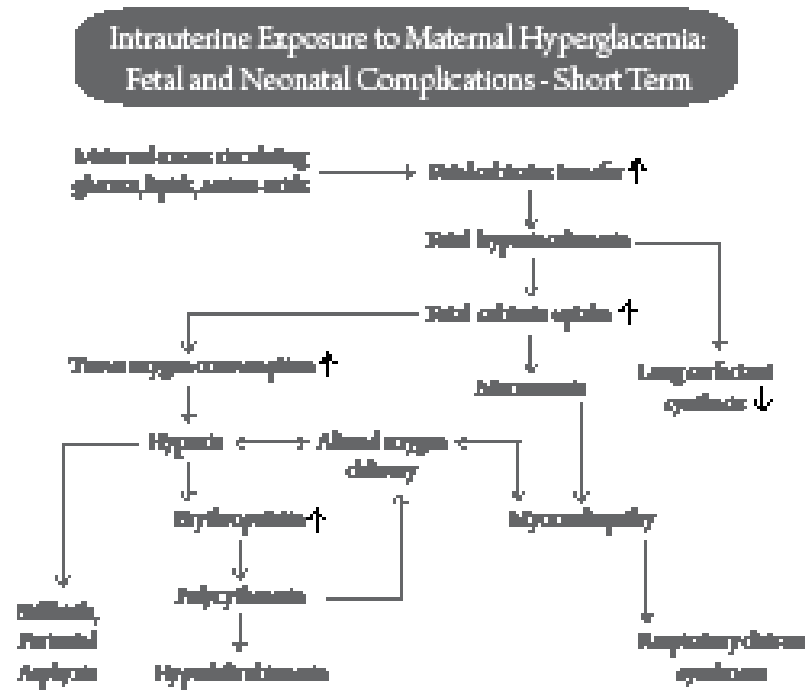


Figure 9.2 Schematic of the fetal and neonatal effects of intrauterine exposure to maternal hyperglycaemia.

Implications for diagnosis

Historical perspective

After decades of uncertainty about the diagnostic criteria of hyperglycaemia in pregnancy, there is an emerging consensus following extensive large studies of outcomes around International Association of Diabetes and Pregnancy Study Group-derived criteria as presented by the WHO in 2013. It is recommended to use a two-hour 75g oral glucose tolerance test with fasting, one-hour and two-hour

18 Freinkel & Metzger, 1979.

criteria as shown in Table 9.1. There is, however, a lack of consensus across the world for the best screening strategy, whether a universal one-step, a two-step or a risk factor-based screening approach should be used.¹⁹

African perspective

Recent studies on the prevalence and risk factors of gestational diabetes in an African setting include those by Mwanri, Kinabo, Ramaiya and Feskens (2015); Macaulay, Dunger and Norris (2014); and Olagbujl and colleagues (Atiba, Olofinbiyi, Akintayo, Awoleke, Ade-Ojo and Fasubaa and the Gestational Diabetes Study Group-Nigeria, 2015).²⁰ Mwanri et al. reported a PubMed-Medline based systematic review of studies published up to June 2014. The 22 studies identified were from Western (n=11), Southern (n=5), Eastern (n=4) and Central (n=2) Africa.²¹

Diagnostic criteria for gestational diabetes varied widely between these studies. Using a 50g glucose challenge test and WHO 1999 criteria, the prevalence of gestational diabetes ranged from 1.5 to three per cent and one to 13.9 per cent, respectively. None of the included studies used criteria from the International Association of Diabetes and Pregnancy Study Group 2010 or the National Institute

19 Atun, R., Davies, J.I., Gale, E.A., Bärnighausen, T., Beran, D., Kengne, A.P., Levitt, N.S., Mangugu, F.W., Nyirenda, M.J., Ogle, G.D. & Ramaiya, K., Sewankambo, N.K., Sobngwi, E., Tesfaye, S., Yudkin, J.S., Basu, S., Bommer, C., Heesemann, E., Manne-Goehler, J., Postolovska, I., Sagalova, V., Vollmer, S., Abbas, Z.G., Ammon, B., Angamo, M.T., Annamreddi, A., Awasthi, A., Besançon, S., Bhadriraju, S., Binagwaho, A., Burgess, P.I., Burton, M.J., Chai, J., Chilunga, F.P., Chipendo, P., Conn, A., Joel, D.R., Eagan, A.W., Gishoma, C., Ho, J., Jong, S., Kakarmath, S.S., Khan, Y., Kharel, R., Kyle, M.A., Lee, S.C., Lichtman, A., Malm, C.P., Mbaye, M.N., Muhimpundu, M.A., Mwangomba, B.M., Mwangi, K.J., Nair, M., Niyonsenga, S.P., Njuguna, B., Okafor, O.L.O., Okunade, O., Park, P.H., Pastakia, S.D., Pekny, C., Reja, A., Rotimi, C.N., Rwunganira, S., Sando, D., Sarriera, G., Sharma, A., Sidibe, A., Siraj, E.S., Syed, A.S., Van Acker, K. & Werfalli, M. 2017. Diabetes in sub-Saharan Africa: from clinical care to health policy. *The Lancet Diabetes & Endocrinology*, 5(8):622-667. [https://doi.org/10.1016/S2213-8587(17)30181-X].

20 Macaulay, S., Dunger, D.B. & Norris, S.A. 2014. Gestational diabetes mellitus in Africa: a systematic review. *PLoS One*, 9:e97871. [https://doi.org/10.1371/journal.pone.0097871]; Olagbujl, B.N., Atiba, A.S., Olofinbiyi, B.A., Akintayo, A.A., Awoleke, J.O., Ade-Ojo, I.P. & Fasubaa, O.B. & Gestational Diabetes Study Group-Nigeria. 2015. Prevalence of and risk factors for gestational diabetes using 1999, 2013 WHO and IADPSG criteria upon implementation of a universal one-step screening and diagnostic strategy in a sub-Saharan African population. *European Journal of Obstetrics & Gynecology and Reproductive Biology*, 189:27-32. [https://doi.org/10.1016/j.ejogrb.2015.02.030].

21 Mwanri et al., 2015.

for Health and Clinical Excellence 2015. Overweight or obesity, family history of diabetes, macrosomia or age older than 30 years were the main risk factors of gestational diabetes. Macaulay et al. reported the prevalence of gestational diabetes (estimate: 9.3 per cent) using criteria of the WHO or the American Diabetes Association 2012, while Olagbuji et al. used criteria of the WHO 1999, the WHO 2013, the modified International Association of Diabetes and Pregnancy Study Group and the International Association of Diabetes and Pregnancy Study Group, and reported prevalence rates of 3.8 per cent, 8.1 per cent, 7.5 per cent and 8.6 per cent.²² Glycosuria was the only correlate of gestational diabetes based on criteria of the WHO 2013 and the International Association of Diabetes and Pregnancy Study Group.

For the first time in an African population, we have explored the diagnostic utility of fasting plasma glucose or random blood glucose alone and the added value of 50g glucose challenge test and the performance of the guidelines for gestational diabetes screening of the WHO 1999, the International Association of Diabetes and Pregnancy Study Group 2010 and the National Institute for Health and Clinical Excellence 2015.

We conducted a cross-sectional study among pregnant women attending antenatal clinics in two major cities in Cameroon. We enrolled consenting pregnant women who attended antenatal care at the participating health facilities, on a consecutive basis until reaching a target sample of 1 000. Pregnant women at 24-28 weeks of gestation were eligible. We excluded women with known diabetes based on medical records. Overall, each consenting participant underwent a risk factor assessment, a random blood glucose test, a fasting plasma glucose test, a one-hour 50g glucose challenge test and a two-hour 75g oral glucose tolerance test.

Risk factor assessment

A structured questionnaire was used to record risk factors for gestational diabetes, including age, occupation, education level, parity, history of a previous stillbirth, history of macrosomia (birth weight $\geq 4\ 000\text{g}$), physical activity levels, dietary habits, and characteristics of the ongoing pregnancy. Blood pressure was the average from three consecutive measurements in a sitting position after a ten-minute rest using an Omron M4[®] recorder. Height and weight were measured in light indoor clothing and without shoes. The body mass index was calculated in kg/m^2 . Overweight was defined as having a body mass index of $\geq 25\text{kg}/\text{m}^2$ and obesity as $\geq 30\text{kg}/\text{m}^2$.

22 Macaulay, Dunger & Norris, 2014; Olagbuji et al., 2015.

Testing for gestational diabetes

The women underwent biochemical testing for gestational diabetes on two different occasions. At the first visit, a random plasma glucose test and a one-hour post load 50g glucose challenge test were conducted. At the second visit within one week of the first one, participants underwent testing (after an eight to 12-hour overnight fast) including fasting plasma glucose test, and a 75g oral glucose tolerance test with an assessment of blood glucose at 30, and 120 minutes after a glucose load.

Diagnostic criteria for gestational diabetes

Gestational diabetes was defined by applying three sets of criteria:

- The WHO's definition (1999) as either fasting plasma glucose $\geq 7\text{mmol}/\text{L}$ or two-hour post a 75g oral glucose tolerance test, plasma glucose (two-hour PG) $\geq 7.8\text{mmol}/\text{L}$;²³
- An approximation of the International Association of Diabetes and Pregnancy Study Group-criteria as either fasting plasma glucose $\geq 5.1\ \text{mmol}/\text{L}$ or two-hour PG $\geq 8.5\text{mmol}/\text{L}$;²⁴ and
- The National Institute for Health and Clinical Excellence 2015-criteria as fasting plasma glucose $\geq 5.6\text{mmol}/\text{L}$ and two-hour PG $\geq 7.8\text{mmol}/\text{L}$.²⁵

Implications of the evidence

The prevalence of gestational diabetes in Cameroon varies substantially across diagnostic criteria, from 5.9 per cent by the WHO criteria to 17.7 per cent by the International Association of Diabetes and Pregnancy Study Group-criteria, and 11 per cent by the National Institute for Health and Clinical Excellence-criteria. The presence of gestational diabetes appears to be determined by previous obstetrical

23 World Health Organization (WHO). 1999. *Definition, diagnosis and classification of diabetes mellitus and its complications: Report of a WHO consultation*. Part 1, Diagnosis and classification of diabetes mellitus. [<https://apps.who.int/iris/handle/10665/66040>] (Accessed 10 September 2019).

24 Metzger, B.E., Gabbe, S.G., Persson, L.P., Dyer, A.R., Oats, J.M. & Buchanan, T.A. 2010. International association of diabetes and pregnancy study groups recommendations on the diagnosis and classification of hyperglycemia in pregnancy. *Diabetes Care*, 33(3):676-682. [<https://doi.org/10.2337/dc09-1848>].

25 National Institute for Health and Care Excellence. 2015. *Diabetes in pregnancy: management from preconception to the postnatal period*. NICE guideline [NG3]. [[nice.org.uk/guidance/ng3](https://www.nice.org.uk/guidance/ng3)] (Accessed 10 September 2019).

history and dietary habits. Irrespective of the diagnostic criteria and tests thresholds used, a considerable proportion of women was likely to have severe glucose intolerance and thus was at risk for adverse perinatal outcomes. A conceptually simple diagnostic algorithm with optimal screening yield can be derived based on the performance of various tests in this population and is potentially useful for routine clinical practice in resource-limited settings.

The prevalence of gestational diabetes depends on the chosen screening strategy with the highest prevalence obtained using guidelines of the International Association of Diabetes and Pregnancy Study Group. Irrespective of the diagnostic criteria and test thresholds used, a considerable proportion of women have severe glucose intolerance and are thus at risk for adverse perinatal outcomes. Physical activity, history of stillbirth and alcohol consumption, age, family history of diabetes and macrosomia are significant determinants of gestational diabetes in African populations. Unlike random blood glucose, fasting plasma glucose could be used in a simple screening algorithm to define the segment of pregnant women to be further screened via a 75g oral glucose tolerance test. Where feasible, however, a single step testing strategy using a 75g oral glucose tolerance test is optimal for gestational diabetes screening.

Based on the performance of the screening tests used in our study we propose a simple screening algorithm to optimally identify women with gestational diabetes in sub-Saharan Africa where limited resources are a major deterrent to the implementation of a large-scale and sustainable programme for prevention and management of gestational diabetes-associated complications. The screening algorithm is practical for resource-limited settings and uses fasting glucose measurements, as shown in Figure 9.2. Such a screening strategy, allowing testing of pregnant women first in a fasting state, will facilitate an opportunistic approach to screening and has the potential to maximise the yield of screening in an environment where regular clinic attendance can be an issue.

Comparison with other studies and explanation of our results

A recent study from Nigeria using the WHO criteria to diagnose gestational diabetes reported a prevalence of 8.3 per cent; whereas a previous South-African study found a much lower prevalence (1.5 per cent) with similar criteria in a rural setting.²⁶

26 Atun et al., 2017; Mamabolo, R.L., Alberts, M., Levitt, N.S., Delemarre-van de Waal, H.A. & Steyn, N.P. 2007. Prevalence of gestational diabetes mellitus and the effect of weight on measures of insulin secretion and insulin resistance in third-trimester pregnant rural women residing in the Central Region of Limpopo Province, South Africa. *Diabetic Medicine*, 24(3):233-239. [https://doi.org/10.1111/j.1464-5491.2006.02073.x].

Such differences in gestational diabetes prevalence with previous studies may relate to the fact that these studies have used different screening strategies and diagnostic criteria than those of the screening approach in this study. Elevated rates of gestational diabetes in Cameroonian women may be related to the growing obesity in women in sub-Saharan Africa.²⁷ In our study, only previous stillbirth and alcohol consumption were associated with the presence of gestational diabetes. There are several possible explanations for the lack of association between traditionally known risk factors and gestational diabetes, which include our relatively small sample size with a low prevalence of some of these risk factors in our sample, or the low awareness of these risk factors in our population. The paradoxical association of increased physical activity from walking with a high prevalence of gestational diabetes may simply be related to chance or the subjective nature of physical activity assessment.

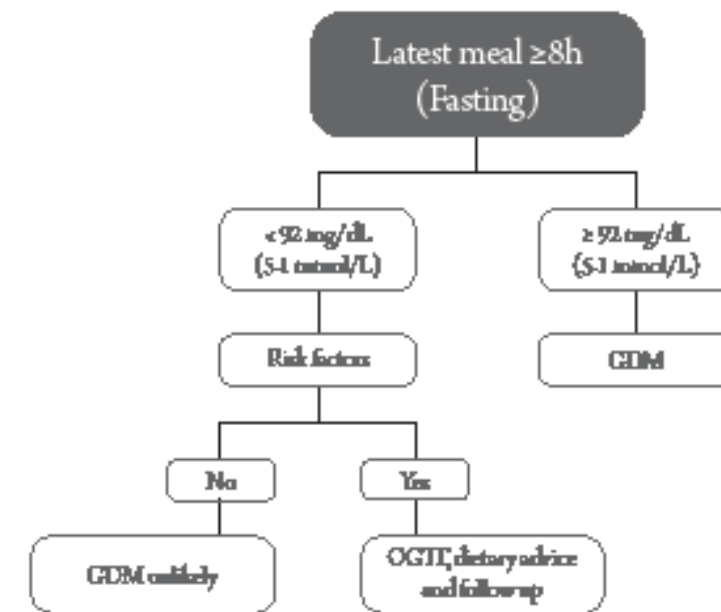


Figure 9.3 Proposed screening algorithm for gestational diabetes in resource-limited settings.

Our estimates of the performance of various screening tests differ from those reported in previous studies.²⁸ The observed difference is at least partially related

27 Mwanri et al., 2015; Macaulay, Dunger & Norris, 2014.

28 Senanayake, H., Seneviratne, S., Ariyaratne, H. & Wijeratne, S. 2006. Screening for gestational diabetes mellitus in southern Asian women. *Journal of Obstetrics and Gynaecology Research*, 32(3):286-291. [https://doi.org/10.1111/j.1447-

to population structure with potential differential gestational diabetes baseline risk, sample size and tests used, as well as cut-offs. Indeed, many previous studies did not include random blood glucose in their assessment, although it is a fast, simple, and relatively inexpensive test. However, its accuracy has been less frequently studied than that of other screening tests, with indications that its performance as a screening test for gestational diabetes may be limited. Nasrat, Johnstone and Hasan (1988) found a sensitivity of 16 per cent and a specificity of 96 per cent using a threshold value of 7mmol/L or 6.4mmol/L if evaluated against two-hour postprandial.²⁹ Consistent with our findings, Jowett, Samanta and Burden (2017) concluded that random glucose measurement might not be sufficiently sensitive for screening on gestational diabetes as a stand-alone test.³⁰ Despite these limitations, from a public health perspective, including fasting plasma glucose as an initial test in a stepwise screening for gestational diabetes using a combination of various tests, appear as a promising practical approach for detecting gestational diabetes in under-resourced settings (where universal screening is not always possible). Opportunistic screening with random blood glucose would lead to more gestational diabetes cases diagnosed.

Conclusion

Rapid demographic, sociocultural, and economic transitions are driving increases in the risk and prevalence of diabetes and other non-communicable diseases in sub-Saharan Africa. The impacts of these transitions and their health and economic consequences are evident. In 1990, the leading causes of death in sub-Saharan Africa were HIV/Aids, lower respiratory infections, diarrhoeal diseases, malaria, and vaccine-preventable diseases in children. In more recent years, cardiovascular diseases and their risk factors are replacing infectious diseases as the leading causes of death in this region, and rates of increased cardiovascular risk factors are

predicted to be higher in sub-Saharan Africa than in other parts of the world. Thus, sub-Saharan Africa, containing a high proportion of the world's least developed countries, will face the multifaceted challenge of dealing with a high burden of infectious diseases and diseases of poverty, while also addressing the increasing burden of cardiovascular disease and its risk factors. At present, many of the health systems in sub-Saharan Africa struggle to cope with infectious diseases. Meeting the goals of the United Nations high-level meeting on non-communicable diseases (to reduce premature mortality from non-communicable diseases by 25 per cent by 2025) and the Sustainable Development Goals (to reduce premature mortality from non-communicable diseases by a third by 2030) requires a coordinated approach within countries, starting with a firm consideration of disease burden, needs, and priorities.³¹

0756.2006.00400.x]; Agarwal, M.M., Dhatt, G.S. & Punnose, J. 2006. Gestational diabetes: utility of fasting plasma glucose as a screening test depends on the diagnostic criteria. *Diabetic Medicine*, 23(12):1319-1326. [<https://doi.org/10.1111/j.1464-5491.2006.01987.x>]; Agarwal, M.M., Dhatt, G.S. & Shah, S.M. 2010. Gestational diabetes mellitus: simplifying the international association of diabetes and pregnancy diagnostic algorithm using fasting plasma glucose. *Diabetes Care*, 33(9):2018-2020. [<https://doi.org/10.2337/dc10-0572>].

29 Nasrat, A.A., Johnstone, F.D. & Hasan, S.A. 1988. Is random plasma glucose an efficient screening test for abnormal glucose tolerance in pregnancy? *British Journal of Obstetrics and Gynaecology*, 95(9):855-860. [<https://doi.org/10.1111/j.1471-0528.1988.tb06569.x>].

30 Jowett, N.I., Samanta, A.K. & Burden, A.C. 2017. Screening for diabetes in pregnancy: is a random blood glucose enough? *Diabetic Medicine*, 4(2):160-3. [<https://doi.org/10.1111/j.1464-5491.1987.tb00854.x>].

31 Atun et al., 2017.



10

DIABETES IN PREGNANCY: LESSONS FOR DEVELOPING COUNTRIES

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Pregnancy diabetes is fast becoming a common condition across the world with developing countries particularly affected. In the short term, maternal hyperglycaemia worsens pregnancy outcomes, but in the long run, it appears to be a precursor to diabetes and cardiovascular disease in the mother and obesity and diabetes in the child. Thus, pregnancy diabetes is thought to contribute to the escalating epidemic of obesity and diabetes. Classic thinking is that pregnancy diabetes consists of pre-gestational diabetes and gestational diabetes. There are considerable confusion and controversy about the diagnosis and management of gestational diabetes. There is increasing evidence that risk factors and metabolic

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4 Epidemiology Research Unit.

disturbances of gestational diabetes patients are present long before pregnancy, implicating peri-conceptual fetal programming of future obesity and diabetes.

This chapter reviews what developing countries need to consider as a public health challenge in the context of gestational diabetes and how to contribute to research that will improve the understanding of the condition: biology, diagnosis, cost-effective treatment, and long-term contribution to the health and economy of the nation. A lot can be learned from the experience of the developed world that will help to avoid the pitfalls plaguing this field. Forming a multinational consortium may improve the efficiency of such research.

Gestational diabetes – definition and pathological aspects

The consensus definition of gestational diabetes is ‘carbohydrate intolerance of variable severity with onset or first recognition during pregnancy’, presenting several issues.⁵ The definition includes both ‘pregnancy-induced’ as well as undiagnosed pre-existing hyperglycaemia under gestational diabetes. Phenotypes strongly associated with diabetes such as obesity may have already been present in the majority of the women who develop gestational diabetes. Also, this definition encompasses a wide range of glucose levels, including severe hyperglycaemia associated with newly discovered type 1 or type 2 diabetes mellitus in the same frame as mild hyperglycaemia characterising ‘pregnancy-induced’. This wide range of levels presents problems related to management guidelines during pregnancy and postpartum follow-up. The current World Health Organization (WHO) guidelines, thus, recommend categorising hyperglycaemia in pregnancy into ‘overt diabetes mellitus’ and ‘gestational diabetes’, the latter broadly corresponding to impaired fasting glucose or impaired glucose tolerance in the non-pregnant state.⁶ A diabetic pregnancy could thus be a pregnancy in a woman who already had diabetes (diagnosed or undiagnosed), or it may be because of hyperglycaemia purportedly induced by pregnancy. Notwithstanding these confusions, gestational diabetes is of concern because of adverse outcomes in the mother and the fetus. With a global rise in the prevalence of obesity and glucose intolerance among young people,

gestational diabetes is fast becoming a major public health problem, especially in transitioning populations such as India and Africa.

Pregnancy is conventionally considered a diabetogenic condition. Gestational steroid hormones and placental lactogen promote insulin resistance which facilitates nutrient transfer to the fetus.⁷ Gestational diabetes is thought to occur when pancreatic β -cells fail to cope with the increased demands for insulin. Risk factors that impair the β -cell function (capacity) or exacerbate insulin resistance (load) facilitate the development of hyperglycaemia. These include maternal genetic predisposition (family history of diabetes), low birth weight or macrosomia at birth, advanced age, obesity, short stature, polycystic ovary syndrome, to name a few. It is noteworthy that except for a few pregnancy-related risk factors (excess weight gain in pregnancy, twin pregnancy, male fetus), the majority of risk factors are pre-pregnancy or intergenerational. These considerations indicate a substantial pre-pregnancy component for gestational diabetes.

The last decade has seen considerable confusion and debates on diagnosis, management and short- and long-term implications of gestational diabetes. Some of these might be better understood by learning the history of ‘pregnancy and diabetes’. The first reports of the implications of hyperglycaemia in pregnancy for mother and baby were already available in the 1800s.⁸ These initial studies mainly described diabetic mothers who became pregnant and resulted in serious outcomes, including high rates of mortality in both mother and the baby. The invention of insulin in 1923 considerably reduced these extreme outcomes. Over the next many decades, the attention shifted to congenital anomalies and fetal overgrowth. In the 1950s, Jorgen Pedersen first proposed a mechanism underlying accelerated fetal growth in diabetic pregnancies.⁹ In his classic ‘hyperglycaemia-hyperinsulinism’ hypothesis, he suggested that increased trans-placental transmission of glucose results in hypertrophy of fetal islet tissue and insulin hypersecretion. Fetal hyperinsulinemia stimulates growth and increases fetal size. In 1980, Norbert Freinkel extended this idea to include lipids and amino acids and suggested that insulin, as well as insuline-like growth factors, promote greater tissue anabolism and macrosomia.¹⁰ He suggested that this will also reflect on future obesity and diabetes (‘fuel-mediated teratogenesis’). The multinational Hyperglycaemia and Adverse

5 Hadden, D.R. 1998. A historical perspective on gestational diabetes. *Diabetes Care*, 21(Supplement 2):B3-B4. [<https://www.ncbi.nlm.nih.gov/pubmed/9704219>]; World Health Organization (WHO). 1999. Definition, diagnosis and classification of diabetes mellitus and its complications: Report of a WHO consultation. Part 1, Diagnosis and classification of diabetes mellitus. [<https://apps.who.int/iris/handle/10665/66040>].

6 WHO. 2013. Diagnostic Criteria and Classification of Hyperglycaemia First Detected in Pregnancy. Diabetes Programme. [https://www.who.int/diabetes/publications/Hyperglycaemia_In_Pregnancy/en/].

7 Lain, K.Y. & Catalano, P.M. 2007. Metabolic changes in pregnancy. *Clinical Obstetrics and Gynecology*, 50(4):938-948. [<https://doi.org/10.1097/GRF.0b013e31815a5494>].

8 Hadden, 1998.

9 Pedersen, J. 1954. Weight and length at birth of infants of diabetic mothers. *Acta Endocrinologica (Copenhagen)*, 16(4):330-342. [<https://doi.org/10.1530/acta.0.0160330>].

10 Freinkel, N. 1980. Banting Lecture 1980. Of pregnancy and progeny. *Diabetes*, 29(12):1023-35. [<https://doi.org/10.2337/diab.29.12.1023>].

Pregnancy Outcomes study supported this idea by demonstrating graded positive associations between maternal glycemia and neonatal weight, adiposity, and β -cell function across the range of glycemia that is not overt diabetes, at the same time posing challenges to the definition and management of gestational diabetes as a distinct entity.¹¹ The current attention is thus focussed on milder degrees of glucose intolerance during pregnancy.¹²

Screening and diagnostic guidelines for gestational diabetes – the ongoing debate

There is still a lack of consensus among scientists and clinicians on screening and diagnosis of gestational diabetes. The earlier definitions of gestational diabetes were based either on the prediction of future diabetes in the mother or were arbitrarily chosen to correspond to the oral glucose tolerance test criteria in non-pregnant individuals. In 1964, O’Sullivan and Mahan gave one of the first guidelines for diagnosing gestational diabetes using whole blood glucose levels during a three-hour 100g oral glucose tolerance test.¹³ These guidelines were similar to the definitions used for non-pregnant adults at that time and were aimed at identifying women with future risk of diabetes. In 1979, the National Diabetes Data Group proposed plasma glucose thresholds corresponding to the whole blood glucose thresholds to suit changes in laboratory methodology.¹⁴ These values were later lowered by Carpenter and Coustan (1982) who used specific enzymatic methods to measure glucose.¹⁵ In 1999, the WHO expert group recommended the use of plasma glucose values corresponding to impaired glucose tolerance in non-pregnant adults to diagnose gestational diabetes.¹⁶ However, none of these

11 Metzger, B.E., Lowe, L.P., Dyer, A.R., Trimble, E.R., Chaovarindr, U., Coustan, D.R., Hadden, D.R., McCance, D.R., Hod, M., McIntyre, H.D., Oats, J.J., Persson, B., Rogers, M.S., Sacks, D.A., & HAPO Study Cooperative Research Group. 2008. Hyperglycaemia and adverse pregnancy outcomes. *The New England Journal of Medicine*, 358(19):1991-2002. [https://doi.org/10.1056/NEJMoa0707943].

12 Mestman, J.H. 2002. Historical notes on diabetes in pregnancy. *Endocrinologist*, 12(3):224-242. [https://doi.org/10.1097/00019616-200205000-00010].

13 O’Sullivan, J.B. & Mahan, C.M. 1964. Criteria for the oral glucose tolerance test in pregnancy. *Diabetes*, 13:278-285. [https://www.ncbi.nlm.nih.gov/pubmed/14166677].

14 National Diabetes Data Group. 1979. Classification and diagnosis of diabetes mellitus and other categories of glucose intolerance. *Diabetes*, 28(12):1039-1057. [https://doi.org/10.2337/diab.28.12.1039].

15 Carpenter, M.W. & Coustan, D.R. 1982. Criteria for screening tests for gestational diabetes. *American Journal of Obstetrics and Gynecology*, 144(7):768-773. [https://doi.org/10.1016/0002-9378(82)90349-0].

16 WHO, 1999.

definitions considered the effect of glucose thresholds on short- and long-term fetal outcomes.

The Hyperglycaemia and Adverse Pregnancy Outcomes study focused on the ‘short term’ (perinatal) outcomes in the mother and baby.¹⁷ This large multi-centric study observed a graded linear relationship between fasting, one-hour and two-hour glucose values during the oral glucose tolerance test (24-28 weeks) and a range of pre-defined pregnancy outcomes, particularly offspring birth weight. In 2010, the International Association of Diabetes and Pregnancy Study Group proposed diagnostic guidelines based on the Hyperglycaemia and Adverse Pregnancy Outcomes findings.¹⁸ To translate the above continuous associations into diagnostic thresholds, cut-off values that represent an odds ratio of 1.75 for the outcome of the highest decile of birth weight and cord C-peptide were chosen by consensus.¹⁹ However, Hyperglycaemia and Adverse Pregnancy Outcomes researchers agree that this is an arbitrary definition. These values, based on the increased risk of fetal macrosomia in developed populations, need to be interpreted with caution in countries like India, where small-for-gestational-age births are prevalent even in pregnancies complicated by gestational diabetes.²⁰

The WHO and the International Federation of Gynaecology and Obstetrics accepted the criteria of the International Association of Diabetes and Pregnancy Study Group.²¹ However, many other organisations have not. The screening

17 Metzger et al., 2008.

18 Metzger, B.E., Gabbe, S.G., Persson, B., Lowe, L.P., Dyer, A.R., Oats, J.J.N. & Buchanan, T.A. 2010. International association of diabetes and pregnancy study groups recommendations on the diagnosis and classification of hyperglycaemia in pregnancy. *Diabetes Care*, 33(3):676-82. [https://doi.org/10.2337%2Fdc09-1848].

19 Metzger et al., 2010.

20 McIntyre, H.D., Metzger, B.E., Coustan, D.R., Dyer, A.R., Hadden, D.R., Hod, M., Lowe, L.P., Oats, J.J. & Persson, B. 2014. Counterpoint: Establishing consensus in the diagnosis of GDM following the HAPO study. *Current Diabetes Reports*, 14(6):497. [https://doi.org/10.1007/s11892-014-0497-x]; Elizabeth, K.E., Ashwin, D.A., Sobhakumar, S. & Sujatha, T.L. 2018. Large and Small-for-Gestational-Age (LGA and SGA) Babies born to Mothers with Pre-Pregnancy/Gestational Diabetes Mellitus (PPDM/GDM) Vs. No-DM. *Acta Scientific Paediatrics*, 1(3):23-28. [https://www.actascientific.com/ASPE/pdf/ASPE-01-0020.pdf]; Elango, S., Sankarasubramanian, M.L. & Marimuthu, B. 2018. An observational study of clinical profile of infants born to pregestational and gestational diabetic mothers. *International Journal of Contemporary Pediatrics*, 5(2):557-562. [https://doi.org/10.18203/2349-3291.ijcp20180554].

21 WHO, 2013; Hod, M., Kapur, A., Sacks, D.A., Hadar, E., Agarwal, M., Di Renzo, G.C., Cabero Roura, L., McIntyre, H.D., Morris, J.L., Divakar, H. 2015. The International Federation of gynecology and Obstetrics (FIGO) Initiative on gestational diabetes mellitus: A pragmatic guide for diagnosis, management, and care. *International Journal of*

guidelines also vary. Some recommend one stage universal screening of pregnant women (75g oral glucose tolerance test, the WHO and the International Federation of Gynaecology and Obstetrics) while others recommend a 50g challenge followed by a definitive oral glucose tolerance test. Some recommend only selective testing (high-risk groups: such as a family history of diabetes, obesity and high prevalence ethnicity).

Indian guidelines

In the absence of a national guideline for gestational diabetes diagnosis, there has been a lack of uniformity in screening and diagnostic criteria among healthcare providers in India. In 2005, the Diabetes in Pregnancy Study Group in India proposed a one-step non-fasting glucose tolerance test and the diagnosis based on the 120-minutes plasma glucose value of more than 140mg/dl.²² This proposition was justified for its logistic convenience and is endorsed by the Federation of Obstetric and Gynaecological Societies of India. There is a paucity of data for perinatal and long-term outcomes and efficacy of diagnosis and treatment.

Changing trends in gestational diabetes prevalence: diagnostic criteria vs. secular trends

All these different diagnostic guidelines continue to baffle the average clinician. One of the major implications of changing thresholds has been the different detection rates of gestational diabetes. The rates are highest using criteria of the International Association of Diabetes and Pregnancy Study Group because of the lowest glucose thresholds and the requirement for only a single abnormal value during the oral glucose tolerance test.²³ Some researchers argue that this may be one of the factors for the higher prevalence of gestational diabetes observed in recent studies.²⁴ Another recent study in Demark contended that the WHO 2013 criteria

might not be suitable for their population because they inappropriately label a large number of women with low or no risk as gestational diabetes.²⁵

The prevalence of type 2 diabetes is increasing rapidly in the world and affecting the young, particularly in transitioning populations.²⁶ With a rise in obesity and glucose intolerance among women of reproductive ages, a parallel rise in the prevalence of gestational diabetes is anticipated. Currently, the global prevalence of gestational diabetes stands at ~16 per cent, which corresponds to the global rates of glucose intolerance in non-pregnant women of reproductive age.²⁷ These figures appear even more dramatic in transitioning populations such as India. In the 1980s-1990s, the rates of gestational diabetes were low (one to five per cent) while recent reports have quoted figures up to 20 per cent. While it is conceivable that there is a real rise in the incidence, differences in oral glucose tolerance test criteria complicate interpretation. The highest rates were observed using the International Association of Diabetes and Pregnancy Study Group's criteria. The Diabetes in Pregnancy Study Group in India's estimates is ~25 per cent lower compared to the International Association of Diabetes and Pregnancy Study Group's criteria.²⁸ Despite these difficulties in interpretation, some facts are consistent: higher maternal age, urban residence and overweight are associated with higher prevalence. In the Pune Maternal Nutrition Study, data is available in mother-daughter pairs over 20 years and shows a many-fold increase in the incidence of pregnancy hyperglycaemia in the daughter. Importantly, pregnancy glycemia was significantly associated with childhood and adolescent glycemia, suggesting that the so-called gestational diabetes women have metabolic abnormalities from early childhood. Given the importance of pre and periconceptional maternal nutritional in 'fetal programming' of diabetes and other non-communicable diseases, diagnosing and

Gynecology and Obstetrics, 131(Supplement 3):173-211. [[https://doi.org/10.1016/S0020-7292\(15\)30033-3](https://doi.org/10.1016/S0020-7292(15)30033-3)].

22 Seshiah, V., Das, A.K., Balaji, V., Joshi, S.R., Parikh, M.N. & Gupta, S. & Diabetes in Pregnancy Study Group. 2006. Gestational diabetes mellitus-guidelines. *The Journal of the Association of Physicians of India*, 54:622-628. [<https://www.ncbi.nlm.nih.gov/pubmed/16941793>].

23 Li, K.T., Naik, S., Alexander, M. & Mathad, J.S. 2018. Screening and diagnosis of gestational diabetes in India: a systematic review and meta-analysis. *Acta Diabetologica*, 55(6):613-625. [<https://doi.org/10.1007/s00592-018-1131-1>].

24 Cundy, T. 2012. Proposed new diagnostic criteria for gestational diabetes--a pause for thought? *Diabetic Medicine*, 29(2):176-180. [<https://doi.org/10.1111/j.1464-5491.2011.03407.x>]; Vinter, C.A., Tanvig, M.H., Christensen, M.H., Ovesen, P.G.,

Jørgensen, J.S., Andersen, M.S., McIntyre, H.D. & Jensen, D.M. 2018. Lifestyle intervention in Danish obese pregnant women with early gestational diabetes mellitus according to WHO 2013 criteria does not change pregnancy outcomes: Results from the LiP (Lifestyle in Pregnancy) Study. *Diabetes Care*, 41(10):2079-2085. [<https://doi.org/10.2337/dc18-0808>].

25 Vinter et al., 2018.

26 International Diabetes Federation (IDF). 2015. *IDF Diabetes Atlas 7th Edition* (2015). [<https://bit.ly/38wj43I>].

27 International Diabetes Federation (IDF). 2011. *Diabetes in Pregnancy: Protecting Maternal Health*. Policy Briefing. [<https://bit.ly/35lgVWP>].

28 Tripathi, R., Verma, D., Gupta, V. K., Tyagi, S., Kalaivani, M., Ramji, S. & Mala Y.M. 2017. Evaluation of 75 g glucose load in non-fasting state [Diabetes in Pregnancy Study group of India (DIPSI) criteria] as a diagnostic test for gestational diabetes mellitus. *Indian Journal of Medical Research*, 145(2):209-214. [https://doi.org/10.4103/ijmr.IJMR_1716_15].

treating gestational diabetes in late pregnancy may be like closing the door after the horse has bolted.

It will be crucial to document effects of glycemia and other metabolites ('fuels') on short- and long-term outcomes both in the mother and the child in the developing countries where malnutrition is still common to understand the significance of diagnosis and treatment of gestational diabetes.

Implications of gestational diabetes for the mother

Gestational hyperglycaemia is associated with several maternal morbidities. These include increased vulnerability to infections, preterm and caesarean deliveries with their associated risks to the mother, and trauma associated with fetal macrosomia and shoulder dystocia.²⁹ Women with gestational diabetes are also more likely to have preeclampsia. Many of these morbidities may have a common risk factor, i.e. obesity.

Type 2 diabetes is one of the most commonly observed long-term outcomes among gestational diabetes women. A recent review showed that 2.6 to 70 per cent of women with gestational diabetes had diabetes when examined six weeks to 28 years postpartum, respectively.³⁰ Though few, Indian studies have noted a high prevalence of diabetes in postnatal follow up of gestational diabetes women. Using data from a diabetic clinic, Kale and colleagues (Yajnik, Kulkarni, Meenakumari, Joglekar, Khorsand, Ladkat, Ramdas and Lubree, 2004) showed that more than 50 per cent of the gestational diabetes women had diabetes when followed 4.5 (\pm two) years after delivery.³¹ In a hospital-based cohort study in Mysore, the prevalence of diabetes was 37 per cent in the gestational diabetes women as opposed to two per cent among the women without gestational diabetes five years after delivery.³²

29 Kjos, S.L. & Buchanan, T.A. 1999. Gestational Diabetes Mellitus. *The New England Journal of Medicine*, 341(23):1749-1756. [https://doi.org/10.1056/NEJM199912023412307].

30 Kim, C., Newton, K.M. & Knopp, R.H. 2002. Gestational Diabetes and the Incidence of Type 2 Diabetes A systematic review. *Diabetes Care*, 25(10):1862-1868. [https://doi.org/10.2337/diacare.25.10.1862].

31 Kale, S., Yajnik, C., Kulkarni, S., Meenakumari, K., Joglekar, A., Khorsand, N., Ladkat, R.S., Ramdas, L.V. & Lubree, H.G. 2004. High risk of diabetes and metabolic syndrome in Indian women with gestational diabetes mellitus. *Diabetics Medicine*, 21(11):1257-1258. [https://doi.org/10.1111/j.1464-5491.2004.01337.x].

32 Krishnaveni, G., Hill, J., Veena, S., Geetha, S., Jayakumar, M., Karat, C. & Fall, C.H.D. 2007. Gestational diabetes and the incidence of diabetes in the 5 years following the index pregnancy in South Indian women. *Diabetes Research and Clinical Practice*, 78(3):398-404. [https://doi.org/10.1016%2Fj.diabres.2007.06.002].

Nearly 60 per cent of the gestational diabetes women also had features of metabolic syndrome (versus 26 per cent in women without gestational diabetes), suggesting an increased cardiovascular risk. In a recent study conducted in two obstetric units in New Delhi and Hyderabad, 72 per cent of the women with gestational diabetes were found to have dysglycaemia within five years of delivery including 32 per cent with type 2 diabetes.³³ In the *Women in India with GDM Strategy (WINGS)* study, jointly undertaken by the International Diabetes Federation and the Madras Diabetes Research Foundation, 15 per cent of the women, were found to have dysglycaemia within 12 weeks of delivery.³⁴ Age and body mass index status are the key predictors. It may indicate that 12 weeks may be too early to capture abnormalities.

The tracking of glucose from early childhood through pregnancy suggests that the so-called gestational diabetes and post-delivery diabetes are part of a life-course evolution of the metabolic abnormality and suggests against gestational diabetes and the subsequent diabetes being *de novo* conditions. Notwithstanding these issues, it is imperative to follow up gestational diabetes women for glucose and cardiovascular risk and advise appropriate preventive measures and treatment.

Implications of gestational diabetes for the offspring

Maternal hyperglycaemia increases the risk of adverse fetal outcomes. Severe diabetes in the mother during pregnancy is known to increase the risk of early fetal loss, congenital anomalies and neonatal mortality.³⁵ Less-severe hyperglycaemia is associated with fetal macrosomia and adiposity.³⁶ Macrosomia may hinder

33 Gupta, Y., Kapoor, D., Desai, A., Praveen, D., Joshi, R., Rozati, R., Bhatla, N., Prabhakaran, D., Reddy, P., Patel, A. & Tandon, N. 2017. Conversion of gestational diabetes mellitus to future type 2 diabetes mellitus and the predictive value of HBA1C in an Indian cohort. *Diabetic Medicine*, 34(1):37-43. [https://doi.org/10.1111/dme.13102].

34 Bhavadharini, B., Anjana, R., Mahalakshmi, M., Maheswari, K., Kayal, A., Unnikrishnan, R. Ranjani, H., Ninov, L., Pastakia, S.D., Usha, S., Malanda, B., Belton, A., Uma, R. & Mohan, V. 2016. Glucose tolerance status of Asian Indian women with gestational diabetes at 6 weeks to 1 year postpartum (WINGS-7). *Diabetes Research and Clinical Practice*, 117:22-27. [https://doi.org/10.1016/j.diabres.2016.04.050].

35 Balsells, M., García-Patterson, A., Gich, I. & Corcoy, R. 2012. Major congenital malformations in women with gestational diabetes mellitus: a systematic review and meta-analysis. *Diabetes/Metabolism Research and Reviews*, 28(3):252-257. [https://doi.org/10.1002/dmrr.1304]; Schaefer, U., Songster, G., Xiang, A., Berkowitz, K., Buchanan, T. & Kjos, S. 1997. Congenital malformations in offspring of women with hyperglycaemia first detected during pregnancy. *American Journal of Obstetrics and Gynecology*, 177(5):1165-1171. [https://doi.org/10.1016/s0002-9378(97)70035-8].

36 Plows, J., Stanley, J., Baker, P., Reynolds, C. & Vickers, M. 2018. The Pathophysiology

vaginal delivery, exposing both the mother and the fetus to operative risks; a serious example is shoulder dystocia. Other neonatal complications include neonatal hypoglycaemia, polycythaemia, hyperbilirubinemia, hypocalcaemia and respiratory distress syndrome.³⁷

However, it is the long-term implications of gestational diabetes in the offspring, which is the current global focus. It has been long observed that exposure to maternal diabetes in utero predisposes an individual to subsequent obesity and diabetes. Studies in Pima Indians of Arizona, America showed a substantial contribution of maternal diabetes to higher rates of early obesity and diabetes in the offspring.³⁸ These studies highlighted that offspring associations were mainly due to the intra-uterine hyperglycaemia rather than genes or shared post-natal environment by showing that risks were considerably higher in offspring of diabetic mothers than offspring of diabetic fathers or pre-diabetic mothers (mothers who developed diabetes after delivery and thus were genetically predisposed).³⁹ Subsequently, several other studies have confirmed that the Pima Indian findings apply to other populations.⁴⁰

of Gestational Diabetes Mellitus. *International Journal of Molecular Sciences*, 19(11):3342. [https://doi.org/10.3390%2Fijms19113342].

37 Kjos & Buchanan, 1999.

38 Dabelea, D. & Pettitt, D.J. 2001. Intrauterine diabetic environment confers risks for type 2 diabetes mellitus and obesity in the offspring, In addition to genetic susceptibility. *Journal of Pediatric Endocrinology and Metabolism*, 14(8):1085-1091. [https://doi.org/10.1515/jpem-2001-0803].

39 Dabelea & Pettitt, 2001; Pettitt, D.J., Bennett, P.H., Knowler, W.C., Baird, H.R. & Aleck, K.A. 1985. Gestational Diabetes Mellitus and impaired glucose tolerance during pregnancy: long-term effects on obesity and glucose tolerance in the offspring. *Diabetes*, 34(Supplement 2):119-122. [https://doi.org/10.2337/diab.34.2.s119].

40 Silverman, B.L., Metzger, B.E., Cho, N.H. & Loeb, C.A. 1995. Impaired Glucose Tolerance in Adolescent Offspring of Diabetic Mothers: Relationships to foetal Hyperinsulinism. *Diabetes Care*, 18(5):611-617. [https://doi.org/10.2337/diacare.18.5.611]; Vohr, B.R., McGarvey, S.T., Tucker, R. 1999. Effects of maternal gestational diabetes on offspring adiposity at 4-7 years of age. *Diabetes Care*, 22(8):1284-1291. [https://doi.org/10.2337/diacare.22.8.1284]; Clausen, T.D., Mathiesen, E.R., Hansen, T., Pedersen, O., Jensen, D.M., Lauenborg, J. & Damm, P. 2008. High prevalence of type 2 diabetes and pre-diabetes in adult offspring of women with gestational diabetes mellitus or type 1 diabetes: the role of intrauterine hyperglycaemia. *Diabetes Care*, 31(2):340-346. [https://doi.org/10.2337/dc07-1596]; Philipps, L.H., Santhakumaran, S., Gale, C., Prior, E., Logan, K.M., Hyde, M.J. & Modi N. 2011. The diabetic pregnancy and offspring BMI in childhood: a systematic review and meta-analysis. *Diabetologia*, 54(8):1957-1966. [https://doi.org/10.1007/s00125-011-2180-y]; Aceti, A., Santhakumaran, S., Logan, K.M., Philipps, L.H., Prior, E., Gale, C., Hyde, M.J. & Modi, N. 2012. The diabetic pregnancy and offspring

The developmental origins of health and disease (DOHaD) hypothesis proposes that impaired nutrition during fetal development increases an individual's susceptibility to non-communicable disease in later life.⁴¹ This phenomenon is thought to reflect the permanent effects of disturbed fetal nutrition on structural and physiological systems ('programming'). It was initially described by David Barker and colleagues (Hales, Fall, Osmond, Phipps and Clark, 1998) in a retrospective cohort of people born in Hertfordshire where they demonstrated that lower birth weight predisposed to a higher risk of diabetes and related conditions.⁴²

Implications of maternal nutrition and metabolism for the baby: Indian evidence

Research in India suggests that programming by maternal nutritional and metabolic imbalances may be an important factor driving the non-communicable disease epidemic. Specifically, cohort studies in Pune and Mysore have shown that micronutrient imbalances are common among pregnant Indian women (related to among other iron, vitamin B12, folate, vitamin D), and have proposed that intrauterine nutrient deficiencies could alter structural and functional characteristics of the offspring (nutrient mediated teratogenesis).⁴³ On the other

blood pressure in childhood: a systematic review and meta-analysis. *Diabetologia*, 55(11):3114-3127. [https://doi.org/10.1007/s00125-012-2689-8].

41 Barker, D.J., Gluckman, P.D., Godfrey, K.M., Harding, J.E., Owens, J.A. & Robinson, J.S. 1993. Fetal nutrition and cardiovascular disease in adult life. *The Lancet*, 341(8850):938-941. [https://doi.org/10.1016/0140-6736(93)91224-a].

42 Barker, D.J.P. 1998. Mothers, babies and health in later life. 2nd Edition. London: Churchill Livingstone; Barker, D.J.P., Hales, C.N., Fall, C.H.D., Osmond, C., Phipps, K. & Clark, P.M.S. 1993. Type 2 (non-insulin-dependent) diabetes mellitus, hypertension and hyperlipidaemia (syndrome X): relation to reduced foetal growth. *Diabetologia*, 36(1):62-67. [https://doi.org/10.1007/bf00399095].

43 Yajnik, C.S., Deshpande, S.S., Jackson, A.A., Refsum, H., Rao, S., Fisher, D.J., Bhat, D.S., Naik, S.S., Coyaji, K.J., Joglekar, C.V., Joshi, N., Lubree, H.G., Deshpande, V.U., Rege, S.S., & Fall, C.H.D. 2008. Vitamin B12 and folate concentrations during pregnancy and insulin resistance in the offspring: the Pune Maternal Nutrition Study. *Diabetologia*, 51:29-38. [https://doi.org/10.1007%2Fs00125-007-0793-y]; Krishnaveni, G.V., Veena, S.R., Winder, N.R., Hill, J.C., Noonan, K., Boucher, B.J., Karat, S.C. & Fall, C.H.D. 2011. Maternal vitamin D status during pregnancy and body composition and cardiovascular risk markers in Indian children: the Mysore Parthenon study. *The American Journal of Clinical Nutrition*, 93(3):628-635. [https://doi.org/10.3945/ajcn.110.003921]; Yajnik, C.S. 2009. Nutrient-mediated teratogenesis and fuel-mediated teratogenesis: two pathways of intrauterine programming of diabetes. *International Journal of Gynecology & Obstetrics*, 104(Supplement 1):27-31. [https://doi.org/10.1016/j.ijgo.2008.11.034].

hand, owing to rapid socio-economic development (urbanisation) young women are becoming increasingly adipose, insulin resistant and glucose-intolerant during pregnancy, contributing to a rapidly rising incidence of gestational diabetes among both rural and urban women. Micronutrient deficiencies and gestational diabetes may co-exist in the same women, thereby exposing the growing fetus to multiple programming pathways (Dual Teratogenesis) (Figure 10.2 and 10.3).⁴⁴

The initial evidence for possible programming effect of maternal hyperglycaemia in India came from a birth cohort study at the Holdsworth Memorial Hospital in Mysore.⁴⁵ This study showed that adult men and women with type 2 diabetes were more likely to be shorter and fatter at birth (higher ponderal index) and were born to women with higher weight and larger pelvic diameters. There were no glucose measurements, but it was postulated that these mothers might have been glucose intolerant.⁴⁶ It was hypothesised that widespread fetal growth retardation in India predisposes individuals to insulin resistance, and leads to glucose intolerance in pregnant women if exposed to obesogenic environments that accompany urbanisation. Thus, maternal under-nutrition results in diabetes in the next generation, which in the case of female offspring manifests as gestational diabetes, thus perpetuating the risk cycle.

The Mysore Parthenon Study is a purpose-designed hospital-based prospective birth cohort established to examine the life-course predictors of non-communicable diseases in hyperglycaemic pregnancies. As expected, neonates of gestational diabetes mothers were heavier, longer and more adipose than control babies (offspring of a non-gestational diabetes mother and non-diabetic father).⁴⁷ There was a clustering of cardiovascular risk markers, including adiposity, higher glucose, insulin resistance (based on homeostasis model assessment: HOMA-IR) and blood pressure in offspring of diabetic mothers during childhood and

adolescence.⁴⁸ The difference in subcutaneous adiposity between offspring of diabetic mothers and offspring of non-diabetic mothers continued to increase across childhood (Figure 10.1). The Parthenon study showed for the first time that maternal diabetes programmes neuroendocrine stress responses in the offspring, suggesting that this may be one of the pathways for their greater cardiovascular risk.⁴⁹ Adolescent offspring of diabetic mothers exhibited greater systolic blood pressure, cardiac output, and stroke volume responses than control offspring to a standardised psychosocial stressor that involved performing public speaking and mental arithmetic tasks in front of a panel of two adult 'judges' (Trier Social Stress Test).⁵⁰ In all these associations, effects were stronger for several risk outcomes among offspring of diabetic mothers than in the offspring of diabetic fathers suggesting an independent role of intrauterine hyperglycaemia in addition to genetic influences.

The Pune Maternal Nutrition Study described the influence of maternal size, physical nutrition activity on fetal growth and future risk of diabetes. The study started 25 years ago when undernutrition was the major theme in rural India. The average mother in the Pune Maternal Nutrition Study had a body mass index of 18.1kg/m², and only an occasional mother had gestational diabetes. In these thin and normoglycemic pregnancies, maternal circulating glucose, cholesterol, high-density lipoprotein cholesterol and triglyceride concentrations were significant predictors of neonatal size and body composition.⁵¹ The babies weighed an average 2.7kg but had higher adiposity (subscapular skinfold, and abdominal fat) compared to an English baby weighing 3.5kg.⁵² This 'thin-fat' Indian baby also had

44 Yajnik et al., 2009; Krishnaveni, G.V., Hill, J.C., Veena, S.R., Bhat, D.S., Wills, A.K., Karat, C.L.S., Yajnik, C.S. & Fall, C.H.D. 2009. Low plasma vitamin b12 in pregnancy is associated with gestational 'diabesity' and later diabetes. *Diabetologia*, 52(11):2350-2358. [https://doi.org/10.1007/s00125-009-1499-0].

45 Fall, C.H.D., Stein, C.E., Kumaran, K., Cox, V., Osmond, C., Barker, D.J. & Hales, C.N. 1998. Size at birth, maternal weight, and non-insulin-dependent diabetes (NIDDM) in South Indian adults. *Diabetic Medicine*, 15(3):220-227. [https://doi.org/10.1002/(SICI)1096-9136(199803)15:3<220::AID-DIA544%3E3.0.CO;2-O].

46 Fall et al., 1998.

47 Hill, J.C., Krishnaveni, G.V., Annamma, I., Leary, S.D. & Fall, C.H.D. 2005. Glucose tolerance in pregnancy in South India: Relationships to neonatal anthropometry. *Acta Obstetrica et Gynecologica Scandinavica*, 84(2):159-165. [https://doi.org/10.1111/j.0001-6349.2005.00670.x].

48 Krishnaveni, G.V., Hill, J.C., Leary, S.D., Veena, S.R., Saperia, J., Saroja, A., Karat, S.C. & Fall, C.H. 2005. Anthropometry, glucose tolerance, and insulin concentrations in Indian children: relationships to maternal glucose and insulin concentrations during pregnancy. *Diabetes Care*, 28(12):2919-2925. [https://doi.org/10.2337/diacare.28.12.2919]; Krishnaveni, G.V., Veena, S.R., Hill, J.C., Kehoe, S., Karat, S.C. & Fall, C.H. 2010. Intra-uterine exposure to maternal diabetes is associated with higher adiposity and insulin resistance and clustering of cardiovascular risk markers in Indian children. *Diabetes Care*, 33(2):402-404. [https://doi.org/10.2337/dc09-1393]; Krishnaveni, G.V., Veena, S.R., Jones, A., Srinivasan, K., Osmond, C., Karat, S.C., Kurpad, A.V. & Fall, C.H. 2015. Exposure to maternal gestational diabetes is associated with higher cardiovascular responses to stress in adolescent Indians. *The Journal of Clinical Endocrinology and Metabolism*, 100(3):986-993. [https://doi.org/10.1210/jc.2014-3239].

49 Krishnaveni et al., 2015.

50 Krishnaveni et al., 2015.

51 Kulkarni, S., Kumaran, K., Rao, S., Chougule, S., Deokar, T., Bhalerao, A., Solat, V.A., Bhat, D.S., Fall, C.H. & Yajnik, C.S. 2013. Maternal Lipids Are as Important as Glucose for Fetal Growth. *Diabetes Care*, 36(9):2706-2713. [https://doi.org/10.2337/dc12-2445].

52 Yajnik, C.S., Fall, C.H., Coyaji, K.J., Hirve, S.S., Rao, S., Barker, D.J., Joglekar, C.

elevated cord blood concentrations of leptin and insulin but lower adiponectin, suggesting intrauterine programming of fetal body composition and endocrine axes by small maternal size and undernutrition. The Mysore study and studies in migrant Indians in the UK and Canada showed that the thin-fat phenotype is exaggerated by maternal hyperglycaemia.⁵³ The follow-up studies in Pune showed that the cardio-metabolic risk factors are highest in children who were born 'light' but grew 'heavy' during childhood and adolescence, even though not obese by international standards.⁵⁴ Such a 'mismatch' pattern of growth represents the double burden of malnutrition within a lifetime with serious consequences for the risk of non-communicable diseases. One of the maternal nutritional imbalances, which influenced fetal growth, body composition and diabetes risk was a coexistence of the low vitamin B12 and high folate status.⁵⁵ This low status may be ascribed to a vegetarian diet (deficient for vitamin B12 but rich for folates) and the iatrogenic use of high dose folic acid to prevent anaemia and neural tube defects, a practice based on folic acid trials in B12 adequate western populations. This policy ignored that vitamin B12 deficiency may have a major role in aetiology of neural tube defects in Indians. In the Mysore study, maternal body mass index and glycemia were inversely related to plasma vitamin B12 concentrations, suggesting a double burden of malnutrition (micronutrient deficiency, macronutrient excess).⁵⁶ We proposed that such a combination of risk factors promotes a 'dual teratogenesis' (Figure 10.2 and 10.3) which will exaggerate fetal programming of non-communicable diseases

and that such a situation may be common in many countries in Africa, increasing the burden of obesity and diabetes at a young age.⁵⁷

The India GDM study at the Diabetes Unit, KEM Hospital, Pune followed up children born to diabetic and non-diabetic mothers two to 26 years after delivery.⁵⁸ We confirmed the elevated risk of obesity, adiposity, diabetes and other cardio-metabolic risk factors in the young children of diabetic compared to non-diabetic pregnancies. Interestingly, parental (both maternal and paternal) size and glucose intolerance had a mirror image effect on obesity-adiposity and glucose intolerance in the child, maternal glucose had an additional effect on obesity-adiposity of the child.⁵⁹

Does maternal hyperglycaemia have any beneficial effect on the fetus? Brain preservation is a fundamental driver of fetal growth and has a priority over other structures in adverse conditions.⁶⁰ Previous studies (mostly in pre-gestational uncontrolled diabetic pregnancies) reported compromised cognitive abilities in offspring of diabetic mothers compared to control offspring.⁶¹ Interestingly, in the Parthenon study, maternal hyperglycaemia was associated with better cognitive function in offspring of diabetic mothers, which persisted after controlling for confounding factors like parental education and socio-economic status.⁶² Notwithstanding residual confounding, an interesting possibility is that extra fuel supply to the developing fetus may enhance brain development in an otherwise undernourished pregnancy. In such situations, gestational diabetes may have evolutionary benefits for fetal survival. There is a need for expanding

& Kellingray, S. 2003. Neonatal anthropometry: the thin-fat Indian baby. The Pune Maternal Nutrition Study. *International Journal of Obesity and Related Metabolic Disorders*, 27(2):173-180. [https://doi.org/10.1038/sj.ijo.802219].

- 53 Krishnaveni et al., 2010; Anand, S., Gupta, M., Schulze, K., Desai, D., Abdalla, N., Wahi, G., Wade, C., Scheufler, P., McDonald, S.D., Morrison, K.M., Vasudevan, A., Dwarakanath, P., Srinivasan, K., Kurpad, A., Gerstein, H.C. & Teo, K.K. 2015. What accounts for ethnic differences in newborn skinfold thickness comparing South Asians and White Caucasians? Findings from the START and FAMILY Birth Cohorts. *International Journal of Obesity*, 40(2):239-244. [https://doi.org/10.1038/ijo.2015.171]; Lawlor, D., West, J., Fairley, L., Nelson, S., Bhopal, R., Tuffnell, D., Freeman, D.J., Wright, J., Whitelaw, D.C. & Sattar, N. 2014. Pregnancy glycaemia and cord-blood levels of insulin and leptin in Pakistani and white British mother-offspring pairs: findings from a prospective pregnancy cohort. *Diabetologia*, 57(12):2492-2500. [https://doi.org/10.1007/s00125-014-3386-6].
- 54 Yajnik, C.S., Joglekar, C.V., Pandit, A.N., Bavdekar, A.R., Bapat, S.A., Bhave, S.A., Leary, S.D. & Fall, C.D. 2003. Higher Offspring Birth Weight Predicts the Metabolic Syndrome in Mothers but Not Fathers 8 Years after Delivery: The Pune Children's Study. *Diabetes*, 52(8):2090-2096. [https://doi.org/10.2337/diabetes.52.8.2090].
- 55 Yanik et al., 2008.
- 56 Krishnaveni et al., 2009.

57 Yajnik, 2009.

- 58 Wagle, S., Kumaran, K., Ladkat, R., Bhat, D., Yajnik, P. & Yajnik, C. 2018. Comparison of Cardio-metabolic Risk Factors in Offspring Of Diabetic Mothers (ODM) And Nondiabetic Mothers (ONDM) In India. *Diabetes*, 67(Supplement 1). [https://doi.org/10.2337/db18-1418-P].
- 59 Wagle et al., 2018.
- 60 Yajnik, C.S. 2004. Obesity epidemic in India: intrauterine origins? *Proceedings of the Nutrition Society*, 63(3):387-396. [https://doi.org/10.1079/pns2004365].
- 61 Dionne, G., Boivin, M., Séguin, J.R., Pérusse, D. & Tremblay, R.E. 2008. Gestational diabetes hinders language development in offspring. *Pediatrics*, 122(5):e1073-9. [https://doi.org/10.1542/peds.2007-3028]; Ornoy, A. 2005. Growth and neurodevelopmental outcome of children born to mothers with pregestational and gestational diabetes. *Pediatric Endocrinology Reviews*, 3(2):104-113. [https://bit.ly/38uvlpz].
- 62 Veena, S.R., Krishnaveni, G.V., Srinivasan, K., Kurpad, A.V., Muthayya, S., Hill, J.C., Kiran, K.N. & Fall, C.H.D. 2010. Childhood cognitive ability: relationship to gestational diabetes mellitus in India. *Diabetologia*, 53(10):2134-2138. [https://doi.org/10.1007/s00125-010-1847-0].

these investigations in the developing countries, and also to study 'cost-benefit' of maternal gestational diabetes to put a proper perspective on this condition which is rapidly escalating.

Gestational diabetes management and effects on offspring risk

The majority of evidence linking maternal diabetes with offspring adiposity and glucose intolerance is observational. There is a potential for confounding by many factors. Two randomised clinical trials of glycaemic control in gestational diabetes women: the Australian Carbohydrate Intolerance Study in Pregnant Women and the National Institutes of Health trials in late pregnancy demonstrated a reduction in fetal macrosomia and associated perinatal morbidity (shoulder dystocia, neonatal hypoglycaemia).⁶³ Despite this, there is little evidence for the reduction of childhood obesity in both the trials. Interestingly, there was a reduction of fasting glycemia and insulin resistance in girls in the National Institutes of Health trial but not in the boys (post hoc analysis). There is an urgent need for the follow up of children born in various pregnancy trials to establish the long-term benefits of treating mild gestational diabetes. It is also imperative to confirm the findings in relatively undernourished populations, and fetuses are growth restricted (small-for-gestational-age) because the treatment of gestational diabetes is invariably associated with a reduction in the baby's size.

Are we missing the window?

Preconceptual and early pregnancy periods are crucial for ovum growth and development, ovulation, fertilisation, implantation, placentation and organogenesis. Even a small alteration in the intrauterine 'milieu' during this period could have substantial effects on these processes and phenotype of the fetus.⁶⁴ There is now a growing understanding on the role of maternal nutrition and

metabolism in the preconceptional period on the maturation of oocytes, optimising gamete function and thus embryo potential with consequences for the long-term health of the offspring.⁶⁵ The epigenetic 'reprogramming', happening soon after fertilisation, may also be influenced by any pre-existing maternal conditions. Thus, pre-gestational nutrition and metabolism could have a major programming effect on the embryo even before gestational diabetes has been recognised.

The current practice of screening for gestational diabetes in the third trimester of pregnancy is based on experience in low prevalence western populations many decades ago. The 'yield' was supposed to be highest at this time point in pregnancy, for which metabolic-endocrine explanations were suggested.⁶⁶ However, the majority of women diagnosed with gestational diabetes had elevated glucose in early pregnancy even in an American clinic, suggesting a substantial contribution of pregestational glucose intolerance.⁶⁷ It is noteworthy that a comparable prevalence of glucose intolerance in young non-pregnant American women to that in pregnant women led to a suggestion in 1988 that gestational diabetes could represent undiagnosed pre-gestational hyperglycaemia.⁶⁸ Interestingly, John Jarrett asserted that gestational diabetes is 'an incidental pregnancy in a woman with glucose intolerance'.⁶⁹

Poston, L., Barrett, G., Crozier, S.R., Barker, M., Kumaran, K., Yajnik, C.S., Baird, J. & Mishra, G.D. 2018. Before the beginning: nutrition and lifestyle in the preconception period and its importance for future health. *The Lancet*, 391(10132):1830-1841. [https://doi.org/10.1016/S0140-6736(18)30311-8].

- 65 Fleming, T.P., Watkins, A.J., Velazquez, M.A., Mathers, J.C., Prentice, A.M., Stephenson, J., Barker, M., Saffery, R., Yajnik, C.S., Eckert, J.J., Hanson, M.A., Forrester, T., Gluckman, P.D. & Godfrey, K.M. Origins of lifetime health around the time of conception: causes and consequences. *The Lancet*, 391(10132):1842-1852. [https://doi.org/10.1016/S0140-6736(18)30312-X]; Metzger, B.E., Coustan, D.R. & Organizing Committee. 1980. Summary and Recommendations. *American Diabetes Association's First International Gestational Diabetes Workshop. Diabetes Care*, 3(3):499-501. [https://care.diabetesjournals.org/content/diacare/3/3/499.full.pdf].
- 66 Metzger, Coustan & Organizing Committee, 1980; Moyer, V. & U.S. Preventive Services Task Force. 2014. Screening for gestational diabetes mellitus: U.S. Preventive Services Task Force recommendation statement. *Annals of Internal Medicine*, 160(6):414-420. [https://doi.org/10.7326/M13-2905].
- 67 Super, D., Edelberg, S., Philipson, E., Hertz, R. & Kalhan, S. 1991. Diagnosis of gestational diabetes in early pregnancy. *Diabetes Care*, 14(4):288-294. [https://doi.org/10.2337/diacare.14.4.288].
- 68 Harris, M.I. 1988. Gestational diabetes may represent discovery of preexisting glucose intolerance. *Diabetes Care*, 11(5):402-411. [https://doi.org/10.2337/diacare.11.5.402].
- 69 Jarrett, R.J. 1993. Gestational diabetes: a non-entity? *BMJ*, 306(6869):37-38. [https://doi.org/10.1136%2Fbmj.306.6869.37].

63 Crowther, C., Hiller, J., Moss, J., McPhee, A., Jeffries, W., Robinson, J. & Australian Carbohydrate Intolerance Study in Pregnant Women Trial Group. 2005. Effect of Treatment of Gestational Diabetes Mellitus on Pregnancy Outcomes. *New England Journal of Medicine*, 352(24):2477-2486. [https://doi.org/10.1056/NEJMoa042973]; Landon, M., Spong, C., Thom, E., Carpenter, M., Ramin, S., Casey, B., Wapner, R.J., Varner, M.W., Rouse, D.J., Thorp, J.M. Jr., Sciscione, A., Catalano, P., Harper, M., Saade, G., Lain, K.Y., Sorokin, Y., Peaceman, A.M., Tolosa, J.E. & Anderson, G.B. & Eunice Kennedy Shriver National Institute of Child Health and Human Development Maternal-Fetal Medicine Units Network. 2009. A Multicenter, Randomized Trial of Treatment for Mild Gestational Diabetes. *New England Journal of Medicine*, 361(14):1339-1348. [https://doi.org/10.1056/NEJMoa0902430].

64 Stephenson, J., Heslehurst, N., Hall, J., Schoenaker, D.A.J.M., Hutchinson, J., Cade, J.E.,

A substantial range of risk factors for gestational diabetes (obesity, central obesity, dysglycaemia, dyslipidaemia, non-alcoholic fatty liver disease, chronic inflammation, polycystic ovarian syndrome and other endocrine disturbances) are present pre-gestationally and track from childhood into adult age.⁷⁰ Thus, most of the risk of gestational diabetes is already present before conception and exposes the fetus to adverse conditions in the peri-conceptual period. Presence of a large fetus, polyhydramnios and higher abdominal wall obesity in the fetus on ultrasound examination at the time of diagnosis of gestational diabetes suggests ongoing hyperglycaemia from early pregnancy.⁷¹ Reported higher prevalence of neural tube defects and other congenital anomalies in gestational diabetes pregnancies also suggests peri-conceptual metabolic disturbance.⁷² Studies observing pre-pregnancy factors such as weight gain up to pregnancy, lipoprotein abnormalities and mild dysglycemia in relation to the risk of GDM provide further support to a pre-existing susceptibility to glucose intolerance in these women.⁷³ We suggest that the so-called gestational diabetes in the high-risk developing populations of the world may represent undiagnosed pregestational diabetes in a substantial proportion of cases. This possibility needs to be tested in a wider population in different countries to revise the policy for the timing of screening for ‘pregnancy’

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- 70 Han, E., Krauss, R., Xu, F., Sridhar, S., Ferrara, A., Quesenberry, C. & Hedderson, M.M. 2016. Pre-pregnancy adverse lipid profile and subsequent risk of gestational diabetes. *The Journal of Clinical Endocrinology and Metabolism*, 101(7):2721-2727. [https://doi.org/10.1210/jc.2015-3904]; Solomon, C., Willett, W.C., Carey, V.J., Rich-Edwards, J., Hunter, D.J., Colditz, G.A., Stampfer, M.J., Speizer, F.E., Spiegelman, D. & Manson, J.E. 1997. A Prospective Study of Pre-gravid Determinants of Gestational Diabetes Mellitus. *Journal of the American Medical Association*, 278(13):1078-1083. [https://doi.org/10.1001/jama.1997.03550130052036]; McClain, M., Srinivasan, S., Chen, W., Steinmann, W. & Berenson, G. 2000. Risk of Type 2 Diabetes Mellitus in Young Adults from a Biracial Community: The Bogalusa Heart Study. *Preventive Medicine*, 31(1):1-7. [https://doi.org/10.1006/pmed.2000.0682].
- 71 Venkataraman, H., Ram, U., Craik, S., Arungunasekaran, A., Seshadri, S. & Saravanan, P. 2016. Increased fetal adiposity prior to diagnosis of gestational diabetes in South Asians: more evidence for the ‘thin-fat’ baby. *Diabetologia*, 60(3):399-405. [https://doi.org/10.1007/s00125-016-4166-2].
- 72 Balsells, M., García-Patterson, A., Gich, I. & Corcoy, R. 2012. Major congenital malformations in women with gestational diabetes mellitus: a systematic review and meta-analysis. *Diabetes/Metabolism Research and Reviews*, 28(3):252-257. [https://doi.org/10.1002/dmrr.1304]; Schaefer, U., Songster, G., Xiang, A., Berkowitz, K., Buchanan, T. & Kjos, S. 1997. Congenital malformations in offspring of women with hyperglycaemia first detected during pregnancy. *American Journal of Obstetrics and Gynecology*, 177(5):1165-1171. [https://doi.org/10.1016/s0002-9378(97)70035-8].
- 73 Han et al., 2016; Schaefer et al., 1997.

hyperglycaemia. Interestingly, a pre-conceptual supplement with micronutrient-rich snack reduced the incidence of gestational diabetes in the Mumbai slums.⁷⁴

Given that the majority of risk factors of gestational diabetes are initiated early in life, the prevention measures should start during adolescence to target lifestyle factors such as diet, physical activity and stress management. The rapidly increasing prevalence of obesity in the young is an obvious target for prevention, but the improvement of general and micronutrient nutrition in the undernourished is equally important. The measures to improve birth weight in malnourished populations should be carefully followed up as the effect of increased neonatal size on its body composition, and future risk of diabetes is not yet clear. We need to keep in mind the possibility that the measures to shift birth weight upward across the range may inadvertently increase adiposity in the absence of specific nutrient supply to the growing fetus.

Conclusion and research agenda

Even as the prevalence of gestational diabetes and its adverse consequences are on the rise in India and other developing countries, there is no clear direction for screening, diagnosis, management and long-term follow-up of mothers and their offspring. In particular, there is a need for investigation to see if international criteria are applicable for both the short-term and long-term outcomes in different populations, keeping an open mind on possible adverse effects of the treatment itself in certain situations. The current standards of management of gestational diabetes are challenging in resource-poor settings (rural India and in underprivileged urban pregnancies). The challenges are multiple and predominantly driven by limited awareness among patients and primary care physicians, poverty, the paucity of specialist clinicians, non-affordability and limited availability of medication and glucose monitoring facilities.

On this background, developing countries have a great opportunity to learn from history and contribute to a better understanding of fetal programming in a situation of rapidly evolving double burden of malnutrition, also guiding some of the ‘double duty’ actions to blunt the effect of rapid transition on the escalating epidemic of diabetes and other related non-communicable diseases.

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- 74 Sahariah, S., Potdar, R., Gandhi, M., Kehoe, S., Brown, N., Sane, H., Coakley, P.J., Marley-Zagar, E., Chopra, H., Shivshankaran, D., Cox, V.A., Jackson, A.A., Margetts, B.M., Fall, C.H. 2016. A daily snack containing leafy green Vegetables, fruit, and milk before and during pregnancy prevents gestational diabetes in a randomized, controlled trial in Mumbai, India. *Journal of Nutrition*, 146(7):1453S-1460S. [https://doi.org/10.3945/jn.115.223461].

One way to achieve these is to form a consortium of developing countries to improve pregnancy outcomes. The international DOHaD society may be able to coordinate such efforts. Some of the objectives could be to:

- Establish pre-conceptional birth cohorts to collect relevant information and create a biobank to study life-course evolution of health and disease, including research in clinics and community, with an eye on translation.
- Revisit the issues related to definition and diagnosis of gestational diabetes: glucose dose, timing, cut points, short- and long-term outcomes. The criteria need to be evidence-based, need-based and pragmatic given the continuous nature of associations and therefore, impossible to agree on an arbitrary threshold.
- Evolve strategies for the treatment of pregnancy diabetes in resource-poor settings, specific for the region, cultural-religious factors, socio-economic conditions and will broadly follow the aim of 'personalised' medicine. It will be crucial to remember the principle of 'do no harm' given the large burden of fetal undernutrition in diabetic pregnancies in the transition situations, introducing maternal food restrictions may do unexpected harm.

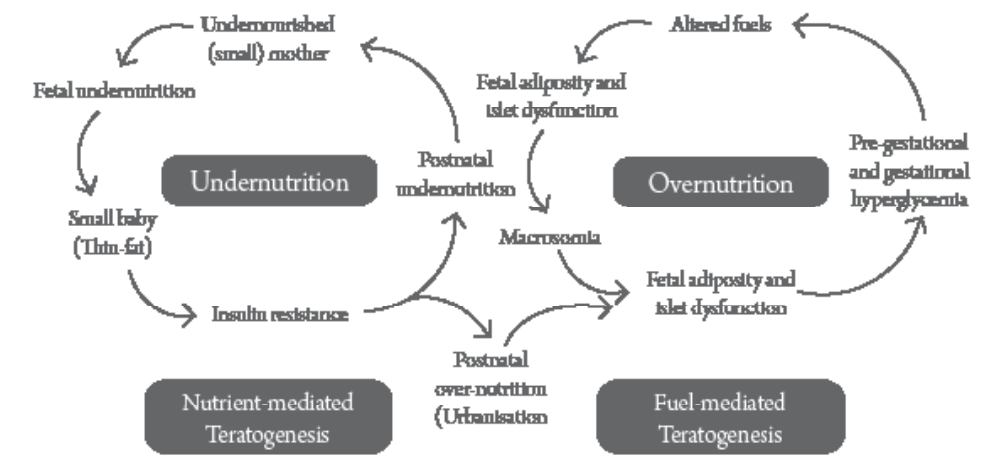


Figure 10.2 Dual Teratogenesis: fetal programming in rapid transition. Interrelationship of two major maternal factors (undernutrition and overnutrition) in fetal programming. An undernourished mother produces a small (thin-fat) insulin resistant baby. If this baby remains undernourished in postnatal life; the cycle is proliferated. If the thin-fat insulin resistant baby is over-nourished, it becomes obese and hyperglycemic. An obese and hyperglycemic mother produces a "macrosomic" baby at higher risk of obesity and hyperglycemia. Rapid transition shifts the balance from undernutrition to overnutrition and contributes to the escalation of the diabetes epidemic.

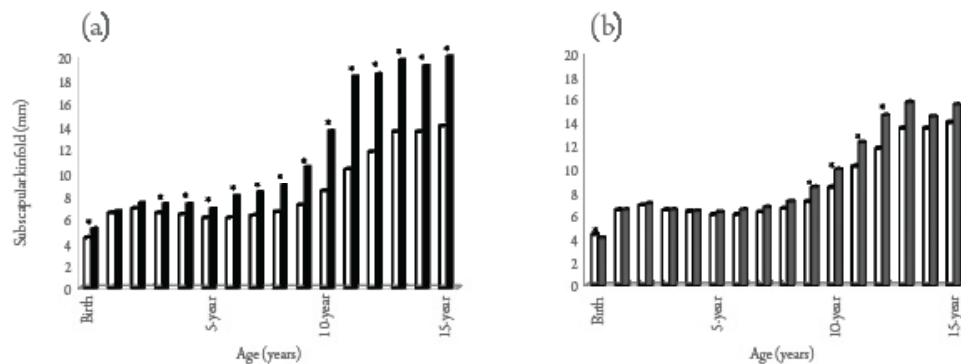


Figure 10.1 Subscapular skinfold thickness in (a) offspring of diabetic mothers (ODM) and (b) offspring of diabetic fathers (ODF) compared to control offspring. Bars represent subscapular thickness in the Parthenon cohort children at each year from birth to 15 years of age; ODM: black bars; Control Offspring: white bars; ODF: grey bars. *P less than 0.05 for comparison between ODM and Controls and ODF and controls. The difference in subscapular skinfold thickness between ODM and controls continued to increase as the children aged (a); a similar increase was not seen in ODF (b).

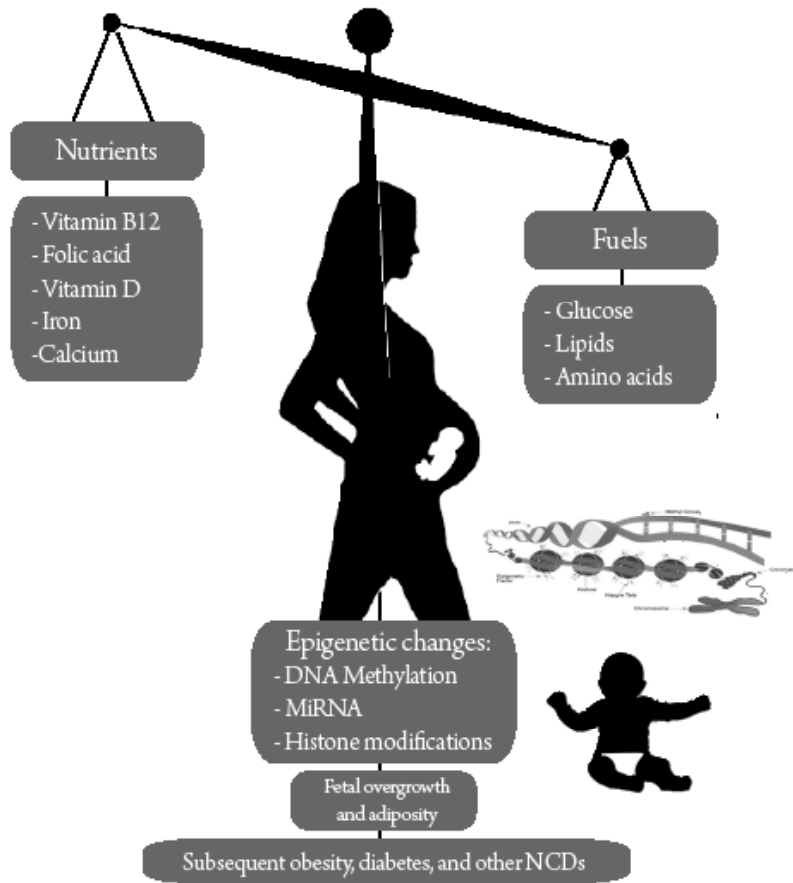
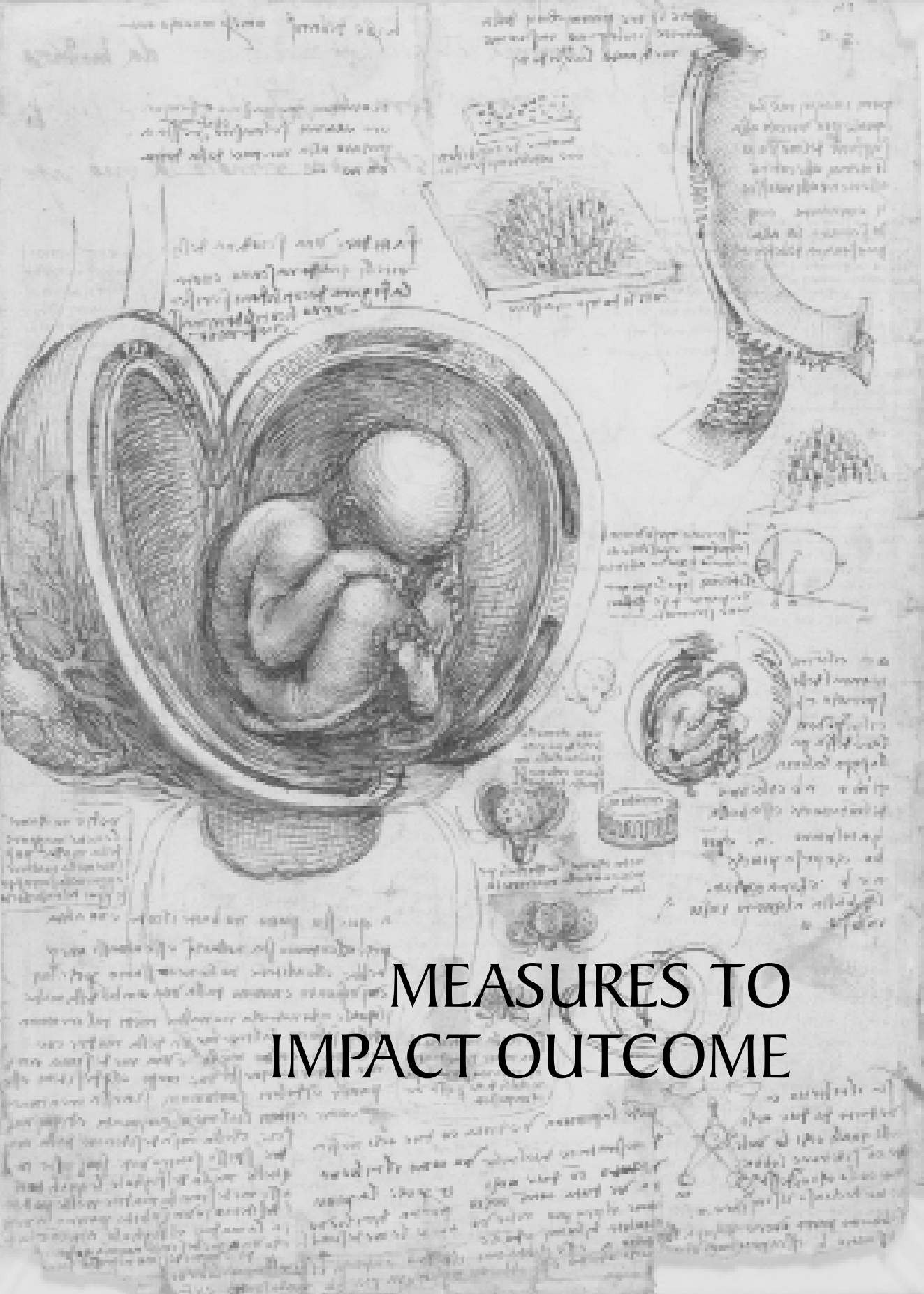


Figure 10.3 The proposed mechanisms in the ‘dual teratogenesis’ in a diabetic pregnancy in the developing countries, an example of dual burden of malnutrition. In developing countries, a rapid nutritional transition is creating unique situations in pregnancy. There is a coexistence of excess ‘fuels’ (high glucose, amino acids and lipids) along with deficiencies and imbalances of ‘micronutrients’ (vitamin B12, Folate, Iron, Calcium and vitamin D). This transition puts in motion a ‘dual teratogenesis’ in the developing fetus promoting growth disturbances, excess adiposity and other problems. In the long-term, these ‘programming’ influences promote the development of non-communicable diseases like diabetes and cardiovascular disease. These effects are mediated both by direct fuel transfer and accumulation and also by epigenetic mechanisms such as DNA methylation, histone modification and miRNAs. Pre-conception and pregnancy are the most prominent windows for such intergenerational influences.



MEASURES TO IMPACT OUTCOME



11

PHOTO-ESSAYS: A CREATIVE FORMAT FOR EFFECTIVE COMMUNICATION

Lynn Stothers,¹ Ronald Mukisa²
and Andrew J Macnab³

Scientists and educators regularly face the challenge of effectively, concisely and interestingly communicating their ideas and findings, and the need to engage readers unfamiliar with the concepts or issues they want to describe.

In the context of advancing the developmental origins of health and disease (DOHaD) agenda, effective communication is essential, particularly when aiming to engage government agencies, inform leaders in the health care professions, and motivate organisations able to drive change in the community. Hence, it is

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3 STIAS; Faculty of Medicine, Department of Paediatrics, University of British Columbia, Vancouver, Canada.

important to consider approaches that might make key DOHaD concepts and health promotion strategies more readily accessible to any target population.

In this chapter, we share our experience from a collaboration between the Peter Wall Institute for Advanced Studies (PWIAS) at the University of British Columbia, and STIAS at Stellenbosch University to explore ways to make research and global public health issues accessible and meaningful to a broad readership; we identified the genre of photo-essay as an established and valid format, and describe its origins and principles.

A photo-essay effectively presents a broad range of facts and data to varied audiences because the format principally relies on the impact visual images have. When well-chosen images are combined with appropriate captions and a concise explanatory text, the resulting composition can engage and inform a wide range of readers, and in a way likely to allow even those unfamiliar with the topic to rapidly gain an overall understanding of the information and recommendations presented.

Photographs are a powerful way to furnish evidence because they expand the scope of the information provided and uniquely engage individual readers. The reader cannot be made to look at the images in the presented order, nor can the time spent on each image be indicated. So, we suggest that a photo-essay offers a very individual, informative yet flexible format for sharing ‘what works and why’, and how, and under what circumstances it works in the context of DOHaD.

Introduction

Photo-essays borrow from the field of photojournalism and are now a publication option where a series of images is the principal means of telling the story – many such stories relating to health and wellbeing.

Creative licence is used to compile representative images into a sequence that conveys the background, method, results and outcome(s) of the project to be described. The images must be good photographs, selected on individual photographic merit, as well as for the specifics and relevance of what they contain. Selected images need to be of high resolution; edited optimally for light, colour and contrast; and cropped to increase their clarity and relevance. The ethics of photojournalism apply, hence inappropriate manipulation of images or including erroneous captions are unacceptable.

Photo-essays are a novel and informative way to report on applied health, social or scientific topics. The format is an excellent one to use for a research presentation for scientific meetings but is also well suited to prepare informative brief reports or executive summaries aimed at government agencies.

The concept of a photo-essay comes from the discipline of photojournalism, a particular form of journalism that uses images to tell a news story.⁴ The central premise is that a picture is ‘worth a thousand words.’ Hence, by combining an effective photo or a series of photos a story can be told with the minimum of written text as the scene is set by the images, and often the direct and key message of the story is presented through the image.⁵

While the term photo-essay is usually understood to refer only to a series of still images and accompanying text, there are various adaptations on this theme, for instance, the news stories used in broadcast journalism where video footage is accompanied by a reporter speaking on or off-camera.⁶

For applied science and health reports to use the medium of the photo-essay, a creative format is necessary that is not only informative but also interesting to follow and that quickly conveys the key elements of the story to the reader. A good model is the one used in journals like the *International Journal of Epidemiology*, calling for photo-essays to combine 10-15 images with 200-500 words of accompanying text on topics relating to health and wellbeing.⁷ Areas covered by published examples include global health care delivery concepts; roles of health care providers; epidemiology of illness or injury; intervention to address a specific infectious disease, and how the World Health Organization (WHO)’s ‘Health-Promoting Schools’ provide an environment that can help advance the United Nations’ ‘Sustainable Development Goals.’⁸

- 4 Caple, H. & Knox, J.S. 2012. Online news galleries, photojournalism and the photo essay. *Visual Communication*, 11(2):207-36. [<https://doi.org/10.1177%2F1470357211434032>]; Marn, R. & Roldn, J. 2012. Photo essays and photographs in visual arts-based educational research. *International Journal of Education through Art*, 6(1):7-23. [https://doi.org/10.1386/eta.6.1.7_1]; Kobre, K. 1980. *Photojournalism: The Professionals' Approach*. Somerville, MA: Curtin & London, Inc.
- 5 Knox, J.S. 2008. Reporting Bloodshed in Thai Newspapers: a comparative case study of English and Thai. In: Thomson, E.A. & White, P.R.R. (eds). *Communicating conflict: Multilingual case studies of the news media*. London: Continuum. 173-202.
- 6 Zelizer, B. 2005. Journalism through the Camera's Eye. In: Allan, S. (ed). *Journalism: Critical Issues*. Maidenhead: Open University Press; Layton, R. 2011. *Editing and News Design: How to Shape the News in Print and Online Journalism*. South Yarra: Palgrave Macmillan.
- 7 International Journal of Epidemiology. 2020. *Instructions to Authors*. [https://academic.oup.com/ije/pages/Instructions_To_Authors].
- 8 Stothers, L. & Macnab, A. 2017. Global implementation of advanced urological care: Policy implementation research. *Canadian Urological Association Journal*, 11(6):157-60. [<https://doi.org/10.5489%2Fcuaj.4117>]; Mukisa, R., Macnab, A.J. & Stothers, L. 2017. Health promotion in low- and middle-income countries: ‘Youth Champions’ as agents for

Another style just relies on the graphic content of the images chosen; here a larger number of photos are combined, there is no accompanying text or reference list, but again short captions are used to explain each image. An example of this style depicts the care provided for the wounded during the Iraq War.⁹ The stark reality of this style of essay is at one end of the spectrum, while at the other, a more artistic style can be used where the photos are accompanied by artistically rendered text captions, along the lines of those in photobooks made using Apple software, or on scenic postcards. One example of this genre is the report of a digital photographic experiment prepared by archaeologists, combining elements of archaeological ethnography with photography.¹⁰ Anthropology is also a discipline where photographs and photographic evidence are relied on heavily for both the successful conduct of projects and comprehensive reporting. One essay describes how photographic documentation aided research conducted by an international team in refugee camps in Afghanistan; members of the team who had to remain remote from the project site for security reasons used photos taken in the camps to understand important cultural elements relevant to the research. Being remote enabled them to contribute effectively to the delivery and evaluation of this project, which employed an innovative male-centred intervention to address a cultural issue relevant to improving mortality and morbidity among mothers and infants in this vulnerable population.¹¹

change. *Proceedings of the International Conference on Health and Disease*, 2:6-13. [<https://bit.ly/3lnDdwu>]; Stothers, L., Mutabazi, S., Mukisa, R. & Macnab, A.J. 2016. The burden of bladder outlet obstruction in men in rural Uganda. *International Journal of Epidemiology*, 45(6):1763-1766. [<https://doi.org/10.1093/ije/dyw285>]; Curry, T.J. & Strauss, R.H. 1994. A little pain never hurt anybody: A photo-essay on the normalization of sport injuries. *Sociology of Sport Journal*, 11(2):195-208. [<https://doi.org/10.1123/sj.11.2.195>]; Macnab, A.J., Mukisa, R., Mutabazi, S. & Steed, R. 2015. Malaria in Uganda: school-based rapid diagnostic testing and treatment. *International Journal of Epidemiology*, 45(6), December 1759-1762. [<https://doi.org/10.1093/ije/dyw262>]; Macnab, A.J. & Mukisa, R. 2017. The UN Sustainable Development Goals: using World Health Organization's 'Health Promoting Schools' to create change. *Global Health Management Journal*, 1(1): 23-27. [<https://doi.org/10.35898/ghmj-1190>].

- 9 Peoples, G.E., Jezior, J.R. & Shriver, C.D. Caring for the wounded in Iraq – a photo essay. *New England Journal of Medicine*, 351(24):2476-2480. [<https://doi.org/10.1056/NEJMp048327>].
- 10 Hamilakis, Y., Anagnostopoulos, A. & Ifantidis, F. 2009. Postcards from the edge of time: Archaeology, photography, archaeological ethnography (a photo-essay). *Public Archaeology*, 8(2-3):283-309. [<https://doi.org/10.1179/175355309X457295>].
- 11 Aria, W., De Freitas, J., Francis, M. & Macnab, A.J. 2019. Engaging Afghan men at a societal level to increase women's access to contraception. *Medical Anthropology Theory*, 6(4):152-165 [<https://doi.org/10.17157/mat.6.4.732>].

Guidelines for composition

During the conduct or evaluation of a project, the taking of digital images must be a defined role of one member of the team, and the necessary consent forms must be prepared for those whose images will be recognisable in print, to give their informed written consent for these images to be used.

When preparing a report or executive summary consider including an image taken during a research or project delivery or stock images such as those available on Google images. Ensure that the images are:

- Interesting and add meaning and context to the topic of the essay;
- Objective and a fair and an accurate representation of the topic they depict in both content and tone;
- Complementary to each other and the written elements of the essay; and
- Informative, making the reader easily understand the facts and message of the essay.

Beyond this, the creator of a photo-essay has considerable scope to add artistic touches to the essay. The rules are few and the canvas broad.

- When putting the photo-essay together:
 - o Write the overview wording that describes the purpose of the essay.
 - o Select an image that illustrates the narrative.
 - o Write a caption for each selected image that describes the elements in the image that are relevant to the essay topic.
- When choosing images:
 - o Select high-resolution images for clarity in print versions of the essay or when viewed as an online publication.
 - o Use a photo editing programme to optimise contrast and lightness/darkness and extraneous crop detail.
 - o Avoid using poor quality images in terms of exposure, focus, white balance or distracting content.
- Include 10-15 to provide a source of background material which expands on the points covered in the essay or to corroborate specific facts, methods or data mentioned in the text.

- Begin the essay with a general image or two to set the scene; these represent the issue the essay intends to portray, much the way the introduction does in a conventional paper.
- Next, add images that relate to specific elements of the purpose of the essay topic in the way the methods section of a paper does.
- Follow with close-up images of people, devices or situations that show the key elements or effect(s) of the topic or intervention; these are like items presented in the results section of a scientific report.
- End with general, outcome or closure images that indicate the endpoint(s) and relevance of the message of the essay.
- Add an appropriate reference to the text and in a conventional reference list:
 - Format the references and include them in the text as required by the journal chosen for the report – look at the instructions for authors.
 - Number them in sequence in the text using superscript or inclusion in brackets if the Vancouver style is required; this makes the text easier to read than Harvard style which requires author names and year of publication in brackets.
 - Do not include references in the image captions as a rule. However, when the image or caption contains a particular fact or element of the essay, not included in the accompanying text, add a reference.
- Consider the ethics of the essay:
 - A major question for authors and editors relates to photo-manipulation. Nowadays, digital images can be edited and even ‘photo-shopped’ to such an extent that elements or individuals can be freely altered, or even deleted or added. Ethically, there is no place for this in a conventional photo-essay, where such images are unacceptable.
 - Most pictures are simply refined for contrast, colour enhancement or to make them lighter or darker, and cropped to make them illustrate clearly the parts of the image relevant to the photo-essay. This form of editing (photo-manipulation) is acceptable.
 - Another ethical issue relates to false or misleading captioning; captions must be accurate and informative, and ideally, they add wording that compliments and expands on the information provided in the written text.

While only a small number of journals accept submission of photo-essays, this format is also an excellent one to use as the basis for a concise executive summary, to prepare a research presentation for a scientific meeting, or for materials intended to educate lay members of a target audience. Photo-essays can also be used as the basis for progress reports to project supervisors or funding agencies and are a good format for young investigators to consider.

It is important to remember that the images chosen are intended to tell the story, with the accompanying text providing background, methods and selected data, complementing the photographs. A good essay should engage the interest of the reader visually, and allow a rapid grasp of the topic, issue or approach presented. The ability to take in the subject matter quickly is important in a world where we have less and less time to read entire articles and formal reports. Also, photo-essays appeal to an audience that is broader than fellow scientists or educators; the lay public can often learn a lot from a well-constructed photo-essay. After all, the principles employed have a good pedigree, as they are founded on the journalistic premise that a story must both engage the interest of a reader and allow rapid acquisition of information.

A recurring need with much of the DOHaD information we want to share is to describe ‘what works’, while also explaining ‘why’. Photographs can help in this regard by showing a level of detail about a problem and how it can be solved that would prove too lengthy and involved for many readers if we tried to present it using the written word alone. Also, the reality is that individual readers vary and they are interested in particular elements of what is presented. They want to take away different levels of information when learning ‘what works and why’. When any of us look at a photograph; what peak our interest and the impact thereof differs from person to person, meaning a photo-essay has the unique ability to ‘speak’ effectively to a much broader audience, with a much wider range of interests and life experience, than a written report or summary can usually achieve.

While considerable creative leeway exists in the construct of a photo-essay, as in photojournalism and broadcast journalism, it is expected that a code of ethics is followed, requiring that work based on photographic images or video footage must tell the story with pictures that are honest and not inappropriately manipulated.

Simple photo-essays are readily assembled if a photographic record of enough depth and quality has been compiled during the ‘planning’, ‘conducting’ and ‘evaluation’ phases of a project. For those who wish, however, considerable opportunities exist to be creative in the design and execution of photo-essays. Online publication lends itself to a faithful reproduction of full-colour images and video montages in large formats. However, the subjective review process to assess the merit of an

image-based submission, and its suitability for publication counterbalance this creative option.

An example follows of how images, captions and text can be combined to introduce the topic of the Sustainable Development Goals and how they can be advanced using school-based programmes based on the WHO's Health-Promoting School model.

Photo-essay

Advancing the Sustainable Development Goals through the WHO's Health-Promoting School programmes

The global relevance of the Sustainable Development Goals is implicit from the range of targets they address. The 17 Sustainable Development Goals overarchingly aim to address poverty worldwide.¹²



Figure 11.1 The United Nations Development Programme poster illustrates the 17 Sustainable Development Goals.

As Sustainable Development Goals 1-6 directly address factors that contribute to health, disease and wellbeing in children (poverty, malnutrition, health, education, empowering women and girls, and water), an innovative approach is to use the WHO's Health-Promoting School model to create change.¹³

12 United Nations (UN). 2020. *Sustainable Development Goals*. [www.un.org/sustainabledevelopment/sustainable-development-goals] (Accessed 4 March 2020).
 13 World Health Organization (WHO). 2013. *What is a health promoting school?* [https://bit.ly/311Ovdn] (Accessed 4 March 2020); West, P., Sweeting, P. & Leyland, A. 2004. School effects on pupil's health behaviours: evidence in support of health promoting school. *Research Papers in Education*, 19(3), September:261-291.



Figure 11.2 Child malnutrition and disease are addressed specifically in Sustainable Development Goals 1 and 4.

School-based health promotion employs multi-disciplinary strategies to engage a school community. The WHO's ultimate objective is to generate life-long awareness of choice and behaviour, offering a way to influence the social determinants of health, positively.¹⁴ Health-Promoting School programmes have been used successfully to address many specific locally-identified diseases, living circumstances and lifestyles that negatively impact health, e.g. diarrhoea, dental caries, diet, hygiene, malaria, mental health, sexual health, and worms.¹⁵

[https://doi.org/10.1080/02671522.2004.10058645]; Tang, K.C., Nutbeam, D., Aldinger, C., St Leger, L., Bundy, D., Hoffmann, A.M., Yankah, E., McCall, D., Buijs, G., Arnaut, S. & Morales S. 2008. Schools for health, education and development: a call for action. *Health Promotion International*, 24(1):68-77. [https://doi.org/10.1093/heapro/dan037].
 14 U.N., 2020; WHO, 2013; Tang et al., 2008; Viner, R.M., Ozer, E.M., Denny, S., Marmot, M., Resnick, M., Fatusi, A. & Currie, C. 2012. Adolescence and the social determinants of health. *The Lancet*, 379(9826):1641-1652. [https://doi.org/10.1016/S0140-6736(12)60149-4].
 15 Macnab et al., 2015; Kwan, S.Y.L., Petersen, P.E., Pine, C.M. & Borutta, A. 2005. Health-promoting schools: an opportunity for oral health promotion. *WHO Bulletin*, 83(9):677-685. [https://doi.org/S0042-96862005000900013]; Migele, J., Ombeki, S., Ayalo, M. & Biggerstaff, M. & Quick, R. 2007. Diarrhea prevention in Kenyan school through the use of simple safe water and hygiene intervention. *American Journal of Hygiene and Tropical Medicine*, 76(2):351-353. [https://doi.org/10.4269/ajtmh.2007.76.351]; Mukisa, R., Macnab, A.J., Mutabazi, S. & Steed, R. 2017. Teachers as agents of change: school-based diagnosis of malaria positively impacts child morbidity. *Proceedings of the International Conference on Applied Science and Health*, 93-102. [https://bit.ly/3pjRay0]; Kirby D, Obasi A, Laris B. The effectiveness of sex education and HIV education interventions in schools in developing countries. *WHO Technical Report Series*, 938:103-150. [https://bit.ly/3kqeJ4l]; Paul-Ebhohimhen, V.A., Poobalan, A. &



Figure 11.3 A classroom in a school with a WHO's Health-Promoting School programme: the visual aids around the walls speak to health knowledge, factors that are protective and healthy behaviours.

The fundamental Health-Promoting School approach is suited to the Sustainable Development Goals as two synergistic educational principles drive change: the acquisition of knowledge via creative additions to the curriculum, and learning health-promoting behaviours through the conduct of school-based healthy practice exercises.



Figure 11.4 Visual aids made by pupils and the use of age-appropriate 'voice' and 'messaging' underscoring Health-Promoting School learning principles.

Van Teijlingen, E.R. 2008. A systematic review of school-based sexual health interventions to prevent STI/HIV in sub-Saharan Africa. *BMC Public Health*, 8(4). [https://doi.org/10.1186/1471-2458-8-4]; Miguel, E. & Kremer, M. 2004. Worms: identifying impacts on education and health in the presence of treatment externalities. *Econometrica*, 72(1): 159-217. [https://bit.ly/3pdAxnH].



Figure 11.5 Healthy practices being learned through sessions that teach and reinforce health-related skills (e.g. tooth brushing, hand washing, mosquito control, food cultivation, preparation and safe storage).

Health-Promoting School programmes, particularly in low- and middle-income countries, often include planting a school garden. It has been documented that school gardening contributes to improved nutrition and academic achievement, promotes healthier eating, enhances environmental awareness and fosters skill development in multiple fields.¹⁶ These skills, ranging from how to grow food and team building to commercial expertise from produce marketing, are all relevant to Sustainable Development Goals 1-6 and are accrued comparably worldwide.¹⁷



Figure 11.6 School gardens generate awareness of cultivation techniques, food security and sustainable agriculture and acquisition of life skills, in addition to growing produce.

16 Henry Doubleday Research Association. 2012. Food Growing in Schools – Taskforce Report. *Garden Organic*. Full Report. pp.1-66. [https://bit.ly/319LTaa].
 17 Armstrong, D. 2000. A survey of community gardens in upstate New York: Implications for health promotion and community development. *Health and Place*, 6:319-327. [https://doi.org/10.1016/s1353-8292(00)00013-7].



Figure 11.7 School garden produce can be used in lunch programmes to supplement the nutrition of pupils who come to school hungry and can improve both health and educational attainment.

When a garden's produce is also used to feed children who come to school hungry, their educational achievement results improve, presumably reflecting the reversal of the effects of malnutrition on the cognitive behaviour of these children and their ability to learn.¹⁸ Hence, while local factors will drive the choice of crops schools will grow, the nutritional benefit of the produce chosen is relevant. In our Health-Promoting School programmes in Africa, we plant maize with iron-rich beans grown under the canopy; together these provide a good yield with a nutritious combination of complex carbohydrates, protein, and micronutrients. Recently we have successfully introduced a new orange-fleshed sweet potato varietal which is particularly rich in bioavailable nutrients including Vitamins A, B5, B6 and C.¹⁹

- 18 Macnab, A.J. & Kasangaki, A. 2012. 'Many voices, one song': a model for an oral health programme as a first step in establishing a health promoting school. *Health Promotion International*, 27(1):63-73. [<https://doi.org/10.1093/heapro/dar039>]; Bundy, D.A., Shaeffer, S., Jukes, M., Beegle, K., Gillespie, A., Drake, L., Lee, S.H., Hoffman, A.M., Jones, J., Mitchell, A. & Wright, C. 2006. School-based health and nutrition programs. In: Jamison, D.T., Breman, J.G. & Measham, A.R. (eds). *Disease Control Priorities in Developing Countries*. 2nd Edition. Washington, DC: The World Bank. 1091-1108.
- 19 Hotz, C., Loechl, C., De Brauw, A., Eozenou, P., Gilligan, D., Moursi, M., Munhaua, B., Van Jaarsveld, P., Carriquiry, A. & Meenakshi J.V. 2012. A large-scale intervention to introduce orange sweet potato in rural Mozambique increases vitamin A intakes among children and women. *British Journal of Nutrition*, 108(1):163-176. [<https://doi.org/10.1017/S0007114511005174>].



Figure 11.8 Sweet potatoes grow as an underground tuber on the plant *Ipomoea batatas*.



Figure 11.9 Orange fleshed varietals offer important nutritional benefits in low- and middle-income countries and contain high levels of beta-carotene.

Orange-fleshed sweet potato cultivation should be promoted as Vitamin A deficiency is prevalent in more than 50 per cent of countries worldwide, with more than 250 000 preschool children and many pregnant and lactating mothers affected.²⁰ Vitamin A deficiency weakens immunity, stunts growth, increases child and maternal mortality and is the most prevalent preventable cause of blindness worldwide; eating orange-fleshed sweet potato reduces rates of blindness.²¹

- 20 WHO. 2009. Global Prevalence of Vitamin A Deficiency in Populations at Risk 1995-2005: WHO Global Database on Vitamin A deficiency. *Nutrition*. [<https://bit.ly/3klCivl>].
- 21 WHO. 2020. *Vitamin A deficiency/ Micronutrient deficiencies*. [<http://www.who.int/nutrition/topics/vad/en/>] (Accessed 1 March 2020); Low, J.W., Arimond, M.,

When parents understand that micronutrients in fruit and vegetables improve child health and learning, and especially that they can prevent delayed reading, they are motivated to help plant and maintain school gardens.²² Parents and children then benefit by acquiring knowledge and skills side by side, and robust improvements in nutrition, food security, and sustainable agriculture are achievable.²³



Figure 11.10 Eating fruit and vegetables has known beneficial effects for health; increased awareness, production and consumption are fundamental aims of the Sustainable Development Goals.

The Sustainable Development Goals are a challenge, but importantly, the WHO now endorses school programmes as a way to address the social determinants of health worldwide.²⁴ Schools are recognised to provide the most effective and efficient way to reach a large segment of the population, and globally more than

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- Osman, N., Cunguara, B., Zano, F. & Tschirley, D. 2007. A food-based approach introducing orange-fleshed sweet potatoes increased vitamin A intake and serum retinol concentrations in young children in rural Mozambique. *The Journal of Nutrition*, 137(5):1320-1327. [https://doi.org/10.1093/jn/137.5.1320].
- 22 Macnab & Kasangaki, 2012; Knai, C., Pomerleau, J., Lock, K. & McKee, M. 2006. Getting children to eat more fruit and vegetables: a systematic review. *Preventive Medicine*, 42(2):85-95. [https://doi.org/10.1016/j.ypmed.2005.11.012].
- 23 Pérez-Rodrigo, C. & Aranceta, J. 2001. School-based nutrition education: lessons learned and new perspectives. *Public Health Nutrition*, 4(1a):131-139. [https://doi.org/10.1079/phn2000108]; Macnab, A.J., Gagnon, F. & Stewart, D. 2014a. Health Promoting Schools: Consensus, challenges and potential. *Health Education*, 114(3):170-185. [https://bit.ly/34szNmL].
- 24 WHO. 2008. *Closing the gap in a generation: health equity through action on the social determinants of health*. Commission on Social Determinants of Health – Final Report. [https://bit.ly/2QxIIAF]; Marmot, M., Friel, S., Bell, R., Houweling, T.A. & Taylor, S. 2008. Closing the gap in a generation: health equity through action on the social determinants of health. *The Lancet*, 372(9650):1661-1669. [https://doi.org/10.1016/S0140-6736(08)61690-6].

one billion children have the potential to benefit from change created through Sustainable Development Goals-focused initiatives based on the WHO's Health-Promoting School model.



Figure 11.11 Vitamin A deficiency is the principal preventable cause of blindness. Orange sweet potato consumption preserves vision and is a nutritional adjunct that aids learning.



Figure 11.12 Education in safe and supportive schools is a powerful determinant of health.²⁵ Children engaged in effective WHO's Health-Promoting School initiatives will acquire knowledge and behaviours that are directly applicable to advancing the Sustainable Development Goals.

Conclusion

Photography is now more popular and accessible than ever due to the rapid development of digital photography and ubiquity of cameras in even the most basic cellular phones. There are many examples of useful resources that explain and illustrate how to take technically competent and visually engaging images.²⁶

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- 25 Tang et al., 2008.
- 26 Collier, J. & Collier, M. 1986. *Visual Anthropology: Photography as a research method*. EPDF. [https://bit.ly/3nfy1v8]; Carol, H. 2015. *Read this if you want to take good photographs*. London: Laurence King Publishing.

Learning facts and forming opinions from photographs, or related images like film or videos is unlike being educated by the written word, and a daily occurrence globally for the majority of people.²⁷ Photographic images are more accessible than words in many parts of the world, particularly where populations include a significant number of people who remain illiterate or are not conversant with the principal languages in which academics write. Because of this, photos are a powerful way to furnish evidence; they can alter and enlarge the scope of what we see, and even provide an ethical subtext through what they depict, that is difficult to convey in words alone.

Care must be taken to make sure that the images selected are of high quality both in terms of resolution and the impact of the subject matter they depict, and consent must be obtained from the individuals in the photos who can be recognised in the versions used. Photographic images are a very effective and powerful way of communicating as they invoke emotion; hence, a potential pitfall when using them is that they can overtly or subliminally promote or perpetuate stereotypes; authors should be mindful of this when selecting images, and editors alert to the possibility when reviewing photo-essay submissions.

The photo-essay format has its origins in photojournalism, but a series of photographs is now an effective way to report advances in health and science, frame a report, or tell a story to a broad and varied target audience. As nothing holds a reader to look at the images in the order they are presented, nor indicates the amount of time to be spent on each image, a photo-essay offers a very individual, informative yet flexible format for sharing ‘what works and why’.

Hence, communicating scientific information and public health recommendations using photo-essays has broad relevance for disseminating policy implementation research.²⁸ In particular, as a way to respond to calls for DOHaD concepts to be translated into an accessible, multi-level approach for informing the next generation, and one that promotes DOHaD as a new and exciting way to achieve a healthier life.²⁹

27 Macnab, A.J. & Mukisa, R. 2018. Celebrity endorsed music videos: innovation to foster youth health promotion. *Health Promotion International*, 34(4), August:716-725. [<https://doi.org/10.1093/heapro/day042>];

28 Stothers, L. & Macnab, A. 2017. Global implementation of advanced urological care: Policy implementation research. *Canadian Urological Association Journal*, 11(6):157-160. [<https://doi.org/10.5489%2Fcuaj.4117>].

29 McKerracher, L., Moffat, T., Barker, M., Williams, D. & Sloboda, D. 2018. Translating the Developmental Origins of Health and Disease concept to improve the nutritional environment for our next generations: A call for a reflexive, positive, multi-level approach. *Journal of Developmental Origins of Health and Disease*, 10(4):420-428.

Acknowledgements

The children and adults (identifiably) photographed consented to the pictures being used in the dissemination and publication of this research.

This project grew out of a collaboration between colleagues at the Stellenbosch Institute for Advanced Study (STIAS) at Stellenbosch University and the Peter Wall Institute for Advanced Studies (PWIAS) at the University of British Columbia. Andrew J Macnab and Ronald Mukisa are grateful to STIAS for the support, enabling them to work together in residence as a Fellow and Invited Scholar. Lynn Stothers is grateful to PWIAS for her appointment as Distinguished Scholar in Residence.

Elements of this chapter were published previously in an editorial and series of articles in the open-access publication the *Global Health Management Journal* and as part of the Proceedings of the International Conference of Applied Science and Health at Mahidol University, Thailand.

[<https://doi.org/10.1017/S2040174418001034>]; International Society for developmental origins of health and disease (DOHaD). 2015. The Cape Town Manifesto – November 2015: A healthy start builds a bright future. *International Society for DOHaD*, Cape Town. [<https://bit.ly/3ajwzfD>].



12

THE WORLD HEALTH ORGANIZATION'S 'HEALTH-PROMOTING SCHOOL' MODEL: A POTENTIAL AVENUE FOR DEVELOPMENTAL ORIGINS OF HEALTH AND DISEASE EDUCATION IN AFRICA

Andrew J Macnab¹

Traditional health care strategies to manage illness are based on the tenets of prevention and cure. Health promotion is an urgent matter from both a health and economic standpoint, as most non-communicable diseases cannot be cured, and the future costs of management are prohibitive. Hence, a new focus on prevention involving youth has been widely called for, including by the Cape Town Manifesto.²

This chapter reviews the challenge and opportunities of engaging youth in health promotion related to the developmental origins of health and disease (DOHaD) agenda. It explores the potential for using the World Health Organization (WHO)'s

1 Stellenbosch Institute for Advanced Study, Wallenberg Research Centre at Stellenbosch University, Stellenbosch, South Africa; Department of Pediatrics, University of British Columbia, Vancouver, Canada.

2 International Society for developmental origins of health and disease (DOHaD). 2015. *The Cape Town Manifesto – November 2015: A healthy start builds a bright future*. International Society for DOHaD, Cape Town. [<https://bit.ly/3aJwzFD>].

'Health-Promoting School' model as part of health initiatives in Africa to promote the adoption of a DOHaD related health agenda.

At a societal level, effective disease prevention must often rely on the application of new science and technological innovation, plus legislation to dictate change. However, at an individual level, alterations in health behaviours are required to contain the epidemic of DOHaD-related non-communicable diseases, which can only be achieved through learning and increased awareness driving attitudinal change. The challenge facing DOHaD related health promotion is how we, as a society, can disseminate valid information widely and frame compelling arguments to engage and motivate individuals to improve their health and change their behaviours. The nature of DOHaD also predicates that the most fertile place to invest in prevention and health improvement strategies is the next generation.

The WHO estimates are that school-based health promotion has the potential to reach one billion children worldwide. Health-Promoting School programmes are a proven means of providing children with the knowledge and practical ways to improve their health and have been shown to positively impact a range of specific health issues and health behaviours. Importantly in the context of Africa, the integrated educational approach used in Health-Promoting School has proved to be applicable and beneficial even in low- and middle-income settings. Significantly in the context of prevention, children who participate in good Health-Promoting School programmes have been shown to develop improved resilience, self-esteem and self-efficacy; traits recognised to engender a greater desire and increased ability to exercise control over their lives, and characteristics all likely relevant to advancing the DOHaD agenda.

Introduction

Health-Promoting Schools provide classroom education and school-based activities that increase knowledge and develop behaviours that benefit the health of children; such schools are also an investment in the wellbeing of the broader community.³ The WHO has endorsed this school-based health promotion model, called for an increase in the number of Health-Promoting Schools worldwide, and advocates the adoption of "a whole-school approach to enhance the health and educational outcomes of children and adolescents through teaching and

learning experiences initiated in the schools".⁴ This enhancement is achieved by combining a range of complementary approaches in the context of everyday life directed towards knowledge and actions that increase control over factors known to determine future health. Encouraging children to adopt healthy lifestyle habits relevant to the prevention of illness and injury is a central objective. However, because it is recognised that positive experiences at school strongly influence how children develop in terms of their self-esteem, self-efficacy and sense of control over their lives, a formative Health-Promoting School environment is recognised to also contribute to future emotional health and psychosocial resilience.⁵

Today vast numbers of children worldwide experience deficiencies that negatively impact a broad range of health indicators. These deficiencies vary depending on the country concerned, but many can be addressed through Health-Promoting School initiatives, and the investment required is small taken in the context of the escalating burden of healthcare costs. Furthermore, even where national resources for health are sparse, and massive demands such as issues related to HIV/Aids dominate agendas, effective education and behavioural change have been achieved through school-based education, and the potential demonstrated for the model to be employed more widely. Importantly in the context of DOHaD, not only do school-based programmes provide access to the key target age group, exploring opportunities to implement the WHO's Health-Promoting School programmes offers a unique opportunity for collaboration between stakeholders (e.g. ministries) who conventionally work in relative isolation.⁶ Evaluation of Health-Promoting School programmes indicates that a range of benefits are accrued across disciplines including Health, Education, Finance, and Social Services.⁷

4 WHO, 2013a.

5 Macnab, A.J., Gagnon, F. & Stewart, D. 2014a. Health Promoting Schools: Consensus, challenges and potential. *Health Education*, 114(3):170-185. [<https://bit.ly/34szNmL>]; Stewart, D., Sun, J., Patterson, C., Lemerle, K. & Hardie M. 2004. Promoting and building resilience in primary school communities: Evidence from a comprehensive 'health promoting school' approach. *International Journal of Mental Health Promotion*, 6:26-33. [<https://doi.org/10.1080/14623730.2004.9721936>].

6 Pentecost, M., Macnab, A.J., Mayekiso, A. & Ross, F. 2018. Beyond the dyad: making intervention DOHaD interventions more inclusive. *Journal of Developmental Origins of Health and Disease*, 9(1):10-14. [<https://doi.org/10.1017/S2040174417000629>]; Macnab, Gagnon & Stewart, 2014a.

7 Stewart-Brown, S. 2006. What is the evidence on school health promotion in improving health or preventing disease and, specifically, what is the effectiveness of the health promoting schools approach? *Health Evidence Network Report*. [<https://bit.ly/31o7iVp>]; Tang, K.C., Nutbeam, D., Aldinger, C., St Leger, L., Bundy, D., Hoffmann, A.M., Yankah, E., McCall, D., Buijs, G., Arnaout, S. & Morales S. 2008. Schools for health,

3 World Health Organization (WHO). 2013a. What is a health promoting school? *School and Youth Health*. [http://who.int/school_youth_health/gshi/hps/en/index.html]; St Leger, L., Young, I., Blanchard, C. & Perry, M. 2009. Promoting health in schools from evidence to action. *International Union for Health Promotion and Education*. [<https://bit.ly/34wrB4L>].

Health-Promoting School initiatives in sub-Saharan Africa

In a 2004 evaluation, Mukoma and Filsher identified that up to that time, no Health-Promoting School programmes had been described in Africa.⁸ However, at the international colloquium in Stellenbosch in November 2011, forty people from five continents came together at the Stellenbosch Institute for Advanced Study (STIAS) to share their global and regional experience about Health-Promoting Schools. They recognised that globally, a moral imperative exists to ensure that all children and adolescents are provided with the resources and environment necessary to enable them to reach their potential. High, low, and middle-income countries were represented; participants from South Africa, Uganda, and Rwanda described the experience with pilot programmes, and several elements of the Ugandan programme have been described in the literature. A consensus statement was created to summarise the current evidence, strategies, challenges, and potential of the WHO's Health-Promoting School model.⁹ It was evident that within sub-Saharan Africa the potential for the model to contribute to future health has not as yet been recognised, despite the existence of some of the most prevalent and severe global health problems in this region.¹⁰

A specific challenge for South Africa is that the school system is not healthy; there are recognised deficiencies regarding infrastructure, resources and lack of motivation amongst teachers. As a consequence, the promise and potential that sound educational programmes are known to provide are not being fulfilled. Two reports from 1998/1999 identified the need to establish Health-Promoting Schools in South Africa as a means of addressing the major challenge of improving the health status of all citizens, and particularly of youth and children.¹¹ Data indicated that 87.2 per cent of health and education professionals supported establishing

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- education and development: a call for action. *Health Promotion International*, 24(1):68-77. [https://doi.org/10.1093/heapro/dan037].
- 8 Mukoma, W. & Filsher, A.J. 2004. Evaluations of health promoting schools: a review of nine studies. *Health Promotion International*, 19(3):357-368. [https://doi.org/10.1093/heapro/dah309].
- 9 Macnab, A.J. 2013. The Stellenbosch consensus statement on Health Promoting Schools. *Global Health Promotion*, 20(1):78-81. [https://doi.org/10.1177/1757975912464252].
- 10 Sippel, L., Kiziak, T., Woellert, F. & Klingholz, R. 2011. Africa's demographic challenges. How a young population can make development possible. *Berlin Institute for Population and Development*. [https://bit.ly/3gwQSYl].
- 11 Vergnani, T., Filsher, A.J., Lazarus, S., Reddy, P. & James, S. 1998. Health promoting schools in South Africa: needs and prospects. *South African Journal of Child and Adolescent Mental Health*, 10(1):44-58. [https://doi.org/10.1080/16826108.1998.9632345]; Swart D, Reddy P. 1999. Establishing networks for health promoting schools in South

Health-Promoting School networks; how such networks should be structured and would function is described, and perceived barriers and strategies to address them outlined.¹² These reports also presented thirteen tasks critical to achieving Health-Promoting Schools in South Africa, and still provide a valuable template for those contemplating Health-Promoting School networks. Today, South Africa still lacks effective Health-Promoting Schools. However, a National Development Plan is currently looking at multiple ways to improve key issues in society, including health, education, and social integration. Importantly the exploratory process to investigate options for change are broad, and the overall plan has a longer than usual timeline (up to 2030). This plan offers a unique opportunity for agencies (ministries), traditionally functioning in 'silos', to collaborate in considering the potential for adopting a Health-Promoting School approach to implement broad changes their mandates have in common and together would have the potential to address many of the United Nations' 'Sustainable Development Goals' and within them several root causes of DOHaD-related non-communicable disease.

The necessity for such 'collaboration across sectors' in the context of Health-Promoting Schools has been recognised previously, and the development of Health-Promoting School networks identified as a way to encourage greater intersectoral cooperation.¹³ From the evidence of Health-Promoting School evaluations elsewhere, and particularly the experience of countries who have actively promoted Health-Promoting School activities, health benefits could be achieved in parallel with the recognised advantages of motivating girls and boys to pursue and value educational opportunities.¹⁴ There is also the investment value in

Africa. *Journal of School Health*, 69(2):47-50. [https://doi.org/10.1111/j.1746-1561.1999.tb06366.x].

- 12 Vergnani et al., 1998.
- 13 Macnab, A.J., Stewart, D. & Gagnon, F. 2014b. Health Promoting Schools: Initiatives in Africa. *Health Education*, 114(4):246-259. [https://doi.org/10.1108/HE-11-2013-0057].
- 14 Moon, A.M., Mullee, M.A., Rogers, L., Thompson, R., Speller, V. & Roderick, P. 1999. Helping schools to become health-promoting environments – an evaluation of the Wessex Healthy Schools Award. *Health Promotion International* 1000, 14(2):111-122. [https://doi.org/10.1093/heapro/14.2.111]; Stewart et al., 2004; Wyn, J., Cahill, H., Holdsworth, R., Rowling, L. & Carson, S. 2000. MindMatters, a whole-school approach promoting mental health and wellbeing. *Australian and New Zealand Journal of Psychiatry*, 34(4):594-601. [https://doi.org/10.1080/j.1440-1614.2000.00748.x]; Lee, A., Cheng, F. & St Leger, L.H. 2007a. Hong Kong Healthy School Team. The status of Health Promoting Schools in Hong Kong and implications for further development. *Health Promotion International*, 22(4):316-326. [https://doi.org/10.1093/heapro/dam029]; Inchley, J., Muldoon, J. & Currie, C. 2007. Becoming a health promoting school: evaluating the process effective implementation in Scotland. *Health Promotion International*, 22(1):65-71. [https://doi.org/10.1093/heapro/dal059].

social capital the Health-Promoting School model offers, with the demonstrated improvements in participating children's physical and mental health, and greater overall sense of control over their lives.¹⁵ These are all fundamentally important key elements for progress with national agendas to improve health and the wellbeing of society in any country, and goals which could be achieved with appropriate vision and collaboration with a relatively modest investment.¹⁶

Although health promotion has begun to be used in African countries as a means of increasing societal responsibility for health, programme delivery is often compromised by limited collaboration between the disciplines acting as health educators.¹⁷ Establishing more Health-Promoting Schools would provide a real opportunity to promote new avenues for collaboration between the district government officers responsible for community engagement related to health, education, gender, nutrition and agriculture. Health promotion has been described as the provision of a set of tools rather than a process.¹⁸ As a cohesive team, this group could implement school-based health promotion and deliver components of content, oversight, and support provided by outside agencies or centres of higher learning in other programmes. Such engagement would also enable these officials to become more student-centred and potentially enhance integration within the health care system. Importantly, more Health-Promoting Schools would benefit children; the age group that makes up such a large proportion of African populations currently, and the segment of the population recognised to be most at risk concerning their health literacy, but also with the highest potential to improve.¹⁹

15 Stewart et al., 2004; WHO. 2009. *Promoting health and development: closing the implementation gap*. Call to action, 7th Global Conference on Health Promotion, Nairobi, Kenya, October 26-30. [<https://www.who.int/mediacentre/events/meetings/7gchp/en/>].

16 Davidson, R.G., Rustein, S., Johnson, K., Suliman, E., Wagstaff, A. & Amouzou, A. 2007. Socioeconomic differences in Health, Nutrition, and Population within developing countries. Country reports on HNP and poverty, Washington, DC: World Bank Group. [<https://bit.ly/34r3pRc>].

17 Nyamwaya, D. 2003. Health Promotion in Africa: strategies, players, challenges and projects. *Health Promotion International*, 18(2):85-87. [<https://doi.org/10.1093/heapro/18.2.85>].

18 Nyamwaya, 2003.

19 Lee, A., Wong, M.C.S., Keung, V.M.K., Yuen, H.S.K., Chung, F. & Mok, J.S.Y. 2008. Can the concept of health promoting schools help to improve students' health knowledge and practices to combat the challenge of communicable diseases: Case study in Hong Kong? *BMC Public Health*, 8:42. [<https://doi.org/10.1186/1471-2458-8-42>].

Potential for Health-Promoting School initiatives

Health promotion and disease prevention are essential to reduce the healthcare burden on children and to positively impact future health in the context of DOHaD, particularly in developing countries and disadvantaged populations where investment in prevention is so much more economically realistic than the hope to pay the cost of future care. It is recognised that endeavour to promote healthy behaviours should begin early in life, and the desire to positively impact the health of children is a consistent theme, and thus the WHO advocates Health-Promoting Schools as a valid and successful model for achieving positive change.²⁰ Existing evidence can guide stakeholders in designing and implementing programmes that are both effective and have cost-benefit.²¹

Worldwide Health-Promoting Schools have the potential to positively impact over one billion children by creating a positive environment that fundamentally influences attitudes, beliefs, and behaviours, and the growing population of children and youth in Africa are a significant population that would benefit.²² The positive messages and practical interventions experienced by children in Health-Promoting School programmes can be reinforced throughout their remaining years in school, as it is recognised that schools strongly influence how children's self-efficacy, self-esteem, resilience, and sense of control over their lives develop. Some believe the potential benefits are more than families alone can impart because of positive exposure to the powerful influence of teacher support and peer networks.²³ The recent international colloquium at STIAS reviewed the educational and social science concepts underlying Health-Promoting Schools; factors that contribute to success or failure; health topics that can be used as 'entry points' to initiate programmes; and processes to document impact. The lessons learned reiterate many elements of the experience of others, but also emphasise the relative simplicity, low cost, and inherent flexibility of the Health-Promoting School model.²⁴

20 Lee, A. 2009. Health-promoting schools: evidence for a holistic approach to promoting health and improving health literacy. *Applied Health Economic Health Policy*, 7(1):11-17. [<https://doi.org/10.2165/00148365-200907010-00002>].

21 Stewart-Brown, 2006.

22 Macnab, A.J. & Mukisa, R. 2018. Priorities for African youth to engage in the DOHaD agenda. *Journal of Developmental Origins of Health and Disease*, 9(1):15-19. [<https://doi.org/10.1017/S2040174417000423>].

23 Stewart et al., 2004.

24 Macnab, 2013.

Novel educational initiatives are needed to address future health in the context of DOHaD; approaches must be found that resonate with youth, and engage school communities so that they choose to 'own' and sustain effective programmes.²⁵ Health Promoting Schools offer a means of educating the next generation innovatively and in a participatory way, enabling them to be more knowledgeable about their health, and aware of practical ways to positively influence their lifestyle and the future wellbeing of the next generation.

Mandate of the WHO's Health-Promoting School model

The broad mandate of health promotion is to reduce unhealthy behaviours, improve preventive services and create a better social and physical environment. Schools that follow the WHO's Health-Promoting School model are an investment with the potential to impact every child in the school positively, but also benefit the broader community beyond. Health-Promoting School initiatives combine a range of complementary approaches in the context of everyday life directed towards knowledge and action that enable individuals and communities to increase their control over determinants of health, and thereby improve their health and wellbeing.²⁶ A central objective is to encourage the adoption of healthy lifestyle habits in children. However, the ultimate goal of the WHO's Health-Promoting School model is to establish 'health literacy'.²⁷ This change in school culture and ethos is intended to continually strengthen the school's capacity as a healthy setting for living, learning and working because it is recognised that how children develop is strongly influenced by their years at school,²⁸ and that positive experiences contribute to their future emotional health and psychosocial resilience.²⁹ The knowledge, attitudes and behaviours established in childhood are also known to have a significant impact, beneficial or otherwise, on behaviours and circumstances later, because the habits and attitudes of living established during these early years translate into adult life.

25 Pentecost et al., 2018; Macnab & Mukisa, 2018.

26 WHO, 2009; Davidson et al., 2007; Nutbeam, D. 2000. Health literacy as a public health goal: a challenge for contemporary health education and communication strategies into the 21st century. *Health Promotion International*, 15(3):259-267. [https://doi.org/10.1093/heapro/15.3.259].

27 Nutbeam, 2000; WHO: Department of Communicable Disease Prevention, Control and Eradication. 1997. *Promoting health through schools report of a WHO Expert Committee on Comprehensive School Health Education and Promotion*. WHO Technical Report Series, 870. [https://www.who.int/schistosomiasis/resources/who_trs_870/en/].

28 WHO, 1997.

29 Stewart et al., 2004.

This means that what young people learn can either have a positive or harmful impact in their later lives.³⁰ While this potential for schooling to drive future life choices is important in itself, in the context of DOHaD, we now know that such impact extends further, as parental knowledge and behaviours also determine key elements in the future health of their offspring.³¹

Children from disadvantaged sections of society are at particular risk, as they already experience deficiencies that negatively impact a broad range of health indicators.³² Hence, the call for investment to improve the health, wellbeing, and social competence of children is almost universal; this call is central to the challenge of the current United Nations' Sustainable Development Goals and is echoed by the voices of policymakers and parents worldwide. In this context, much can be achieved through health promotion at a community level, mainly through Health-Promoting Schools, and importantly such initiatives are well within the ability of even low-income countries, as the model focuses on positive change in the school and its immediate culture. Establishing Health-Promoting Schools requires a mindset change and refined educational investment, more than providing significant resources, engaging non-government organisations, or obtaining international funding. Because of this, the Health-Promoting School model is especially relevant where national resources for health are sparse, and massive demands such as HIV-related issues or Covid-19 contingencies dominate agendas.³³

What is a Health-Promoting School?

The history, evolution, and concepts underlying health promotion in schools, the factors that contribute to success or failure, and processes to document impact are well described.³⁴ The Stellenbosch consensus statement "summarized and

30 Kendall, P.R.W., Mangham, C. & Young, D.W. 2004. An ounce of prevention. *Paediatrics and Child Health*, 9(3):151-152. [https://doi.org/10.1093/pch/9.3.151]; Daar, A.S., Singer, P.A., Persad, D.L., Pramming, S.K., Matthews, D.R., Beaglehole, R., Bernstein, A., Borysiewicz, L.K., Colagiuri, S., Ganguly, N. & Glass, R.I. 2007. Grand challenges in chronic non-communicable diseases. *Nature*, 450(7169):494. [https://doi.org/10.1038/450494a].

31 Wagstaff, A. 2002. Poverty and health inequalities. *WHO Bulletin*, 80: 97-105. [http://www.euro.who.int/document/e88185.pdf].

32 Davidson et al., 2007; Lister-Sharp, D., Chapman, S., Stewart-Brown, S. & Sowden, A. 1999. Health promoting schools and health promotion in schools: two systematic reviews. *Health Technology Assessment*, 3:1-207. [https://bit.ly/2QhmqOQ].

33 Macnab, Gagnon & Stewart, 2014a.

34 Stewart-Brown, 2006; Moon et al., 1999; Inchley, Muldoon & Currie, 2007; WHO, 2009; Viner, R.M., Ozer, E.M., Denny, S., Marmot, M., Resnick, M., Fatusi, A.

endorsed the WHO Health-Promoting Schools concept, and the organization's stated goal of increasing the number of Health-Promoting Schools worldwide".³⁵

The WHO defines a Health-Promoting School as one that:³⁶

- Continually strengthens its capacity as a healthy setting for living, learning and working;
- Fosters health and learning with all the measures at its disposal;
- Engages health and education officials, teachers, teachers' unions, students, parents, health providers and community leaders in efforts to make the school a healthy place;
- Strives to provide a healthy environment, school health education, and school health services along with school/community projects and outreach, health promotion programmes for staff, nutrition and food safety programmes, opportunities for physical education and recreation, and programmes for counselling, social support and mental health promotion;
- Implements policies and practices that respect an individual's wellbeing and dignity and provide multiple opportunities for success and acknowledge reasonable efforts and intentions as well as personal achievements; and
- Strives to improve the health of school personnel, families and community members as well as pupils; and works with community leaders to help them understand how the community contributes or undermines, health and education.

The literature available highlights the concepts, principles, and processes central to the broad range of ways in which the application of the Health-Promoting School model can be used to enrich the education of children worldwide and aid in enabling them to reach their potential.³⁷

& Currie, C. 2012. Adolescence and the social determinants of health. *The Lancet*, 379(9826):1641-1652. [https://doi.org/10.1016/S0140-6736(12)60149-4]; Young, I. 2005. Health promotion in schools – a historical perspective. *Promotion and Education*, 12(3-4):112-117. [https://doi.org/10.1177/10253823050120030103]; St Leger et al., 2009; Macnab, A.J., Kasangaki, A., Mbabali, M., Zavuga, R., Radziminski, N., Budden, H. & Gagnon, F. 2010. Brighter Smiles Africa. Translation of a Canadian community-based health-promoting school program to Uganda. *Education for Health*, 23(2):1-8. [https://bit.ly/2QIYtVu].

35 Macnab, 2013; WHO, 2013a.

36 WHO, 2013b.

37 WHO, 2013a; WHO, 2013b; Viner et al., 2012.

As identified by the WHO, Health-Promoting School programmes aim to educate children to be able to:

- Care for themselves and others.
- Make healthy decisions and take control over life's circumstances.
- Establish a health culture and school ethos that:
 - o Create conditions that are conducive to health (through policies, services, physical/social conditions).
 - o Build capacities for peace, shelter, education, food, income, a stable ecosystem, equity, social justice, and sustainable development.
 - o Promote prevention strategies to address the leading causes of death, disease and disability.
 - o Positively influence health-related behaviours: knowledge, beliefs, skills, attitudes, values and support.

There are, however, recognised variations in how the Health-Promoting School model can be applied. While the fundamental WHO model advocates the whole school approach, a 'top-down' process has also been employed principally to address health issues defined by national or local agencies as significant. Examples include school-based programmes that address smoking, obesity or HIV/Aids.

A 'bottom-up' approach has also been used in many instances to introduce the benefits of a Health-Promoting School using a single health issue of local relevance. Then with the successful implementation of a programme based on Health-Promoting School concepts to address this issue, schools are expected to take ownership of their programme, identify additional health topics of relevance to them, and expand their Health-Promoting School activities.

Examples of where this concept has been successful include the use of health promotion to improve oral health. When participating schools have identified success (through a combination of their viewpoint and formal evaluation processes), a range of issues have been added to their Health-Promoting School agenda. New topics addressed have included: personal hygiene, hand washing, prevention of diarrheal diseases, clean water and sanitation, malaria prevention, school food gardens, and nutrition.³⁸

38 Macnab, A.J. & Kasangaki, A. 2012. 'Many voices, one song': a model for an oral health programme as a first step in establishing a health promoting school. *Health Promotion International*, 27(1):63-73. [https://doi.org/10.1093/heapro/dar039]; Ioannou, S., Kouta, C. & Charalambous, N. 2012. Moving from Health education to health

Such a transition to address other community-specific issues speaks to the flexibility and relevance of using an oral health promotion model; the rationale, process for implementation, and methods of evaluation of this Health-Promoting School 'entry point' are discussed later.

The evidence base

The Stellenbosch consensus statement on the Health-Promoting School model identified that:³⁹

- There is evidence that both health promotion in schools (single-topic targeted programmes) and Health-Promoting Schools (a settings approach including skills, policies, environment, community, and support services) can affect positive change in the lives of school children and the communities in which they live.
- A Health-Promoting School can be transformative for individuals, schools, and communities, enabling and empowering them to attain higher levels of function, and ultimately be stronger citizens with higher capacity for contribution to society.
- A Health-Promoting School has the potential to reduce the burden of disease and improve the resilience of individuals and communities and is thus a mechanism for reducing long-term health care and social welfare costs.
- Adopting the Health-Promoting School model does not necessarily require the provision of significant resources, engagement of non-government organisations, or obtaining of international funding, but instead requires a change in mind-set or a paradigm shift and refinement of educational investment.
- The Health-Promoting School model has become a major theme in health and education strategy, providing a framework for school-based health promotion activity, widely accepted. In countries like Scotland, for instance, Health-Promoting School activity is now supported by a national Health-Promoting School unit established in 2002.⁴⁰ Health promotion units exist in the United Kingdom and Hong Kong, and in Australia, the Health-Promoting School rationale is well accepted with multiple programmes implemented

promotion. Developing the health education curriculum in Cyprus. *Health Education*, 112(2):153-169. [<https://doi.org/10.1108/09654281211203420>].

39 Macnab, 2013.

40 Inchley, Muldoon & Currie, 2007.

and evaluated. In Cyprus, the health education curriculum has moved from traditional health education focus on individual lifestyle or behaviour modification to approaches that recognise and address the determinants of health.⁴¹

Four themes have been identified that are central to effective Health-Promoting School implementation:⁴²

Ownership and empowerment

These are considered essential to success. Teachers and staff are empowered through 'shared ownership' of the change and innovation, and by a programme structure enabling each member's involvement in planning and strategic decision making; this makes staff more likely to 'buy-in' and establish a belief that a Health-Promoting School programme is 'rooted in the school'. As we have found in our projects, ownership is fostered by conscientious dialogue to identify issues relevant to the school, its pupils, and staff, and sharing of results with the school community that allows strategic change to be driven by the experience and priorities of the school. A project leader within the school (elsewhere described as the project 'champion') is the best resource to engage and motivate other staff, parents and the pupils, and relay the message that everyone in the school community has a valid role to play.

Leadership and management

Leadership by a 'champion' in the school embeds the programme in the school structure and life, and this individual effectively acts as 'the driver for change' central to the Health-Promoting School model. The joint management process for the programme is agreed by the initiating individuals or agency and the school, but day to day running and problem-solving in the programme should devolve to the school. However, programme support, follow up visits, motivation, and effective communication from those initiating the Health-Promoting School programme is a given requirement.

41 Lee, A., Cheng, F., Yuen, H., Ho, M., Lo, A., Leung, T. & Fung, Y. 2007b. Achieving good standards in Health Promoting Schools: Preliminary analysis one year after implementation of the Hong Kong Healthy Schools Award Scheme. *Public Health*, 121(10):752-760. [<https://doi.org/10.1016/j.puhe.2007.01.014>].

42 Inchley, Muldoon & Currie, 2007.

Collaboration

Establishing a common understanding of the underlying principles of the Health-Promoting School intervention and negotiating mutually agreed goals and expectations are valuable. This process clarifies what each partner has to offer and what they can expect to gain from involvement. Within most Health-Promoting school programmes, there are at least three spheres where effective collaboration is required:

- partnership working with external professionals;
- pupil participation (including pupil involvement in a Health-Promoting School planning committee, via pupil councils, and through buddy and monitor systems); and
- parent involvement.

Integration

It is important that Health-Promoting School programmes are not viewed as a 'discrete' activity or 'add on' but rather an opportunity to affect a new way of being that permeates all aspects of school life and links to the core objectives and ethos of the school. Integration is essential for sustainability. Fostering a sense of common purpose is another way of describing this process, aided by successes (however small) and the sense of programme ownership that tends to follow demonstrated and acknowledged progress and achievement. In this context, participating in the process of evaluation, having the results shared within the school and amongst parents, and participation in award schemes recognising the adoption of the Health-Promoting School-principles and programme achievement is constructive.⁴³

Factors which overlap and complement these themes have also been identified, and include:

- The need to involve parents and families in their children's health education;
- The involvement of the wider community;
- The importance of a comprehensive, coordinated, cross-curricular programme throughout the school curriculum;
- The need to combine health education with other health-promoting initiatives in the school;

43 Moon et al., 1999; Nelson, J., Martin, K., Nicholas, J., Easton, C. & Featherstone, G. 2001. Food growing activity in schools. *National Foundation for Education Research*, Slough, UK. [<https://www.nfer.ac.uk/food-growing-activities-in-schools/>].

- The need for a variety of teaching methods and strategies actively involving students in their learning, focussing on them as individuals and on their present needs; and
- The need to develop a constructive role for young people from the target population in all decision-making processes relating to health.⁴⁴

Literature addressing evidence of the effectiveness of Health-Promoting School programmes primarily relates to first-world experience with Health-Promoting Schools.⁴⁵ Mukoma found no evaluation from Africa in a review in 2004, but subsequently, there have been reports from several low and middle-income countries.⁴⁶ These include experience gained from the adaptation of a successful Health-Promoting School project in a Canadian aboriginal community into a useful model for engaging schools in rural Ugandan communities, providing practical examples likely to be useful to others considering the validity and relevance of the Health-Promoting School model. The lessons learned and

44 Moon et al., 1999; Lee et al., 2007a.

45 Stewart et al., 2004; Tang et al., 2008; Moon et al., 1999; Inchley, Muldoon & Currie, 2007; WHO, 2009; Viner et al., 2012; Young, 2005; St Leger et al., 2009; Nelson et al., 2001; Kwan, S.Y.L., Petersen, P.E., Pine, C.M. & Borutta, A. 2005. Health-Promoting schools: an opportunity for oral health promotion. *WHO Bulletin*, 83(9):677-685. [<https://doi.org/S0042-96862005000900013>]; Stewart, D.E. 2008. Implementing Mental Health Promotion in Schools: a Process Evaluation. *International Journal of Mental Health Promotion*, 10(1): 32-41. [<https://doi.org/10.1080/14623730.2008.9721755>]; Brown, T. & Summerbell, C. 2009. Systematic review of school-based interventions that focus on changing dietary intake and physical activity levels to prevent childhood obesity: an update to the obesity guidance produced by the National Institute for Health and Clinical Excellence. *Obesity Reviews*, 10(1):110-41. [<https://doi.org/10.1111/j.1467-789X.2008.00515.x>].

46 Mukoma & Filsher, 2004; Young, 2005; Macnab et al., 2010; Macnab & Kasangaki, 2012; Stewart, 2008; Brown & Summerbell, 2009; Baros, M.V.G., Nahas, M.V., Hallal, P.C., Farias, J.C., Florindo, A.A. & Baros, S.S.H. 2009. Effectiveness of a school-based intervention on physical activity for high school students in Brazil: The Saude na Boa project. *Journal of Physical activity and Health*, 6(2):163-169. [<https://doi.org/10.1123/jpah.6.2.163>]; Van Palenstein Helderma, W.H., Munck, L., Mushendw, S., Van't Hof, M.A. & Mrema, F.G. 1997. Effect evaluation of an oral health education programme in primary schools in Tanzania. *Community Dentistry and Oral Epidemiology*, 25(4): 296-300. [<https://doi.org/10.1111/j.1600-0528.1997.tb00943.x>]; Garbin, C.A.S., Garbin, A.J.I., Dos Santos, K.T. & Lima, D.P. 2009. Oral health education in schools: promoting agents. *International Journal of Dental Hygiene*, 7(3):212-216. [<https://doi.org/10.1111/j.1601-5037.2009.00394.x>]; Macnab, A.J., Mukisa, R., Mutabazi, S. & Steed, R. 2015. Malaria in Uganda: school-based rapid diagnostic testing and treatment. *International Journal of Epidemiology*, 45(6), December 1759-1762. [<https://doi.org/10.1093/ije/dyw262>].

evaluations of the effect of the programmes reiterate many elements of the experience of others, and also provide insights of potential value for broader application of the Health-Promoting School model to address the DOHaD agenda, particularly in sub-Saharan Africa and other low and middle-income countries; these lessons include:

- The relative simplicity and inherent flexibility of the Health-Promoting School model;
- The benefits of beginning by addressing a non-stigmatised and simple health issue;
- A modest level of intervention involving a single school can lead to broad community engagement;
- The majority of schools can incorporate the education and health practice components required for effective health promotion; and
- Success with the initial topic/intervention generates a change in school 'health culture' and policies that lead to expansion of health promotion activity to address other community-identified issues.

There is also growing evidence that health education in an effective Health-Promoting School programme has the potential to benefit a broader community. The individual children in the schools benefit, and so do teachers and the school as a whole, but as knowledge and practices introduced in school 'ripple' out to involve siblings and parents, the broader community benefits from what they assimilate and adopt as a wider audience. In this way, children can effectively act as agents of health-promoting change on both the school and at a local community level if given sufficient guidance.⁴⁷ We have heard children in our Ugandan programmes proudly telling fellow pupils from other schools at sports events about their Health-Promoting School activities, and teachers now report to reviewers conducting national surveys of educational institutions, that having a Health-Promoting School 'culture' is an important educational attribute to their school.⁴⁸

Important learning outcomes are also derived from participation in Health-Promoting School programme delivery by those initiating and sustaining effective

47 Simovska, V. & Carlsson, M. 2012. Health-promoting changes with children as agents: findings from a multiple case study research. *Health Education*, 112(3):292-304. [https://doi.org/10.1108/09654281211217803].

48 Macnab & Kasangaki, 2012. Ross, D., Cannon, W., Macnab, A.J. & Kasangaki, A. 2009. Global health experience in Uganda: a unique platform for entering dental school. *Journal of Investigative Medicine*, 57:151-152.

programmes. Examples are the educational opportunities, skills, and experiences gained by trainees from multiple disciplines who participate in Health-Promoting School programme delivery and evaluation; many of whom report the positive impact this had on their future career choice and scope of practice.⁴⁹ Education that occurs in the context of a Health-Promoting School is a 'two-way street' and these schools 'teach' the members of such teams a range of valuable lessons.

Essential first steps for engagement and sustained implementation

The Stellenbosch consensus statement recognised the importance of:

- Respectful dialogue and inclusive engagement with stakeholders as an essential component in the implementation of a Health-Promoting School approach;
- Identifying the central role of teachers and learners and the benefit of investing in other stakeholders, including government ministries (particularly health and education);
- Meaningful involvement of the school community as a whole to ensure the development of a shared common vision and mission;
- Effective communication, empowerment and an enabling environment that leads to community ownership of the programme;
- Adopting an appreciative inquiry or strength-based stance when analysing opportunities for health promotion projects, as this is generally more successful than traditional analysis planning methods; and
- Recognition that Health-Promoting Schools are possible even when only one person sees the potential and acts to initiate the change and champion the cause, but the chances of success improve where strategic partnerships are forged with all individuals and agencies with the potential to contribute.⁵⁰

49 Macnab et al., 2010; Worley, P.S., Prideau, D.J., Strasser, R.P., Silagy, C.A. & Magarey, J.A. 2000. Why should we teach undergraduate medical students in rural communities? *Medical Journal Australia*, 712(12): 615-617. [https://doi.org/10.5694/j.1326-5377.2000.tb124131.x]; Dharamsi, S., Woollard, R., Okullo, I., Kendall, P. & Macnab, A.J. 2014. Health promoting schools as learning sites for physicians in training. *Health Education*, 114(3):186-196. [https://doi.org/10.1108/HE-09-2013-0048].

50 Macnab, 2013.

In the author's experience, it is the initial dialogue to establish rapport and mutual trust, followed by due diligence to ensure that the goals identified are relevant to the community and 'resonate' with the pupils and staff, that predicate the success or failure of a Health-Promoting School initiative. For example, oral health intervention in an Alaskan community failed despite being better funded and resourced than ours, because when the programme was initiated the community did not identify with the purpose or conduct of the health promotion offered. All the planning and funding had been organised in a 'top-down' process with the key step of community engagement omitted:

- Effective processes to combine factual learning with an introduction to healthy practices and behaviours within a supportive environment (these can involve individual and group activities, use a range of expression or experience. Health-promoting programmes can address specific disease entities and health behaviours and promote wellness;
- Inclusion of health education topics in the curriculum through collaboration by members of the Health Promotion agency with the school and the school's teachers. Agency members contribute the key health facts, and 'messages' and teachers add elements in the local language and culturally appropriate visual aids. Novel and participatory activities are encouraged;
- In-class activities where teachers introduce and then regularly revisit the health education topics to underscore key concepts, and use visual aids;
- Initiation of daily in-school health practices by teachers. In an oral health promotion programme, for example, participatory tooth brushing by the whole class at each lunch break to teach and reinforce correct brushing techniques;⁵¹
- Agreement about program support by the initiating agency and a communication strategy to address day to day issues necessary to maintain momentum and focus, as sustaining a programme to the point of self-sufficiency takes time and continuity of practical and emotional support; and
- A continuous cycle of evaluation and feedback to promote the identification of 'what works and why', healthy evolution of the programme and mutually planned future directions for the Health-Promoting School initiative.

51 Macnab, A.J. 2015. Children's Oral Health: The opportunity for improvement using The WHO Health Promoting School Model. *Advances in Public Health*, 2015(651836). [<https://doi.org/10.1155/2015/651836>].

Entry points for initiating Health-Promoting School activities

While the stated goal of the WHO's Health-Promoting School model is to create a whole-school approach that alters the health culture and ethos of the school, one of the challenges is that this 'whole school approach' is often beyond the resources of those wishing to start Health-Promoting School activities to enhance the health and educational outcomes of children.⁵² This challenge applies to both educators interested in initiating a community-based Health-Promoting School programme, and policymakers exploring Health-Promoting School as a means of disease prevention or vector control.⁵³ Consequently, activities focussing on a single health issue that has been successfully piloted is relevant, as these offer 'entry points' to begin Health-Promoting School programmes, 'engage' the school community, and allow evaluation of the potential for a school to progress towards a broader change in its 'health culture'. Through subsequent expansion from a single health-promoting activity, such a school can ultimately progress to a whole-school approach.⁵⁴

Entry points range from simple topics free of stigma to highly complex issues. Suggested topics included oral health, hygiene, nutrition, obesity, diabetes, resilience, clean-up campaigns, tuberculosis, mental health, injury prevention, and gender equity and reduction of gender-based violence. Entry points need to be identified by the community as achievable and relevant to their priorities and needs. Early success with the initial topic often leads to confidence to address other relevant issues. Although primary schools serve as ideal starting venues, preschools, primary, secondary and post-secondary schools all have potential to become Health-Promoting Schools (post-secondary schools include colleges, universities, and trade schools). Initiatives aimed at enabling teachers to become more health-conscious may also identify an effective entry point.

Promotion of oral health is an example of a previously reported entry point to address a specific issue that has proved successful in itself and generated high levels of community 'ownership' that have then provided the impetus for school-based programmes to be sustained and expanded.⁵⁵ Oral health has recognised importance during pregnancy. Hence this topic offers a relevant starting point for programmes intended to inform and engage youth about DOHaD. Oral health promotion programmes have been introduced and evaluated in the USA,

52 Nutbeam, 2000.

53 Laverack, G. & Labonte, R. 2000. A planning framework for community empowerment goals within health promotion. *Health Policy and Planning*, 15(3): 255-262. [<https://doi.org/10.1093/heapol/15.3.255>].

54 Macnab, Gagnon & Stewart. 2014a; Macnab & Kasangaki, 2012.

55 Macnab, 2015.

Canada and Africa, and include cohorts from amongst children from First Nations (predominant indigenous peoples in Canada south of the Arctic Circle) and school children in rural Uganda.⁵⁶ Such programmes are novel in the context of prior experience with Health-Promoting Schools in that they address a topic which is of major relevance yet carries no social stigma. Importantly, the intervention required is non-controversial, involves manageable amounts of information, and is amenable to simple healthy practices such as effective tooth brushing and dietary practice education to reduce sugar consumption. Evidence of clinical improvement and behavioural change should be evident in a relatively short time frame and validated quantitative methods, and robust qualitative measures exist for evaluation of programme effectiveness. These are all key elements characterising a suitable entry point for Health-Promoting School activity.

Any school wanting to begin Health-Promoting School activity can look at oral health promotion as a suitable topic, as poor oral health in children is a global issue, school-based intervention is simple, with the required knowledge and health practice components defined, and valid evaluation options published. Other potential entry points studied that are relevant to the introduction of DOHaD concepts of school-age children include growth, nutrition and physical activity.

Growth

The growth patterns of individual children, and trends in the data from a community, reflect their health and nutritional status and are important health indices. We evaluated school children enrolled in a collaborative health-promotion programme in rural Uganda. Height, weight, and head circumference were measured and plotted against age-matched WHO child growth standards.⁵⁷ The WHO charts use data from multi-ethnic sampling (populations from six countries) to capture the genetic variability among continents and generate a single international growth standard. The concordance of this standard with clinical assessments underscores that this tool documents differences in nurture rather than nature, and hence enables disparities in physical growth to be determined,

56 Macnab & Kasangaki, 2012; Kwan et al., 2005; Worthington, H.V., Hill, B.A., Mooney, J., Hamilton, F.A. & Blinkhorn, A.S. 2001. A cluster randomized controlled trial of a dental health education program for 10-year-old children. *Journal of Public Health and Dentistry*, 61(1):22-27. [<https://doi.org/10.1111/j.1752-7325.2001.tb03351.x>]; Macnab, A.J., Rozmus, J., Benton, D. & Gagnon, F. 2008. 3-year results of a collaborative school-based oral health program in a remote First Nation's community. *Rural and Remote Health*, 8:882. [<http://www.rrh.org.au>].

57 WHO: Multicentre Growth Reference Study Group. 2006. The WHO child growth standards based on length/height, weight and age. *Acta Paediatrica Supplement*, 450:76-85. [https://www.who.int/childgrowth/standards/Growth_standard.pdf].

providing a basis for appropriate community-based intervention (social, dietary, nutritional) and changes in healthcare policy.⁵⁸

Nutrition

Deficiencies in calorie consumption and sub-optimal dietary content are known to be key determinants of health worldwide and impair average growth and life expectancy. Importantly, a lack of key nutrients also causes significant learning difficulties that are remediable with appropriate dietary adjustment. Amongst 6-12-year-old children, food insufficiency is known to be associated with poorer mathematics scores, grade repetition, absenteeism, aggression, psychosocial dysfunction and difficulty getting along with other children.⁵⁹ A 24-hour validated dietary recall questionnaire was used that allows investigation of dietary diversity as a proxy measure of nutritional adequacy. The tool can be modified to incorporate local foods; a component we utilised as our study cohort lived in Africa.

The ease of collecting growth data and ability to use the WHO child growth standards to identify where a child would benefit from interventions to promote appropriate nurture make this a particularly valuable Health-Promoting School activity and one that is relevant world wide.⁶⁰ School communities can take ownership of the data on their pupil's growth data and use it to drive further health promotion activities deemed relevant and appropriate for the local community. For example, it is also a way of teaching children about growth charts and the issue of optimal weight gain in infants, and an opportunity to introduce the importance in the first two years of life for infants of sustained growth along their birth centile, and avoidance of both stunting and obesity. Schools can be taught to monitor the effects of both dietary deficiency and excess in pupils. The high percentage of children with below-average height and weight measurements (below the 50th centile) in the community we studied most probably reflects the impact of local social circumstances, sub-optimal nutrition, and infectious disease. At the school, we studied the parents independently chose to initiate a lunch programme to improve pupil's nutrition using produce grown in a garden that they decided to plant. This decision was the direct result of us sharing with them the information about their children's growth gathered by the school's Health-Promoting School programme, and having the negative impact of poor nutrition on educational

58 Onyango, A.W., De Onis, M., Caroli, M., Shah, U., Sguassero, Y., Redondo, N. & Caroli, B. 2007. Field-testing the WHO growth standards in four countries. *The Journal of Nutrition*, 137(1):149-152. [<https://doi.org/10.1093/jn/137.1.149>].

59 Jyoti, D.F., Frongillo, E.A. & Jones, S.J. 2005. Food insecurity affects school children's academic performance, weight gain, and social skills. *The Journal of Nutrition*, 135(12):2831-2839. [<https://doi.org/10.1093/jn/135.12.2831>].

60 WHO: Multicentre Growth Reference Study Group, 2006.

potential explained. This community 'ownership' of data and independent community-based action that results is an important reminder of how Health-Promoting Schools can drive positive change. This benefit can extend beyond the target school; other schools in the surrounding area have now planted similar gardens and initiated lunch programmes to supplement the diets of malnourished pupils; further evidence of the potential for Health-Promoting School initiatives to generate benefit in the broader community.

It is also important to note that the potential health benefits related to a school garden go beyond nutritional benefits related to the provision of vegetables to supplement a feeding scheme. As related research shows, there are physical, mental and emotional benefits related to providing children with opportunities to become involved with gardening and experience exposure to nature.⁶¹ These broader health benefits should not be overlooked; key findings of a systematic review of the international literature and survey of 1 300 UK learning institutions, are summarised in The Royal Horticultural Society Taskforce report 'Food Growing in Schools'.⁶² It was found that through participation in school food-growing programmes children developed a broad range of skills that included: life skills (cooking and communication), financial and enterprise skills, and skills for employment, e.g. teamwork, and problem-solving. Also that these programmes improved pupil's confidence, resilience, and self-esteem, and positively influenced motivation and behaviour, with increased enthusiasm for school and learning, and better attendance and completion of homework. Behaviour was better in and out of the classroom, and environmental awareness and pro-environmental behaviours were enhanced. Broad benefits were also noted in achievement across the curriculum, particularly for science learning, as well as language skills, maths and food technology, and overall there was greater readiness to learn. In a one-year programme involving six West Yorkshire schools, 84 per cent of students increased their skills, learning on average 15 new ones during the project. Vulnerable children with special educational needs also benefit from gardening in school, often 'finding their voice and re-engaging with education'.⁶³

61 Charles, C. & Louv, T. 2009. Children's Nature Deficit: What we know – and don't know. *Children and Nature Network*. [https://bit.ly/2Qgs0AG]; Moss, S. 2012. *Natural Childhood*. Report of the National Trust, UK. [https://bit.ly/2EeyWeK].

62 Nelson et al., 2001; Harrison, R., Duffy, D., Benton, D. & Macnab, A.J. 2006. 'Brighter Smiles': Health promotion and service-learning in a remote First nation's community. *Canadian Journal of Public Health*, 97(3):237-240. [https://bit.ly/3laBHy5]; Henry Doubleday Research Association. 2012. Food Growing in Schools – Taskforce Report. *Garden Organic*. Full Report. 1-66. [https://bit.ly/3l9LTaa].

63 Royal Horticultural Society. 2012. Moving up, growing on: Gardening for a better future. [https://bit.ly/3gkvBYh].

The use of a dietary diversity questionnaire can add to the evaluation of growth parameters or be conducted as an independent activity. One such tool, included in guidelines from the Food and Agricultural Organisation of the United States, provides a quick, easy, and objective way of identifying potential nutritional concerns, with modification possible to include classification of locally predominant foods.⁶⁴ Hence this activity has broad relevance worldwide, and specific applicability for education related to DOHaD dietary concepts. Results can guide nutrition education and evaluate changes in dietary practices over time. While energy intake amongst the children we studied appeared adequate, the lack of dietary diversity identified places them at risk of nutrient deficiencies, including those associated with a compromised ability to read and learn. Education and resources on how to improve their nutrition were provided to their adult caregivers. Follow up one year later indicated that food variety had increased, with more fruit and milk products added.

Physical activity

Physical inactivity is a growing public health concern and increasingly linked to preventable conditions such as obesity. Obesity and the association with the increasing prevalence of type 2 diabetes make Health-Promoting School initiatives linked to physical activity relevant to introducing children to the fundamentals of DOHaD, and links between weight issues and non-communicable diseases. A review of worldwide trends in childhood overweight and obesity using data on school-age populations in 25 countries and for pre-school populations in 42 countries reported that the prevalence of childhood overweight has increased in almost all countries for which data are available.⁶⁵ While obesity and overweight have increased most dramatically in economically developed countries and urbanised populations, estimates indicate that within the next 20 years, morbidity and mortality in Africa, because of diabetes, will be a higher than from malaria. A reminder that no population is immune and innovative programmes and policies are known to be needed at global, regional and national levels to confront the problem. In this context, as with all other Health-Promoting School initiatives, dialogue to ensure relevance and planning by groups that include youth representatives, are essential to achieve the 'resonance', community-engagement and ultimate community-ownership necessary for any Health-Promoting School-based initiative

64 Kennedy, G., Ballard, T. & Dop, M. 2013. *Guidelines for measuring household and individual dietary diversity*. Food and Agricultural Organization of the US Nutrition and Consumer Protection Division. [http://www.fao.org/3/a-i1983e.pdf].

65 Wang, Y. & Lobstein, T. 2006. Worldwide trends in childhood overweight and obesity. *International Journal of Pediatric Obesity*, 1(1):11-25. [https://doi.org/10.1080/17477160600586747].

to succeed. Importantly, it has been shown from multiple case study research that children can act as agents of change on both a school and community level in programmes aimed at preventing obesity, provided they are engaged effectively and given sufficient guidance.⁶⁶

Methods of evaluation

While there is consensus that “the existing evidence can guide stakeholders in designing and implementing Health-Promoting School programmes that are both effective and cost-effective, it is also clear that there is a need for more robust evidence and methods for evaluating a broader range of long-term outcomes”.⁶⁷

Comprehensive and pluralistic evaluation methodology and independent evaluation have been called for, and Dooris has identified that for evidence to be useful, it should not only demonstrate what works, but how and under what conditions it works.⁶⁸ To date, most Health-Promoting School programmes have only been evaluated using some of the recommended elements. However, a broad range of measures and principles have been used, and many can be applied in evaluation beyond the ones for which they were originally employed. Examples include many of the following measures used originally to evaluate oral health programmes.⁶⁹

Quantitative indices

These where available are the ‘gold standard’; many tools exist that can be applied verbatim or used in a modified form.⁷⁰ Cohorts can be evaluated at baseline before programmes begin, and then annually after that. Appropriately collected and analysed such data are robust and allow valid comparisons to be made within and between national cohorts, and even with international data sets.

66 Simovska & Carlsson, 2012.

67 Macnab, 2013.

68 Mukoma & Filsher, 2004; Lister-Sharp et al., 1999; Petersen, P.E. & Kwan, S. 2004. Evaluation of community-based oral health promotion and oral health disease prevention – WHO recommendations for improved evidence in public health practice. *Community Dental Health*, 21(Supplement 4):319-329. [https://bit.ly/3kmbpYa]; Dooris, M. 2006. Health promoting settings: future directions. *Promotion and Education*, 13(1):4-6. [https://bit.ly/3kfmPNm].

69 Macnab, 2015.

70 WHO. 1987. Oral health surveys: Basic methods. 3rd edition. Geneva. pp.4-6.

Questionnaires

These document demographics, collect quantitative data on knowledge and behaviours, and responses to specific questions can be obtained at baseline and from interval repeat surveys. An example is a simple yet elegant tool for evaluating hand washing as a means of improving hygiene.⁷¹ Other examples include measures of quality of life.⁷² Accuracy can be improved by teachers being involved in the wording of questionnaires designed to ensure appropriate language level and terms, and where necessary having them translate the questions into the local language or be present to explain the meaning and interpret pupils’ responses. One limitation of questionnaire data in Africa is that many children do not know their birthdate.

Self-report

Open-ended questions often yield valuable and unanticipated responses. These can be content coded or used as qualitative data. For example, when asked what changes our Health-Promoting School programme had made regarding their oral health, the predominant response from children was that their mouths no longer ‘smelled bad’. This observation, although subjective, is relevant as it equates with the reduced incidence of gingivitis documented.⁷³

Interviews

While time-consuming, this form of evaluation is well tried and tested. Interviews with teachers evaluate what benefits or barriers they saw from becoming a Health-Promoting School. The evidence of transfer of knowledge by children to other family members and the community at large is also principally gathered in this way, as are statements regarding confidence gained from success with Health-Promoting School programmes. We have also previously reported the value of a video interview process.⁷⁴

71 Zang, C., Mosa, A.J., Hayward, A.S. & Matthews, S.A. 2013. Promoting clean hands among children in Uganda: A school-based intervention using ‘tippy-taps’. *Public Health*, 127(6):586-589. [https://doi.org/10.1016%2Fj.puhe.2012.10.020].

72 Gherunpong, S., Tsakos, G. & Sheiham, A. 2004. Developing and evaluating an oral health-related quality of life index for children: the CHILD-OIDP. *Community Dental Health*, 21(2):161-169. [https://bit.ly/31qhWLj].

73 Quirynen, M., Dadamio, J., Van Den Velde, S., De Smit, M., Dekeyser, C., Van Tornout, M. & Vanderkerckhove, B. 2009. Characteristics of 2000 patients who visited a halitosis clinic. *Journal of Clinical Periodontology*, 36(11): 970-975. [https://doi.org/10.1111/j.1600-051X.2009.01478.x].

74 Macnab, A.J., Kasangaki, A. & Cannon, W. 2012. Videotaped interviews as medium to enhance program evaluation, *Health Promotion International*, 27(1):63-73, [https://doi.org/10.1093/heapro/dar039].

Workshops/parental groups

A range of project stakeholders can be brought together in this way. Such sessions provide an opportunity to share results, obtain feedback of the impact, relevance, and future potential for Health-Promoting School programmes, and hear counterpoint between the school, family and community viewpoints. Such dialogue to share results and plan future directions is particularly valued.

These are all valuable evaluation measures. However, it needs to be remembered that in addition to asking the right question(s) and choosing the best tool(s), enough time has to be allowed for the effectiveness of any Health-Promoting School programme to become apparent. It is also vital to engage with policymakers to plan evaluation relevant to future policy and practice; and in this context to generate evidence of “what works, why it works, and under what conditions it works”.⁷⁵ An element found to help in the process of review is the instigation of award schemes that assess the performance of a school against defined Health-Promoting School themes and provide schools with targets to achieve. Examples are those described from the UK and Hong Kong.⁷⁶ Lee has identified the benefits and also the significant human resources and cost associated with award schemes, and has now developed a self-assessment version.⁷⁷

Opportunities for novel approaches

The WHO’s Health-Promoting School model is inherently flexible; the most dynamic programmes evolve spontaneously and lend themselves to opportunities for innovation.

- Institutes of higher learning can both support and become Health-Promoting Schools.
- Health-Promoting Schools offer a novel 'real world' environment for trainees from institutes of higher learning.
- Innovative use of technology, such as social media, can communicate success, motivate participants and contribute to engagement.
- A virtual ‘wall’ on which participants share stories and photographs can empower schools and inspire for new approaches.

75 Dooris, 2006.

76 Moon et al., 1999; Lee et al., 2007a

77 Lee et al., 2007b.

- Lead focussed discussion sessions with pupils. Including participating children, and especially adolescents, in all phases of design and delivery, adds valuable insight, increases potential relevance and often provides novel opportunities.
- Lead focussed discussion sessions with pupils. This form of dialogue has established that pupils identify the economic benefits of having healthy offspring as a powerful potential incentive for youth to engage in DOHaD-based health promotion.⁷⁸ Similarly asking pupils whom they would listen to as ‘messengers’ for DOHaD health promotion has identified the impact of celebrities endorsing messages through the medium of music videos.⁷⁹
- Forge alliances between government departments and agencies to include multiple disciplines, professionals and sectors. Such ‘bridging strategies’ are one of the most powerful factors influencing the success of Health-Promoting Schools, as such alliances promote healthier public policy as well as more cost-effective, equitable and higher quality collective action to promote wellness.

Future directions

The application of DOHaD science in Africa to impact NCDs and improve health across generations requires investment in the long term;⁸⁰ investment to develop relationships, forge partnerships, establish common ground, and generate synergy. Clearly it will take several years for effects of life-course education programs employing the Health Promoting School model to be evident, and longer still for their full impact to be realized.

To have any chance of success, the culture and merits of Health-Promoting Schools will need to be understood and embraced at a government level by the education sector to have any chance of success. Ideally, participation in the WHO’s Health-Promoting School programmes will come to be seen as a creative educational opportunity with independent merit and broad benefits, rather than an imposed

78 Macnab & Mukisa, 2018.

79 Macnab, A.J. & Mukisa, R. 2018. Celebrity endorsed music videos: innovation to foster youth health promotion. *Health Promotion International*, 34(4):716-725. [https://doi.org/10.1093/heapro/day042].

80 Norris, S.A., Balasubramanian, D., Byass, P., Kimani-Murage, E. & Macnab, A.J., Pauw, C., Singhal, A., Yajnik, C., Akazili, J., Levitt, N. 2017. Understanding and acting on the developmental origins of health and disease in Africa would improve health across generations. *Global Health Action*, 10(1):1334985. [https://doi.org/10.1080/16549716.2017.1334985].

process that adds duties and responsibilities to an already overburdened school system. Where broad or system-wide school-based health promotion is adopted, the creation of a central resource agency that aids and facilitates all elements of the process is a constructive approach, as is evident in practices in Scotland and Hong Kong, and in some of the English and Australian models.⁸¹

Teachers will be needed who understand the goals and potential of Health-Promoting Schools; such individuals will participate more fully and be more likely to sustain their commitment. Those who speak to the attraction of this form of health promotion among educators say that success with an effective Health-Promoting School initiative generates confidence, raises the stature of the school, and almost always motivates communities to address new health promotion issues. However, to be successful in the context of DOHaD will require communities firstly to gain an understanding of the scale and importance of DOHaD-related issues. Then, in schools where confidence and ownership can be generated, the WHO's Health-Promoting School model offers opportunities to engage youth in education regarding the DOHaD agenda.

Society's understanding of DOHaD and the potential for school-based programmes to have a positive impact can perhaps be fostered by what is already known about the benefits of education. Education is the pathway to progress in many aspects of life, particularly in low and middle-income countries, including improved health. Any process that promotes a desire for education and keeps children in school to complete their studies contributes to future health and prosperity. While education of both boys and girls is essential in the context of DOHaD, promoting the education of girls is an example of probably the best investment that can be made globally.⁸²

Women derive multiple health benefits from being educated. One example is that motivating girls to stay in school longer, results in delayed childbearing and thus better obstetric and child health outcomes.⁸³ Hence, educated women have smaller

families, and development opportunities for their families and entire societies grow with a decline in birth rates.⁸⁴

The children of educated mothers also have significant advantages. Infant survival is more dependent on the level of maternal education than the income of the household.⁸⁵ A mother who can read and write is more likely to have her children immunised than one who is uneducated, and also to understand the importance of clean water and how to prevent diarrhoeal diseases better. Completion of six years of maternal schooling is associated with lower odds of a mother's children developing malarial parasitaemia, particularly in rural areas, in eight sub-Saharan countries.⁸⁶ And not only does a child of an educated mother have fewer siblings and tend to be healthier, he/she also has a higher likelihood of attending school, and will have more active maternal encouragement to do so.⁸⁷

Countries that are achieving lower birth rates today can invest more in their young people. Such investment can include additional education and programmes related to the understanding of DOHaD-related health issues, provided governments are part of the DOHaD awareness equation. Potentially, future generations will then profit from improved health and a reduction in non-communicable diseases, and in turn become part of the cycle of continuously improving opportunities for education, better health, and increasing levels of productivity.

As identified by the Berlin Institute for Population and Development, countries must recognise education to be the key factor for long-term progress with their development. Human capital increases through education, and it is a proven means of decreasing both morbidity and mortality. People empowered by education are better able to provide for their wellbeing, including their health and economic progress, and therefore are a benefit to society as a whole.⁸⁸

Hence the relevance of education to the DOHaD agenda, and the potential of Health Promoting Schools as an avenue for delivery.

81 Macnab, Gagnon & Stewart, 2014a.

82 Pentecost et al., 2018; Davies, J.I., Macnab, A.J., Byass, P., Norris, S.A., Nyirenda, M., Singhal, A., Sobngwi, E. & Daar, A. 2018. Developmental Origins of Health and Disease in Africa – influencing early life. *Lancet Global Health*, 6(3):e244-e245. [https://doi.org/10.1016/S2214-109X(18)30036-6]; Sippel et al., 2011.

83 Wolf, S., McCoy, D.C. & Godfrey, E.B. 2016. Barriers to school attendance and gender inequality: Empirical evidence from a sample of Ghanaian schoolchildren. *Research in Comparative and International Education*, 11(2):178-93. [https://doi.org/10.1177/1745499916632424].

84 Sippel et al., 2011.

85 Vergnani et al., 1998.

86 Siri, J.G. 2012. The independent effects of maternal education and household wealth on malaria risk in children. International Institute for Applied Systems Analysis. *Ecology and Society*, 19(1):33. [http://doi.org/10.5751/ES-06134-190133].

87 Mare, R. & Maralani, V. 2005. *How do women's educational attainments affect the educational attainment of the next generation?* California Center for Population Research. [https://escholarship.org/uc/item/4b41k472].

88 Sippel et al., 2011.

Conclusion

Health promotion using the WHO's Health-Promoting School model provides both knowledge and practical skills that enable individuals and the communities they live in to impact key determinants of health positively. Those who are knowledgeable and skilled can avoid many illnesses and injuries, and are more likely to choose a lifestyle and practices that decrease their dependence on government-funded healthcare delivery and therefore the WHO advocates Health-Promoting Schools as an investment in global child health. There is an urgent need to educate our young people about the DOHaD agenda and promote in them knowledge and behaviours aimed at reducing the global burden of non-communicable diseases. The evidence on health promotion through schools is that this is an avenue that is relevant to the context of DOHaD, and hence should be further explored and promoted wherever appropriate.



13

AN APPROACH TO REDUCE THE BLINDNESS BURDEN IN SUB-SAHARAN AFRICA: SPECIAL FOCUS ON CHILDHOOD BLINDNESS

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Sub-Saharan Africa is afflicted with high levels of blindness burden, affecting the quality of life and productivity of its people. While cataracts account for over 40 per cent of blindness, uncorrected refractive error leading to vision loss is over 50 per cent. The number of ophthalmologists and optometrists in the region, who can restore vision by surgery, and provide corrective eyeglasses for uncorrected refractive error, respectively, is woefully inadequate. However, most of these countries have primary health care centres. Workers in these centres have played remarkably successful roles in working with professionals in helping to reduce the burden of blindness due to onchocerciasis and trachoma.

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 - 4 Hyderabad Eye Research Foundation; Stellenbosch Institute for Advanced Study, Wallenberg Research Centre at Stellenbosch University, Stellenbosch, South Africa.

In this chapter, encouraged by these success stories, we suggest that primary health care workers (and recruits from rural areas) be trained for set periods to become what is called Vision Technicians, who will acquire the three R's, namely:

- Recognise the blinding condition.
- Refract and estimate the level of uncorrected refractive error in people and offer corrective eyeglasses.
- Refer patients who need higher levels of care to the nearest hospital for management.

The recruitment and deployment of Vision Technicians can drastically reduce vision deprivation due to uncorrected refractive error; in particular, it can be expected to boost literacy, education and future development of children, and the productivity of adults. In sub-Saharan Africa, the growing popularity of mobile phones and internet access, now makes inter-tier connectivity possible, and organising Vision Technicians, optometrists and ophthalmologists in this way will help overcome the shortage of the latter two professionals to some extent. In addition, the availability of low-cost, high-resolution ophthalmic diagnostic devices will offer considerable economies in care.

A pyramidal model of rural eye care such as this has been tried with success at the LV Prasad Eye Institute, Hyderabad, India (see Figure 1). Hence we suggest an adaptation of this pyramidal model of eye care in order to improve the burden of blindness in Sub-Saharan Africa.



Figure 13.1 Pyramidal model of eye care delivery.

Introduction

Among the 17 United Nations (UN) 'Sustainable Development Goals', also called the '2030 Agenda', Goal 1 aims to end poverty in all its forms, Goal 3 aims to advance good health and well-being for people through universal health coverage, and Goal 17 wants partnership among nations to achieve all these goals. The UN's objective is to achieve these goals by the year 2030. In parallel, 'VISION 2020: The Right to Sight' wishes to eliminate avoidable blindness by the year 2020, two years hence; VISION 2020 is a joint initiative between the World Health Organization (WHO) and the International Agency for the Prevention of Blindness. The Sustainable Development Goals agenda and VISION 2020 are connected, since the burden of vision impairment, and blindness affects both individual and community health and happiness and also the economic growth of nations, due to the negative effect of the blindness burden on the economy.

Across the world, about 36 million people are blind (defined as visual acuity worse than 3/60), while 217 million suffer from moderate to severe visual impairment (MSV) which is visual acuity worse than 6/18 but better than 3/60 in the better eye (Bourne et al., 2017). Of the latter, 124 million have what is called uncorrected refractive error (needing corrective glasses to restore vision), and 65 million suffer from cataracts (opacification of the lens in the eye preventing light from focussing on the retina). The extent of children's blindness is estimated to be less than 0.1 per cent.

Of the two main causes of blindness, uncorrected refractive error is easily corrected. Rosamond Hutt points out that the world economy is robbed of 227 billion dollars every year due to lost productivity among adults who need glasses to correct their uncorrected refractive error.⁵ Providing affordable access to reading glasses alone would boost productivity by 34 per cent. Furthermore, since 80 per cent of all learning occurs through vision, providing corrective eyeglasses to children will boost literacy, education and future development. Hutt notes that "we are blind to the global cost of poor eyesight, but this can change".

Blindness burden in sub-Saharan Africa

It is against this background that we look at the blindness burden in sub-Saharan Africa, a rapidly growing and advancing subcontinent containing 12 per cent of the world population but two per cent of the world's gross domestic product. Economic advancement of sub-Saharan Africa has grown by five per cent per year

⁵ Hutt, R. 2016. We're blind to the global cost of poor eyesight. But this can change. *World Economic Forum: Global Agenda: Humanitarian Action*. [https://bit.ly/34nGZjY].

since 2000, compared to 2.4 per cent growth during the previous two decades. The population has grown by 2.7 per cent, life expectancy at birth rose to 56 years, and adult literacy has come up to 59.3 per cent. Economic growth increased from 1.4 per cent in 2016 to 2.4 per cent in 2017 and is estimated to be 3.1 per cent in 2018 and expected to grow to 3.7 per cent in two years.⁶

About 50 countries comprise sub-Saharan Africa. Among a population of about 1.06 billion, about 1.1 to 1.5 per cent are blind, and moderate and severe vision impairment affects about four per cent of the population. Across sub-Saharan Africa, 62 per cent of the 1.06 billion people are younger than 25 and 40 per cent younger than 15. Visual deprivation among children is of particular concern. The review by Bourne and colleagues (Flaxman, Braithwaite, Cicinelli, Das, Jonas, Keeffe, Kempen, Leasher, Limburg, Naidoo, Pesudovs, Resnikoff, Silvester, Stevens, Tahhan, Wong, Taylor and the Vision Loss Expert Group) points out that in 2015 in the central, eastern, southern and western parts of sub-Saharan Africa, uncorrected refractive error leading to blindness was about 13 per cent.⁷ Uncorrected refractive error leading to moderate and severe vision impairment accounted for 46-48 per cent, trachoma about 0.2 per cent in the central and southern parts, and around 3.4 per cent in the western part, but seven per cent in the eastern region of sub-Saharan Africa. Cataracts accounted for 35-45 per cent of the blindness burden, as earlier pointed out by Naidoo and colleagues (Gichuhi, Basáñez, Flaxman, Jonas, Keeffe, Leasher, Pesudovs, Price, Smith, Turner, White, Wong, Resnikoff, Taylor and Bourne), uncorrected refractive error leading to blindness in sub-Saharan Africa was 13-21 per cent and leading to moderate and severe vision impairment 45-53 per cent.⁸ Cataract related blindness was 31-35 per

cent and leading to moderate and severe vision impairment 16-20 per cent. Sub-Saharan Africa is also characterised by

... an inordinate amount of the global distribution of blindness, largely due to the high prevalence of neglected (infectious) tropical diseases such as trachoma (caused by the bacterium *Chlamydia trachomatis*) and onchocerciasis (river blindness caused by the parasitic worm *Onchocerca volvulus*, and transmitted by black flies breeding on riverfronts), with vision impairment ranking as one of the leading, and significantly preventable causes of disability.⁹

Children

Vision loss and deprivation among children is of particular concern. Besides being affected by infection-related causes, cataracts are of great concern. A cataract may be congenital (children are born with it) or developmental (appearing after the first year of life). It is estimated that in sub-Saharan Africa, about 90 000 children are cataract-blind, and about 19 000 children born every year with congenital cataract.¹⁰ Moreover, estimates from Malawi, Ethiopia, and South Africa suggest that refractive error, myopia, hypermetropia and astigmatism are prevalent to a notable extent (between 2.3-2.9 per cent) among school children in sub-Saharan Africa.¹¹ Several Asian countries have witnessed an increase in myopia as schooling and 'near work' increases.

Retinopathy of prematurity

It is also important to highlight an ophthalmic condition called Retinopathy of Prematurity, which is a pre-developmentally originating disorder. In many

6 Obulutsa, G. 2018. *Sub-Saharan Africa's economic growth to quicken to 3.1 pct in 2018 – World Bank*. Reuters, 18 April. [https://reut.rs/31onUwb].

7 Bourne, R.R.A., Flaxman, S.R., Braithwaite, T., Cicinelli, M.V., Das, A., Jonas, J.B., Keeffe, J., Kempen, J.H., Leasher, J., Limburg, H., Naidoo, K., Pesudovs, K., Resnikoff, S., Silvester, A., Stevens, G.A., Tahhan, N., Wong, T.Y., Taylor, H.R. & Vision Loss Expert Group. 2017. Magnitude, temporal trends, and projections of the global prevalence of blindness and distance and near vision impairment: a systematic review and meta-analysis. *Lancet Global Health*, 5(9), September:e888-e897. [https://doi.org/10.1016/S2214-109X(17)30293-0]; Bourne, R.R.A., Flaxman, S.R., Braithwaite, T., Cicinelli, M.V., Das, A., Jonas, J.B., Keeffe, J., Kempen, J.H., Leasher, J., Limburg, H., Naidoo, K., Pesudovs, K., Resnikoff, S., Silvester, A., Stevens, G.A., Tahhan, N., Wong, T.Y., Taylor, H.R. & Vision Loss Expert Group. 2017. Magnitude, temporal trends, and projections of the global prevalence of blindness and distance and near vision impairment: a systematic review and meta-analysis. *Lancet Global Health*, 5(9), September:e888-e897. [https://doi.org/10.1016/S2214-109X(17)30293-0].

8 Naidoo, K., Gichuhi, S., Basáñez, M.G., Flaxman, S.R., Jonas, J.B., Keeffe, J., Leasher, J.L., Pesudovs, K., Price, H., Smith, J.L., Turner, H.C., White, R.A., Wong, T.Y.,

Resnikoff, S., Taylor, H.R., Bourne, R.R. 7 Vision Loss Expert Group of the Global Burden of Disease Study. 2014. Prevalence and causes of vision loss in sub-Saharan Africa: 1990-2010. *British Journal of Ophthalmology*, 98(5):612-8. [https://doi.org/10.1136/bjophthalmol-2013-304081].

9 Bourne et al., 2017.

10 Courtright, P. 2012. Childhood cataract in sub-Saharan Africa. *Saudi Journal of Ophthalmology*, 26(1), January:3-6. [https://doi.org/10.1016%2Fj.sjopt.2011.10.006].

11 Msiska, V., Njuguna, M. & Kariuki, M. 2008. Magnitude and pattern of significant refractive errors in primary school children of Lilongwe, an urban district in Malawi. *East African Journal of Ophthalmology*, 14:9-41. [https://bit.ly/3hsFyoa]; Eth. J. Health Sci 2014, Alemu 2016; Naidoo, K.S., Raghunandan, A., Mashige, K.P., Govender, P., Holden, B.A., Pokharel, G.P. & Ellwein, L.B. 2003. Refractive error and visual impairment in African children in South Africa. *Investigative Ophthalmology & Visual Science*, 44(9), September:3764. [https://doi.org/10.1167/iov.03-0283].

countries across sub-Saharan Africa, preterm births (babies born before 32 gestational weeks, or weighing less than 1 250-1 500g) account for over 15 per cent of births.¹² Among the several developmental origins of ill health that preterm babies face, Retinopathy of Prematurity is important in the context of a vision of interest here. The baby's eye takes about three-four weeks post-birth to develop fully. It thus becomes important to screen these preterm babies at the neo-natal stage, diagnose Retinopathy of Prematurity, treat it and attempt to save vision. Several South African ophthalmologists have published standard screening and treatment procedures.¹³ Adoption of these procedures across sub-Saharan Africa will be important.

Courtright, Mathenge, Kello, Cook, Kalua and Lewallen have summarised the current methods of eye care in the continent and the kind of specialists available and used.¹⁴ Ophthalmologists provide most of the surgical services and management of several sub-speciality services. However, the number of ophthalmologists in sub-Saharan Africa is far fewer than the requisite number (at least one per at least 20 million people as opposed to one per 2.7 million).¹⁵ Mid-level eye-care personnel mostly consist of clinical officers and nurses who are specialised after

working in primary health for a few years. These are also personnel trained for varying durations from one to three years and are dedicated eye-care personnel. Some of the personnel are trained to perform cataract surgeries and are termed as 'non-physician cataract surgeons' in countries such as Tanzania, Malawi and Kenya.¹⁶ However, such non-physician cataract surgeons are not accepted in a few countries such as Nigeria, South Africa and Rwanda.¹⁷ Optometrists are a cadre of personnel mainly involved in the provision of refraction services. An optometrist is generally a high school graduate who has been trained for three or four years both in theory and practical areas at eye hospitals, and upon completion of the programme, awarded a bachelor's degree. They can work in hospitals or private practice and set up shops as 'opticians'. Although 17 established institutions in nine countries across sub-Saharan Africa offer optometry programmes and degrees, the number is suboptimal (3.7 optometrists per million population, as opposed to the desired 10 per million).¹⁸ Some ophthalmic clinical officers and nurses also provide refraction services. Essentially, refraction services form the second level of care in African countries. Primary eye care in Africa is provided as a large part of primary level health care centres by primary health care workers. The personnel usually form the 'first contact' for any eye-related conditions.

Any model of eye care that is aimed to address significant public health challenges, such as the ones seen in sub-Saharan Africa, should have three key components:

- Financial and geographic accessibility to eye care;
- A mechanism to route patients from a primary to a tertiary level of care; and
- Appropriately trained human resources available to deliver this form of eye care.

A policy paper by the International Agency for the Prevention of Blindness and the Situation Analysis of Optometry in Africa, and other similar reports, indicate the current availability of such resources and the distribution of human resources

- 12 March of Dimes, PMNCH, Save the Children & World Health Organization (WHO). 2012. *Born too soon: The Global Action Report on Pre-term Birth*. [https://bit.ly/3hqrfjE].
- 13 Visser, L., Singh, R., Young, M., Lewis, H. & McKerrow, N. 2013. Guidelines for the prevention, screening and treatment of retinopathy of prematurity (ROP). *South African Medical Journal*, 103(2), November: 116-25. [https://doi.org/10.7196/samj.6305]; Jacoby, M.R. & Du Toit, L. 2016. Screening for retinopathy of prematurity in a provincial hospital in Port Elizabeth, South Africa. *South African Medical Journal*, 106(6):598-601. [https://doi.org/10.7196/SAMJ.2016.v106i6.106663]; Kift, E.V., Freeman, N., Cook, C. & Myer, L. 2016. Retinopathy of prematurity screening criteria and workload implications at Tygerberg Children's Hospital, South Africa: A cross-sectional study. *South African Medical Journal*, 106(6):602-606. [https://doi.org/10.7196/SAMJ.2016.v106i6.10358]; Keraan, Q., Tinley, C., Horn, A., Pollock, T., Steffen, J. & Joolay, Y. 2017. Retinopathy of prematurity in a cohort of neonates at Groote Schuur Hospital, Cape Town, South Africa. *South African Medical Journal*, 107(1):64-69. [https://doi.org/10.7196/SAMJ.2017.v107i1.11226]; Mayet, I. & Cockinos, C. Retinopathy of prematurity in South Africans at a tertiary hospital: a prospective study. *Eye*, 20(1):29-31. [https://doi.org/10.1038/sj.eye.6701779].
- 14 Courtright, P., Mathenge, W., Kello, A.B., Cook, C., Kalua, K. & Lewallen, S. 2016. Setting targets for human resources for eye health in sub-Saharan Africa: what evidence should be used? *Human Resources for Health*, 14:11. [https://doi.org/10.1186/s12960-016-0107-x].
- 15 African Vision Research Institute, International Agency for the Prevention of Blindness (IAPB), International Centre for Eye Health & Sightsavers. 2014. *Addressing the eye health workforce crisis in Sub-Saharan Africa: Business as usual is not an option*. IAPB Policy Paper, October. [https://bit.ly/2EbTjzB].

- 16 Elish, E., Lewallen, S., Kalua, K., Courtright, P., Gichangi, M. & Bassett, K. 2014. Task shifting for cataract surgery in eastern Africa: productivity and attrition of non-physician cataract surgeons in Kenya, Malawi and Tanzania. *Human Resources for Health*, 12(Supplement 1):4. [https://doi.org/10.1186/1478-4491-12-S1-S4]; Lewallen, S., Etya'ale, D., Kello, A.B. & Courtright, P. 2012. Non-physician cataract surgeons in Sub-Saharan Africa: situation analysis. *Tropical Medicine & International Health*, 17:1405-1408. [https://doi.org/10.1111/j.1365-3156.2012.03084.x].
- 17 Elish et al., 2014.
- 18 Lewallen et al., 2012; Oduntan, O.A., Mashige, K.P., Kio, F.E. & Baoadi-Kusi, S.B. 2014. Optometric education in Africa: Historical perspectives and challenges. *Optometry and Vision Science*, 91(3):359-365. [https://doi.org/10.1097/OPX.000000000000153].

for accessing eye care in sub-Saharan Africa.¹⁹ It is evident that both these parameters are far from ideal, and there is a need for novel thoughts to address the present problem.

It is against this background that we need to look at ways and means to reduce the devastating blindness burden on this subcontinent, using both locally available methods and adapting successful models from regions elsewhere in the world with comparable economic and sociological backgrounds. With this aim, the comprehensive and analytical scoping review by Du Toit and colleagues (Faal, Etya'ale, Wiafe, Mason, Graham, Bush, Mathenge and Courtright, 2013) and the suggestions made therein are relevant.²⁰ They quote the International Agency for the Prevention of Blindness Primary Eye Care Working Group's definition, that:

Primary care for eye health is an integrated, participatory, and inclusive component of primary health care consisting of promotive, preventive, curative and rehabilitative services. It is delivered by the health workforce (formal and informal) in conjunction with community members, up to and including services at the front-line health facilities.²¹

Involving people at existing primary health care centres is possible in several ways. A notable and successful example of successful involvement of primary health care centres is the drastic reduction in the prevalence of *onchocerciasis* in the region, through the efforts of the African Programme for *Onchocerciasis* Control.²² With river blindness, while there is still some way to go before total elimination, there is

no denying the fact that this condition is no longer a significant threat to vision.²³ Likewise, the efforts to win over trachoma through the implementation of SAFE – Surgery, Antibiotics, Facial cleanliness and Environmental improvement – involved community participation through primary health care centres, and Ghana is now declared by the WHO to have eliminated trachoma.²⁴

We now need to ask whether frontline workers at the primary health care centres can be trained to look at eye health in at a more cohesive professional level, and offer advice and even possible first level treatment. It is with this in mind that we advocate training primary health care workers, who are present at every primary health care centre, to become Vision Technicians. As Willcox and colleagues (Peersman, Daou, Diakite, Bajunirwe, MUBangizi, Mahmoud, Moosa, Phaladze, Nkomazana, Khogali, Diallo, Maeseneer and Mant, 2015) point out, while additional resources are needed, it should be possible to use existing resources more cost-effectively.²⁵

Training a cadre of eye-care workers

When people come to primary health care centres for any eye-health needs, the priority is for staff to examine their eyes, test vision and record the data. The second is for some of these primary health care workers to be trained to:

- Recognise the vision-impairing, and common blinding conditions of the people referred to them.
- Refract with good accuracy and recommend/ dispense corrective spectacles.
- Refer the patient to a higher-level expert eye physician or ophthalmologist for management if needed.

19 Courtright et al., 2016; Oduntan et al., 2014; African Council of Optometry, Brien Holden Vision Institute, IAPB & Vision Aid Overseas. 2016. Situation Analysis of Optometry in Africa. *Optometry and Vision Science*, 91(3), March:359-65. [https://doi.org/10.1097/OPX.000000000000153];

20 Loughman, J., Moodley, V.R., Holden, B. & Naidoo K., University of Kwa-Zulu Natal & Dublin Institute of Technology, Brien Holden Vision Institute. 2014. Access to optometric education: Challenges in Sub-Saharan Africa. *Literacy Information and Computer Education Journal*, 5(3):1543-1549. [https://doi.org/10.20533/licej.2040.2589.2014.0218].

21 African Vision Research Institute et al., 2014.

22 Du Toit, R., Faal, H.B., Etya'ale, D., Wiafe, B., Mason, I., Graham, R., Bush, S., Mathenge, W. & Courtright P. 2013. Evidence for integrating eye health into primary health care in Africa: a health systems strengthening approach. *BMC Health Services Research*, 13:102. [https://doi.org/10.1186/1472-6963-13-102]. Tekle, A.H., Zouré, H.G.M., Noma, M., Boussinesq, M., Coffeng, L.E., Wilma, A., Stolk, W.A. & Remme, J.H.F. 2016. Progress towards onchocerciasis elimination in the participating countries of the African Programme for Onchocerciasis Control: epidemiological evaluation results. *Infectious Diseases of Poverty*, 5:66. [https://doi.org/10.1186/s40249-016-0160-7].

23 Kim, Y.E., Sicuri, E. & Tediosi, F. 2015. Financial and Economic Costs of the Elimination and Eradication of Onchocerciasis (River Blindness) in Africa. *PLoS Neglected Tropical Diseases*, 9(9):e000405. [https://doi.org/10.1371/journal.pntd.0004056].

24 Colebunders, R., Basáñez, M.G., Siling, K., Post, R.J., Rotsaert, A., Mmbando, B., Suykerbuyk, P. & Hopkins, A. 2018. From river blindness control to elimination: bridge over troubled water. *Infectious Diseases of Poverty*, 7(1):21. [https://doi.org/10.1186/s40249-018-0406-7]; Aryee, J. 2020. *Ghana poised to eradicate NTDs by 2030*. [https://bit.ly/2Qhqtuu]; Kokutse, F. 2018. Ghana makes history on trachoma in Africa. *SciDevNet*, 25 June. [https://bit.ly/32lopGr].

25 Willcox, M.L., Peersman, W., Daou, P., Diakite, C., Bajunirwe, F., Mubangizi, V., Mahmoud, E.M., Moosa, S., Phaladze, N., Nkomazana, O., Khogali, M., Diallo, D., Maeseneer, J.D. & Mant, D. 2015. Human resources for primary health care in Sub-Saharan Africa: progress or stagnation? *Human Resources for Health*, 13:76:1-11. [https://doi.org/10.1186/s12960-015-0073-8].

To provide primary health care workers with these skills requires hands-on training for about 12 months, after which he/she can be certified as a Vision Technician. Such integration of eye health into primary health services has been tried in Tanzania, albeit with limited success, and in India with better results.²⁶ A training programme for a Vision Technician would typically involve high school graduates who work at primary health care centres, or others from the community (and the 'first contact' volunteers). It would include six months of classroom training, followed by clinical and practical training under the supervision of experts in chosen eye hospitals for the next six months. The exit competencies of such Vision Technicians would be:

- demographic information/history recording;
- visual acuity assessment;
- refraction;
- slit-lamp examination;
- measurement of intraocular pressure; and
- direct ophthalmoscopy.

Such training programmes would enable a Vision Technician to do the three Rs:

- Recognise** the blinding conditions.
- Refract** and suggest/offer corrective glasses.
- Refer** the patient who needs greater care to the nearest eye hospital for treatment.

Equipped with these skills a well-trained Vision Technician can play a significant role; with such Vision Technicians appointed to primary health care centres, a

significant portion of uncorrected refractive error will be able to be handled at the primary level. Providing such care to children will boost literacy, achievement in education and future development.²⁷ Impaired vision due to uncorrected refractive error does not need an ophthalmologist or an optometrist to be corrected and restored.

Given the key roles that Vision Technicians and graduate optometrists are known to be able to play in eye-care delivery, we need to learn from existing models that have been successfully implemented elsewhere in countries and communities with resource settings comparable to those in sub-Saharan Africa. A second prerogative is to embrace the present and future technologies and innovations in such a way that they can be adapted for effective use under the conditions found in the countries across sub-Saharan Africa. One area with such innovation is the use of low-cost, high-resolution devices for diagnosis.

Using low-cost, high-resolution devices for diagnosis of eye conditions

Jolley, Mafwiri, Hunter and Schmidt (2017) have pointed out that integration of the kind of eye health care we suggest into primary health services has been tried in Tanzania, and that while the trained Vision Technicians could perform well, they were constrained by the lack of equipment for diagnosis and treatment.²⁸ This finding underscores that while the human resources need to be made available, resources for obtaining and installing the necessary equipment are also a critical factor. It is here that innovative low-cost, high-resolution diagnostic devices become useful. Many of these products were tested, and performance parameters compared to those used by ophthalmologists in their clinics. Bhattacharyya, Khor, Mc Gahan, Dunne, Daar and Singer cite some products such as intraocular lenses for cataract surgery and glasses.²⁹ A group called Smart Vision Labs in the USA lists several devices that can be attached to a person's Smartphone to help self-diagnosis of refractive power and to help in choosing the frame of choice for eyeglasses.³⁰ Satgunam, Datta, Chillakala, Bobbili and Joshi (2017) have devised low-cost equipment to record the perimeter of vision accurately in infants, and the group 'Srujana', based at the LV Prasad Eye Institute, Hyderabad, India, has produced

27 Hutt, 2016.

28 Jolley, E., Mafwiri, M., Hunter, J., Schmidt, E. 2017. Integration of eye health into primary care services in Tanzania: a qualitative investigation of experiences in two district. *BMC Health Serv Res.*, 17(1):823.

29 Rao, G.N. 2015. The Barrie Jones Lecture: Eye care for the neglected population: challenges and solutions. *Eye*, 29:30-54. [https://doi.org/10.1038/eye.2014.239].

30 Smart Vision Labs. 2017. *Vision Industry Disruptors!* March 14. [https://bit.ly/35lqGEs].

26 Willcox, M.L., Peersman, W., Daou, P., Diakite, C., Bajunirwe, F., MUbangizi, V., Mahmoud, E.M., Moosa, S., Phaladze, N., Nkomazana, O., Khogali, M., Diallo, D., Maeseneer, J.D. & Mant. D. 2015. Human resources for primary health care in Sub-Saharan Africa: progress or stagnation? *Human Resources for Health*, 13:76:1-11. [https://doi.org/10.1186/s12960-015-0073-8]; Jolley, E., Mafwiri, M., Hunter, J. & Schmidt, E. 2017. Integration of eye health into primary care services in Tanzania: a qualitative investigation of experiences in two districts. *BMC Health Services Research*, 17:823:1-12. [https://doi.org/10.1186/s12913-017-2787-x]; Rao, GN. 2004. An infrastructure model for the implementation of VISION 2020: the right to sight. *Canadian Journal of Ophthalmology*, 39(6), October:589-590. [https://doi.org/10.1016/s0008-4182(04)80023-1].

low-cost, high-resolution diagnostic devices in ophthalmology.³¹ Many of these have been tested at primary level eye-care centres and are seen to work very well. Examples include:

- the Phoropter, a portable device that allows the user to screen and measure the refractive status (spectacle power) of his/her eyes to within \pm one diopter, (cost less than one US dollar);
- the Bulls-Eye, a device that, when attached to a smartphone, allows the capture of the surface features of the human cornea allowing the examination of the topography of the cornea (cost less than 10 US dollars); and
- Open Indirect Ophthalmoscope, a handheld instrument that offers the fundus imaging of the patient, with an accuracy and resolution comparable to high-end fundus cameras, yet costing less than 800 US dollars.

The International Partnership for Innovative Healthcare Delivery quotes the adaptation of the LV Prasad Eye Institute model in Mexico.³² Thus, using them at primary health care centres and by Vision Technicians in sub-Saharan Africa, in place of the far more expensive equipment used in eye hospitals, would save a considerable amount of money and yet yield high-quality diagnostic data [<http://www.lvpei.org/services/innovation>].

Using mobile phones, internet, and related technology for vision care in sub-Saharan Africa

Even as efforts are being made to increase the number of optometrists, it should be possible to initiate the Vision Technician programmes, connect them with the optometrists in their country through electronic means, and also to the ophthalmologists. African populations have taken to internet usage enthusiastically. In 2018, the total number of internet users in the continent was estimated to be over 453 million, roughly every alternate person.³³ Mobile phone penetration rates

31 Bhattacharyya, O., Khor, S., Mc Gahan, A., Dunne, D., Daar, A.S. & Singer, P.A. 2010. Innovative health service delivery models in low and middle-income countries – what can we learn from the private sector? *Health Research Policy and Systems*, 15;8(24):1-11. [<https://bit.ly/2UizR24>]; [<http://srujana.lvpei.org/>].

32 Satgunam, P., Datta, S., Chillakala, K., Bobbili, K.R. & Joshi, D. 2017. Pediatric Perimeter: a novel device to measure visual fields in infants and patients with special needs. *Translational Vision Science and Technology*, 6(3). [<https://doi.org/10.1167/tvst.6.4.3>].

33 Singhal, M., Moe, J. & Bartlett, R. 2013. Replicating Indian Eye Care Innovation in Mexico: The founding and expansion of salaUno. *International Partnership for Innovative Healthcare Delivery*. Case Study 102. [<https://bit.ly/3aQNPzD>].

have reached 80 per cent across the continent, and as the World Bank report in 2014 noted, more Africans now have a mobile phone than a toilet. Fast internet access has also been rapidly improving. Some ophthalmic clinicians are already using mobile phones to capture the image and examine the retina of Retinopathy of Prematurity patients.³⁴

Given this emerging advantage and the fact that more and more youngsters across Africa are now using electronic communications towards healthcare, we suggest the promotion of this connectivity and information exchange across the tiers of eye care (primary health care centres, Vision Technicians, optometrists, non-physician cataract surgeons and ophthalmologists located in regional, private, mission hospitals and ophthalmic clinics across the country).³⁵

Electronic media could also be used to promote periodic cataract surgery ‘camps’. Such camps involve transporting cataract-needy patients to the nearest centre where cataract surgery can be done, and coordinating what may be called periodic ‘cataract camps’. Given that surgical management of childhood cataracts has improved over time, such cataract camps are worth considering.³⁶ Electronic communication can also offer, and avenue to improve post-operative care such that any potential complications, such as infection are reduced or even avoided.

Conclusion

Given that a major portion of childhood blindness in sub-Saharan Africa is due to uncorrected refractive error, cataract and corneal infection, and specialist resources on the continent are limited, an inter-tier programme for eye care based on successful models elsewhere would be well worth attempting. A successful, working example of this kind of pyramidal model of inter-tier training and information transfer, real-time monitoring of collaborative, interdisciplinary activities, treatment and clinical practice is at the LV Prasad Eye Institute in Southern India, a non-government, not for profit eye care institution. It caters to a population of over 90 million people, 70 per cent of them are semi- or illiterate and they live in rural areas with not-so-efficient primary health care centres; the model this institute offers has successfully delivered quality eye care to over 24 million people over the last 30 years.³⁷

34 Internet World Stats. 2020. *Internet Penetration in Africa 2020 - Q1 - March*. [<https://www.internetworldstats.com/stats1.htm>].

35 Oluleye, T.S., Rotimi-Samuel, A. & Adenekan, A. 2016. Mobile phones for retinopathy screening in Lagos, Nigeria, sub-Saharan Africa. *European Journal of Ophthalmology*, 26(1):92-94. [<https://doi.org/10.5301/ejo.500006666>].

36 Courtright, 2012.

37 Rao, 2015.

Acknowledgements

Dorairajan Balasubramanian thanks the Indian National Science Academy for travel support and the Stellenbosch Institute for Advanced Studies for a Fellowship.



14

SCHOOL-BASED INITIATIVES TO REDUCE MALARIA MORBIDITY AND PROMOTE ACADEMIC ACHIEVEMENT IN CHILDREN

Andrew J Macnab¹

In sub-Saharan Africa, the challenge of addressing illnesses related to the developmental origins of health and disease (DOHaD) is compounded by other determinants of health, most notably the impact of poverty and infectious disease. Research has identified social factors to be the root cause of inequities in health that involve both non-communicable and infectious diseases, hence the calls for remedial action to involve social and treatment strategies.

There is a recognised need for school programmes to educate the next generation about DOHaD, so that young people gain a measure of ‘health independence’ through learned knowledge, acquired skills and positive behaviours with the potential to improve the future health of their offspring. However, this goal is at risk when other adverse social determinants of health exist, and especially where

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infectious diseases are endemic, and morbidity from infection among school children is high. In sub-Saharan Africa, for example, malaria is the principal reason a child will be absent from school. How long a child is absent is a well-accepted measure of the severity of morbidity from malaria. Such absences can be of long duration, and associated residual cognitive compromise can compound the negative impact of malaria on a child's ability to learn.

For this reason, school-based strategies to advance knowledge about DOHaD in sub-Saharan Africa will benefit where school-based programmes addressing malaria are offered in parallel. A variety of educational approaches able to advance knowledge and provide practical skills related to DOHaD lend themselves to parallel programmes. For example, programmes can follow policies to advance the United Nations (UN)' 'Sustainable Development Goals', adopt global strategies to promote the education of girls and implement the World Health Organization (WHO)'s 'Health-Promoting School' model. Malaria morbidity exemplifies how health inequity can negatively impact a child's ability to benefit from education. However, simple and effective school-based approaches exist that can positively impact morbidity, provide access to diagnostic and treatment services, reduce absence due to illness and increase the capacity of large numbers of children to learn.

This chapter reviews global efforts to reduce the impact of malaria on children's health, improve their ability to attend school, enhance their potential for academic achievement and minimise their risk of cognitive impairment. It also describes a successful and inexpensive community participatory intervention model based on WHO-endorsed diagnostic and treatment principles, that also follows the 2017 Lancet Commission's current recommendations on the future of health in sub-Saharan Africa to use 'non-traditional outlets', 'people-centred approaches' and 'improved tools' to address health challenges. This model is suitable for use in schools worldwide where malaria is endemic and can be offered in parallel with school-based strategies to engage youth in the context of the DOHaD agenda.

Introduction

The gross inequalities in health that we see within and between countries present a challenge to the world. A burgeoning volume of research identifies social factors at the root of much of these inequalities in health. Social determinants are relevant to communicable and non-communicable disease alike.²

2 Marmot, M., Friel, S., Bell, R., Houweling, T.A. & Taylor, S. 2008. Closing the gap in a generation: health equity through action on the social determinants of health. *The Lancet*, 372(9650):1661-1669. [[https://doi.org/10.1016/S0140-6736\(08\)61690-6](https://doi.org/10.1016/S0140-6736(08)61690-6)].

Globally, malaria kills more than one million people a year, and perhaps closer to three million when the role of malaria in deaths related to other disease is included. Much mortality in endemic areas is concentrated among children under the age of five years. The number of school-aged children (five to 14 years) who die from malaria is unknown, but in many low- and middle-income countries worldwide, malaria is cited to be the principal reason why a child will be absent from school.

The duration of malaria-related absence, frequency of absence due to repeated infection, residual malaise from sub-optimal treatment and temporary or permanent neurological complications of falciparum malaria are all known to compromise a child's potential to learn. School-age children however have attracted relatively little attention as a group in need of special measures to protect them against malaria. Significantly, it is also anticipated that in coming years there will be an increase in the incidence of both uncomplicated and severe malaria in schoolchildren in previously high endemic areas, because of the tendency for this age group to acquire immunity later in life.

The burden of disease from malaria is greatest among children in low resource settings. Poverty and malaria are inextricably linked. Poverty is concentrated in the tropical and sub-tropical zones where malaria thrives. Poverty per se may promote malaria transmission; malaria may cause poverty by impeding individual and societal economic growth – most likely, causality runs in both directions.

Schools promoting health, including those which use the WHO's Health-Promoting School model, provide opportunities within the formal curriculum to increase 'knowledge' and promote 'healthy practices,' hence the relevance of this model for engaging youth in the context of a range of socially relevant health issues, including the current epidemic of non-communicable diseases, like type 2 diabetes and heart disease. While many schools in Africa include education related to health, the ability of pupils to benefit is often negatively impacted by social determinants of health, which means that the effect of such programmes is limited.

Malaria, for example, robs a child of the ability to attend school, the capacity to be fully present in class when convalescent, and their long-term academic potential if they suffer permanent sequelae. A social factor in this regard is that most teachers send home children found to be sick at school, thereby devolving care decisions to parents. In many families, lack of knowledge about appropriate care for children with probable malaria, and limited access to care facilities in the community, commonly contribute to morbidity, as in many cases appropriate diagnosis and treatment do not occur, or at best are often delayed.

For these reasons, there are widespread calls for innovation and implementation of programmes to address malaria mortality and morbidity in school-age children.

Methods

Searches were undertaken of the published literature on malaria in children using the following search terms, singly, or in combination – malaria, children, school, school children, school-based, teachers, teacher-based, rapid diagnostic testing, artemisinin combination therapy, chemoprevention, Africa, sub-Saharan Africa. Search results were supplemented by papers identified from the reference lists published in these papers and material familiar to the author. The review was limited to the English language and focused predominantly on Africa and research published in the last 20 years, except where prior work had historical relevance.

Background

School-age children have attracted relatively little attention as a group in need of special measures to protect them against malaria.³

New and better diagnostic approaches are required to address malaria in children because of the current levels of morbidity and mortality.⁴ Schools present an obvious and logical opportunity to improve the access of school children to timely diagnosis and treatment.⁵ However, currently, national malaria control interventions do not specifically target school-age children despite increasing evidence that this age group bears the highest burden of infection.⁶ Awareness of the impact of malaria among school-age children has stimulated investigation into

interventions delivered through schools, but there remains no consensus as to the optimal intervention strategy.⁷

Despite being preventable, detectable and curable, malaria remains one of the leading causes of mortality due to infectious disease; *Plasmodium falciparum* malaria is a key global driver of mortality and morbidity with people in sub-Saharan Africa most affected.⁸ The burden of disease is highest in children, although the prevalence of *Plasmodium falciparum* in African school-age children varies widely depending on the level of transmission, setting and season. Hounbedji and colleagues (N'Dri, Hürlimann, Yapi, Silué, Soro, Koudou, Acka, Assi, Vounatsou, N'Goran, Fantodji, Utzinger & Raso, 2015) found seven out of ten school-aged children in Côte d'Ivoire infected with *Plasmodium falciparum* in a national, cross-sectional study of more than 5 000 children from 93 schools, based on combined microscopy results and rapid diagnostic testing.⁹ Nankabirwa and colleagues (Brooker, Clarke, Fernando and Gitonga, 2014) reported that 14-64 per cent of school-age children in Uganda are parasitemic at any one time.¹⁰ In Mali, malaria accounts for 36 per cent of medical consultations in school-aged children during the peak transmission season.¹¹ There is broad agreement that school-age children represent an underappreciated reservoir of malaria infection, have less exposure to antimalarial interventions, and malaria control and elimination strategies need to expand to include this age group.¹²

- 3 Nankabirwa, J., Brooker, S.J., Clarke, S.E., Fernando, D., Gitonga, C.W., Schellenberg, D. & Greenwood, B. 2014a. Malaria in school-age children in Africa: an increasingly important challenge. *Tropical Medicine & International Health*, 19(11):1294-1309. [https://doi.org/10.1111/2Ftmi.12374].
- 4 Bell, D., Fleurent, A.E., Hegg, M.C., Boomgard, J.D. & McConnico, C.C. 2016. Development of new malaria diagnostics: matching performance and need. *Malaria Journal*, 15(406). [https://doi.org/10.1186/s12936-016-1454-8].
- 5 Temperley, M., Mueller, D.H., Njagi, J.K., Akhwale, W., Clarke, S.E., Jukes, M.C.H., Estambale, B. & Brooker, S. 2008. Costs and cost-effectiveness of delivering intermittent preventive treatment through schools in western Kenya. *Malaria Journal*, 7(196). [https://doi.org/10.1186/1475-2875-7-196]; Macnab, A.J., Mukisa, R., Mutabazi, S. & Steed, R. 2016a. Malaria in Uganda: school-based rapid diagnostic testing and treatment. *International Journal of Epidemiology*, 45(6), December:1759-1762. [https://doi.org/10.1093/ije/dyw262].
- 6 Cohee, L.M., Chilombe, M., Ngwira, A., Jemu, S.K., Mathanga, D.P., Laufer, M.K. 2018. Pilot study of the addition of mass treatment for malaria to existing school-based programs to treat neglected tropical diseases. *The American Journal of Tropical Medicine and Hygiene*, 98(1):95-99. [https://doi.org/10.4269/ajtmh.17-0590].

- 7 Temperley et al., 2008; Drake, T.L., Okello, G., Njagi, K., Halliday, K.E., Jukes, Mangham, L. & Brooker, S. 2011. Cost analysis of school-based intermittent screening and treatment of malaria in Kenya. *Malaria Journal*, 10(273). [https://doi.org/10.1186/1475-2875-10-273]; Drake et al., 2011.
- 8 Bell et al., 2016; WHO. 2014. World Malaria Report. *WHO Global Malaria Programme*. [https://bit.ly/2Yx75gK] (Accessed 6 December 2019).
- 9 Hounbedji, C.A., N'Dri, P.B., Hürlimann, E., Yapi, R.B., Silué, K.D., Soro, G., Koudou, B.G., Acka, C.A., Assi, S.B., Vounatsou, P., N'Goran, E.K., Fantodji, A., Utzinger, J. & Raso, G. 2015. Disparities of *Plasmodium falciparum* infection, malaria-related morbidity and access to malaria prevention and treatment among school-aged children: a national cross-sectional survey in Côte d'Ivoire. *Malaria Journal*, 14(7). [https://doi.org/10.1186/1475-2875-14-7].
- 10 Nankabirwa et al., 2014a.
- 11 Barger, B., Maiga, H., Traore, O.B., Tekete, M., Tembini, I., Dara, A., Traore, Z.I., Gantt, S., Doumbo, O.K., Djimde, A.A. 2009. Intermittent preventive treatment using artemisinin-based combination therapy reduces malaria morbidity among school-aged children in Mali. *Tropical Medicine & International Health*, 14(7):784-791. [https://doi.org/10.1111/j.1365-3156.2009.02294.x].
- 12 Walldorf, J.A., Cohee, L.M., Coalson, J.E., Bauleni, A., Nkanaunena, K., Kapito-Tembo, A., Seydel, K.B., Ali, D., Mathanga, D., Taylor, T.E., Valim, C. & Laufer, M.K. 2015.

Delay in the treatment of fever is a potent obstacle to the goal of achieving a reduction in malaria mortality.¹³ Failure to provide WHO-recommended diagnosis and therapy leads to poor disease management, in turn contributing to a cycle of poverty in affected communities.¹⁴ Lack of access to early and accurate diagnosis is common; studies indicate that in sub-Saharan Africa less than 50 per cent of sick, febrile children receive artemisinin combination therapy within 24 hours.¹⁵ Factors limiting children receiving an accurate diagnosis and prompt treatment include:

- access (distance to a clinic and a lack of parental awareness of need);
- cost (of prescribed medication, time away from livelihood, and transport);
- uncertain availability of rapid diagnostic testing diagnostics and artemisinin combination therapy at government clinics;
- inadequate numbers of skilled staff;
- variations in the quality of health care services;
- preference for traditional practices; and
- poor prescribing habits.¹⁶

School-age children are a reservoir of malaria infection in Malawi. *PLoS One*, 10(7): e0134061. [https://doi.org/10.1371/journal.pone.0134061].

- 13 White, N., Pukrittayakarnee, S., Hien, T.T., Faiz, M.A., Mokuolu, O.A. & Dondorp, A.M. 2014. Malaria. *The Lancet*. 383(9918):723-735. [https://doi.org/10.1016/S0140-6736(13)60024-0].
- 14 Amexo, M., Tolhurst, R., Barnish, G., Bates, I. 2004. Malaria misdiagnosis: effects on the poor and vulnerable. *The Lancet*, 364(9448):1896-1898. [https://doi.org/10.1016/S0140-6736(04)17446-1]; Sachs, J. & Malaney, P. 2002. The economic and social burden of malaria. *Nature*, 415(6872):680. [https://doi.org/10.1038/415680a].
- 15 Macnab, A.J., Mutabazi, S., Mukisa, R., Eliab, A., Kigozi, H. & Steed, R. 2016b. The impact on absence from school of rapid diagnostic testing and treatment for malaria. *International Journal of Learning, Teaching and Educational Research*, 15(7):20-37. [https://bit.ly/3jaiQS1]; Simba, D.O., Warsame, M., Kakoko, D., Mrango, Z., Tomson, G., Premji, Z. & Petzold, M. 2010. Who gets prompt access to artemisinin-based combination therapy? A prospective community-based study in children from rural Kilosa, Tanzania. *PLoS One*, 5(8):e12104. [https://doi.org/10.1371/journal.pone.0012104]; Tipke, M., Louis, V.R., Yé, M., De Allegri, M., Beiersmann, C., Sié, A., Mueller, O. & Jahn, A. 2009. Access to malaria treatment in young children of rural Burkina Faso. *Malaria Journal*, 8(266). [https://doi.org/10.1186/1475-2875-8-266].
- 16 Macnab et al., 2016b; Mutabingwa, T.K. 2005. Artemisinin-based combination therapies (ACTs): best hope for malaria treatment but inaccessible to the needy! *Acta Tropica*, 95(3):305-301. [https://doi.org/10.1016/j.actatropica.2005.06.009]; Rutebemberwa, E., Kallander, K., Tomson, G., Peterson, S. & Pariyo, G. Determinants of delay in care-

Compared to younger children, school-age children are brought less often for treatment, and more often to unreliable treatment sources.¹⁷

Global efforts to increase access to rapid diagnostic testing and artemisinin combination therapy have made an impact following WHO endorsement.¹⁸ Diagnostic testing in the public sector in sub-Saharan Africa increased from 36 per cent of suspected cases tested in 2005 to 65 per cent in 2014, with rapid diagnostic testing accounting for 71 per cent of tests.¹⁹ Rapid diagnostic testing is increasingly being incorporated into national malaria management guidelines as an aid to diagnosis in resource-poor settings. The accuracy of rapid diagnostic testing and efficacy of artemisinin combination therapy are good, so effective ways to deliver these agents where they are needed is now key.²⁰ Initiatives often generated by government agencies have explored ways to make rapid diagnostic testing more available and promote improved use of artemisinin combination therapy, predominantly through stocks in pharmacies and private medical clinics.²¹ Availability in rural areas, however, often remains low despite the heightened need.

seeking for febrile children in eastern Uganda. *Tropical Medicine & International Health*, 14(4):4729. [https://doi.org/10.1111/j.1365-3156.2009.02237.x].

- 17 Walldorf et al., 2015.
- 18 Gitonga, C., Amin, A., Ajanga, A., Kangwana, B., Noor, A. & Snow, R.W. 2008. The use of artemether-lumefantrine by febrile children following national implementation of a revised drug policy in Kenya. *Tropical Medicine & International Health*, 13(4):487-494. [https://doi.org/10.1111/j.1365-3156.2008.02026.x].
- 19 WHO. 2015. World Malaria Report. *WHO Global Malaria Programme*. [https://bit.ly/3gn8BYL] (Accessed 6 December 2019).
- 20 Rutebemberwa et al., 2009; Mikhail, A.F., Leslie, T.J., Mayan, M.I., Zekria, R., Mohammad, N., Hasanzai, M.A., Safi, N., Whitty, C.J. & Rowland, M. 2011. Field trial of three different Plasmodium vivax-detecting rapid diagnostic tests with and without evaporative cool box storage in Afghanistan. *Malaria Journal*, 10(169). [https://doi.org/10.1186/1475-2875-10-169]; Khatib, R.A., Selemani, M., Mrisho, G.A., Masanja, I.M., Amuri, M., Njozi, M.H., Kajungu, D., Kuepfer, I., Abdulla, S.M. & De Savigny, D. 2013. Access to artemisinin-based anti-malarial treatment and its related factors in rural Tanzania. *Malaria Journal*, 12(155). [https://doi.org/10.1186/1475-2875-12-155].
- 21 Mbonye, A.K., Magnussen, P., Lai, S., Hansen, K.S., Cundill, B., Chandler, C., Clarke, S.E. 2015. A cluster randomized trial introducing rapid diagnostic tests in registered drug shops in Uganda: Impact on appropriate treatment of malaria. *PLoS One*, 10(7):e0129545. [https://doi.org/10.1371/journal.pone.0129545]; Visser, T., Bruxvoort, K., Maloney, K., Leslie, T., Barat, L.M., Allan, R., Ansah, E.K., Anyanti, J., Boulton, I., Clarke, S.E., Cohen, J.L., Cohen, J.M., Cutherell, A., Dolkart, C., Eves, K., Fink, G., Goodman, C., Hutchinson, E., Lal, S., Mbonye, A., Onwujekwe, O., Petty, N., Pontarollo, J., Poyer, S., Schellenberg, D., Streat, E., Ward, A., Wiseman, V., Whitty, C.J., Yeung, S., Cunningham, J. & Chandler, C. 2017. Introducing malaria rapid

To date, endorsement of school-based use of rapid diagnostic testing or artemisinin combination therapy has been lacking, and innovative national strategies are needed to achieve improved access and utilisation.²²

A Lancet review summarises the decline of the burden of malaria in sub-Saharan Africa with the scaling up of prevention, diagnosis, and treatment. Studies were included if they reported at least two years of data on malaria-specific indicators (clinical or slide diagnosed case numbers, incidence, prevalence, or malaria-specific mortality) in a population of more than 1 000 people.²³ Malaria mortality is concentrated among children,²⁴ and inherently however, remains linked to poverty.²⁵ In countries where it is endemic malaria is reported to be the main reason a school-aged child will die; in parallel, an important measure of the morbidity malaria causes is that infection is the principal reason why a child will be absent from school.²⁶

School teachers recognise the negative impact of malaria on pupil's health and the adverse effects of infection on their ability to learn; they see first-hand the impact on school-age children's performance documented in a structured review (Nankabirwa et al., 2014a).²⁷ They know infection prevents children attending school, that sub-optimal treatment leaves residual malaise that negatively impacts a child's capacity to be fully present in class, and repeated infection can permanently compromise a child's academic potential due to neurological complications.²⁸ The

diagnostic tests in private medicine retail outlets: a systematic literature review. *PLoS One*, 12(3):e0173093. [https://doi.org/10.1371/journal.pone.0173093].

- 22 Hounghbedji et al., 2015; Mutabingwa, 2005; Khatib et al., 2013.
- 23 O'Meara, W.P., Mangeni, J.N., Steketee, R., Greenwood, B. 2010. Changes in the burden of malaria in sub-Saharan Africa. *The Lancet Infectious Diseases*, 10(8):545-55. [https://doi.org/10.1016/S1473-3099(10)70096-7].
- 24 WHO, 2014; Sachs & Malaney, 2002.
- 25 Marmot et al., 2008.
- 26 Brooker, S., Guyatt, H., Omumbo, J., Shretta, R., Drake, L. & Ouma, J. 2000. Situation analysis of malaria in school-aged children in Kenya—what can be done? *Parasitol Today*, 16(5):183-186. [https://doi.org/10.1016/s0169-4758(00)01663-x]; Jukes, M.C.H., Drake, L.J. & Bundy, D.A.P. 2008. Challenges for child health and nutrition. In: Jukes, M.C.H., Drake, L.J. & Bundy, D.A.P., (eds). 2008. *School health, nutritional and education for all: levelling the playing field*. Cambridge, USA: CABI Publishing. pp.11-31. [https://bit.ly/3gpMbG8]; Clarke, S.E., Brooker, S., Njagi, J.K., Njau, E., Estambale, B., Muchiri, E. & Magnussen, P. 2004. Malaria morbidity among school children living in two areas of contrasting transmission in western Kenya. *The American Journal of Tropical Medicine and Hygiene*, 71(6):732-738. [https://doi.org/10.4269/ajtmh.2004.71.732].
- 27 Nankabirwa et al., 2014a.
- 28 Kihara, M., Carter, J.A., Newton, C.R. 2006. The effect of Plasmodium falciparum

review emphasises that due to current trends in lowering malaria transmission, and the tendency for school-age children to acquire immunity later in life, this age group faces an increase in the incidence of both uncomplicated and severe malaria in previously high endemic areas.²⁹ Hence, it needs special measures to protect them against malaria, with more programme implementation and innovative measures, both important. Ongoing research and evaluation are also needed to build the evidence base of 'what works and why,' and where such interventions are most effective.³⁰

A social factor relevant to school-based health promotion in Africa, and most other low- and middle-income countries, is that children found to be sick at school are generally sent home by teachers.³¹ This action devolves key care decisions to parents, which is problematic in malaria-endemic areas, as many families lack knowledge about appropriate care for children with probable malaria. This situation often contributes to morbidity, as in many cases, appropriate diagnosis and timely treatment do not occur.³²

The WHO advocates early, accurate diagnosis of malaria and prompt, effective and affordable treatment within 24 hours of the onset of illness.³³ Validated measures to do this exist, but in most low- and middle-income countries, the health resources necessary are limited and are especially scarce in rural and low resource communities. The fact that malaria symptoms are not specific is an additional factor, as a reliable diagnosis cannot be made based on history and examination

on cognition: a systematic review. *Tropical Medicine & International Health*, 11(4):386-397. [https://doi.org/10.1111/j.1365-3156.2006.01579.x]; Fernando, S.D., Gunawardena, D.M., Bandara, M.R., De Silva, D., Carter, R., Mendis, K.N. & Wickremasinghe, A.R. 2001. The impact of repeated malaria attacks on the school performance of children. *The American Journal of Tropical Medicine and Hygiene*, 69(6):582-588. [https://doi.org/10.4269/ajtmh.2003.69.582]; Holding, P.A. & Snow, R.W. 2001. Impact of Plasmodium falciparum malaria on performance and learning: Review of the evidence. *The American Journal of Tropical Medicine and Hygiene*, 64(Supplement 1):68-75. [https://doi.org/10.4269/ajtmh.2001.64.68].

- 29 Nankabirwa et al., 2014a.
- 30 Ibid.
- 31 Macnab et al., 2016a. Macnab, A.J., Stewart, D. & Gagnon, F. 2014a. Health Promoting Schools: Initiatives in Africa. *Health Education*, 114(4), May:246-259. [https://doi.org/10.1108/HE-11-2013-0057].
- 32 Macnab et al., 2016b; Källander, K., Nsungwa-Sabiiti, J. & Peterson, S. 2004. Symptom overlap for malaria and pneumonia-policy implications for home management strategies. *Acta Tropica*, 90(2):211-214. [https://doi.org/10.1016/j.actatropica.2003.11.013].
- 33 WHO, 2014.

alone.³⁴ Even using a WHO-derived diagnostic algorithm designed for Community Health Workers, trained teachers in Ghana could not match all presumptive malaria to the case definition.³⁵ This difficulty with diagnosing malaria on clinical grounds, lack of knowledge about the need for care, and limited facilities all contribute to morbidity and mortality. Hence, simple, accurate and inexpensive diagnostic tools, health education and the wider availability of effective therapy are needed to reduce the impact of malaria on children.³⁶

Malaria health promotion initiatives centred on schools that increase access to effective diagnostic and treatment measures are an example of the type of innovative, content specific intervention called for by the WHO Commission on Social Determinants of Health to support healthy behaviours. They empower young people to take control of their lives.³⁷ Such 'task-shifting' to school-based programmes can also increase the provision of other essential health services.³⁸ Robust precedents for such approaches exist in successful, valuable and cost-effective teacher-administered health programmes in schools in low- and middle-income countries including the provision of intermittent anti-malarial therapy in Kenya, prophylactic chloroquine in Sri Lanka, and nationwide anti-helminth treatment in Uganda, and Ghana.³⁹ Importantly, cost-benefit analysis shows that

health programme delivery costs can be reduced by having teachers implement such programmes.⁴⁰

Burden of disease in school-age children

While the overall incidence and number of deaths from malaria are decreasing worldwide, the disease is still a major cause of mortality and morbidity among children.⁴¹

Mortality

Fifty per cent of deaths in school-aged children (between five and 14 years) are estimated to be due to malaria in Africa.⁴² Cerebral malaria (severe *Plasmodium falciparum* malaria presenting with neurological symptoms, including coma (Glasgow coma scale less than 11, or a Blantyre coma scale less than three), or with a coma that lasts more than 30 minutes after a seizure)), affects more than half a million children per year in Africa and kills between 10-40 per cent of those infected.⁴³ Poor health, poverty, lack of knowledge at a community level and limited access to care are contributory factors that increase a child's risk.⁴⁴

Morbidity

Studies in Africa and Thailand indicate that malaria causes five-eight per cent of all school absenteeism. Reports from Kenya indicate that primary school students

of school children. *The American Journal of Tropical Medicine and Hygiene*, 74(3):386-393. [http://www.ajtmh.org/content/journals/14761645]; Brooker, S., Kabatereine, N.B., Fleming, F. & Devlin, N. 2008. Cost and cost-effectiveness of nationwide school-based helminth control in Uganda: intra-country variation and effects of scaling-up. *Health Policy Plan*, 23(1):24-35. [https://doi.org/10.1093/heapol/czm041]; Opoku, E.C., Olsen, A., Browne, E., Hodgson, A., Awoonor-Williams, J.K., Yelifari, L., Williams, J. & Magnussen, P. 2016. Impact of combined intermittent preventive treatment of malaria and helminths on anaemia, sustained attention, and recall in northern Ghanaian schoolchildren. *Global Health Action*, 9:32197. [https://doi.org/10.3402/gha.v9.32197].

40 Drake et al., 2011; Fernando et al., 2006; Laxminarayan, R., Chow, J. & Shahid-Salles, S.A. 2006. Intervention Cost-Effectiveness: Overview of Main Messages. In: Breman, J.G., Measham, A.R., Alleyne, G., Jamison, D.T., Claeson, M., Evans, D.B., Jha, P., Mills, A. & Musgrove, P. (eds). *Disease Control Priorities for Developing Countries*. Oxford: Oxford University Press. pp.35-86.

41 WHO, 2015.

42 Nankabirwa et al., 2014a.

43 WHO, 2019; Holding & Snow, 2001.

44 Hounbedji et al., 2015; Sachs & Malaney, 2002; Mutabingwa, 2005.

34 Källander, Nsungwa-Sabiiti & Peterson, 2004.

35 WHO. 1992. *Malaria: A training guide for district health workers on malaria control in tropical Africa*. [https://bit.ly/32krkPB]; Afenyadu, G.Y., Agyepong, I.A., Barnish, G. & Adjei, S. 2005. Improving access to early treatment of malaria: a trial with primary school teachers as care providers. *Tropical Medicine & International Health*, 10(10):1065-1072. [https://doi.org/10.1111/j.1365-3156.2005.01484.x].

36 Nankabirwa et al., 2014a; Bell et al., 2016.

37 Macnab, Stewart & Gagnon, 2014a; WHO. 2008. *Closing the gap in a generation: health equity through action on the social determinants of health*. Commission on Social Determinants of Health - Final Report. [https://bit.ly/2QxIIAF]; Sachs & Malaney, 2002.

38 Agyepong, I.A., Sewankambo, N., Binagwaho, A., Coll-Seck, A.M., Corrah, T., Ezeh, A., Fekadu, A., Kilonzo, N., Lamptey, P., Masiye, F., Mayosi, B., Mboup, S., Muyembe, J.J., Pate, M., Sidibe, M., Simons, B., Tlou, S., Gheorghe, A., Legido-Quigley, H., McManus, J., Ng, E., O'Leary, M., Enoch, J., Kassebaum, N. & Piot, P. 2017. The path to longer and healthier lives for all Africans by 2030: The Lancet Commission on the future of health in sub-Saharan Africa. *The Lancet*, 390(10114):2803-2859. [https://doi.org/10.1016/S0140-6736(17)31509-X].

39 Temperley et al., 2008; Okello, G., Ndegwa, S.N., Halliday, K.E., Hanson, K., Brooker, S.J., Jones, C. 2012. Local perceptions of intermittent screening and treatment for malaria in school children on the south coast of Kenya. *Malaria Journal*, 11(185). [https://doi.org/10.1186/1475-2875-11-185]; Fernando, D., De Silva, D., Carter, R., Mendis, K.N. & Wickremasinghe, R. 2006. Randomized, double-blind, placebo-controlled, clinical trial of the impact of malaria prevention on the educational attainment

miss 11 per cent of school days per year because of malaria, and secondary students can miss 4.3 per cent of school days.⁴⁵ Such data equate with malaria being the cause of approximately 50 per cent of all preventable absenteeism.⁴⁶ Hence, reducing morbidity offers real potential for school children to gain increased educational benefits just from improved attendance.

However, the adverse effects on schooling go far beyond compromised attendance. Even an attack of uncomplicated malaria can cause significant short-term impairment of cognitive performance; the impairment a child experiences often persists for around two weeks; and adverse effects appear to be cumulative with repeated attacks.⁴⁷ Where the principal infecting agent is *Plasmodium falciparum*, the infection can be associated with permanent loss of cognitive and fine motor function from complications, especially where the diagnosis is delayed and/or treatment is sub-optimal.⁴⁸

In the Brazilian Amazon (where the infection is predominantly with *Plasmodium vivax*) multivariate analysis indicates that presenting with at least one episode of malaria, independently, predicts a poor performance at school.⁴⁹ In Asian studies

in low transmission areas, most indices of performance-tested at school entry in a cross-sectional study were poorer as the number of malaria infections experienced by a child increased, after controlling for confounding factors.⁵⁰ School performance of six to 14-year-old children was related to the number of previous episodes of malaria; acute uncomplicated attacks caused short-term learning difficulty for a week or more, and the effects were compounded by subsequent attacks.⁵¹ Thus, the combined effects of absence, sub-optimal convalescent health and long-term neurological compromise can adversely affect performance in class and pass rates, lead to the need for a child to repeat grades, and even cause children to drop out of school altogether.

The exact mechanisms involved in causing long-term detriment to cognitive development and learning ability are debated.⁵² There is a clear relationship between infection intensity and the magnitude of the adverse cognitive effect (i.e. the higher the parasitemia, the higher the impact on the cognitive score).⁵³ Thuilliez and colleagues (Sissoko, Toure, Kamate, Berthelemy and Doumbo, 2010) provide an excellent schematic that illustrates the probable effects and pathways based on a series of studies examining the cognitive function and school performance depending on *falciparum* and *vivax* malaria and evaluating malaria prevention on educational achievement since 2003.⁵⁴

Children who survive 'cerebral' malaria, frequently show clinical evidence of neurological sequelae, including impaired ability to carry out executive functions (e.g. planning, initiating and executing executive tasks), and behavioural disorders that compromise their ability to engage fully in class. Kenyan school children hospitalised for cerebral malaria were 4.5 times more likely to have mild-to-severe learning difficulties three-four years later, even though half of them had no neurological problems at the time of admission.⁵⁵ The risk of impaired intellectual function is increased where seizures accompany clinical malaria.

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- 45 Leighton, C. & Foster, R. 1993. Economic impacts of malaria in Kenya and Nigeria. Major Applied Research Paper No. 6. Health Financing and Sustainability (HFS) Project. *Medical Services Corporation International*. [https://bit.ly/3aQ55ow].
- 46 Fernando et al., 2001; Sachs & Malaney, 2002; Fernando, D., De Silva, D. & Wickremasinghe, R. 2003. Short-term impact of an acute attack of malaria on the cognitive performance of schoolchildren living in a malaria-endemic area of Sri Lanka. *Transactions of The Royal Society of Tropical Medicine and Hygiene*, 97(6):633-639. [https://doi.org/10.1016/s0035-9203(03)80093-7].
- 47 Kihara, Carter & Newton, 2006; Fernando et al., 2001.
- 48 Boivin, M.J., Bangirana, P., Byarugaba, J., Opoka, R.O., Idro, R., Jurek, A.M. & John, C.C. 2007. Cognitive impairment after cerebral malaria in children: a prospective study. *Pediatrics*, 119(2):e360-366. [https://doi.org/10.1542/peds.2006-2027]; Fernando, S.D., Rodrigo, C. & Rajapaske, S. 2010. The 'hidden' burden of malaria: cognitive impairment following infection. *Malaria Journal*, 9(366). [https://doi.org/10.1186/1475-2875-9-366]; Birbeck, G.L., Molyneux, M.E., Kaplan, P.W., Seydel, K.B., Chimalizeni, Y.F., Kawaza, K. & Taylor, T.E. 2010. Blantyre malaria project epilepsy study (BMPES) of neurological outcomes in retinopathy positive pediatric cerebral malaria survivors: a prospective cohort study. *The Lancet Neurology*, 9(12):1173-1181. [https://doi.org/10.1016/S1474-4422(10)70270-2]; Thuilliez, J., Sissoko, M.S., Toure, O.B., Kamate, P., Berthelemy, J. & Doumbo, O.K. 2010. Malaria and primary education in Mali: a longitudinal study in the village of Doneguebougou. *Social Science & Medicine*, 71(2):324-334. [https://doi.org/10.1016%2Fj.socscimed.2010.02.027].
- 49 Vitor-Silva, S., Reyes-Lecca, R.C., Pinheiro, T.R. & Lacerda, M.V. 2009. Malaria is associated with poor school performance in an endemic area of the Brazilian Amazon.

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- Malaria Journal*, 8(230). [https://doi.org/10.1186/1475-2875-8-230].
- 50 Fernando, S.D., Wickremasinghe, R., Mendis, K.N. & Wickremasinghe, A.R. 2003. Cognitive performance at school entry of children living in a malaria endemic area in Sri Lanka. *Transactions of The Royal Society of Tropical Medicine and Hygiene*, 97:161-165. [https://doi.org/10.1016/s0035-9203(03)90107-6].
- 51 Fernando et al., 2001.
- 52 Ibid.; Holding & Snow, 2001.
- 53 Thuilliez et al., 2010.
- 54 Ibid.
- 55 Holding & Snow, 2001.

Thus, prolonged, severe and repeated illness can reduce both the opportunity and the ability of a school-age child to learn. Consequently, there is great potential worldwide for both health and educational benefits to be accrued, where a reduction in child morbidity due to malaria can be achieved.

Historic interventions for malaria

Recognition that the use of malaria suppressive drugs for special groups might be beneficial existed as early as the 1920s.⁵⁶ The use of quinine in the Gold Coast (Ghana) was reported in 1925 but achieved little success.⁵⁷ Pyrimethamine, the first synthetic antimalarial tried, controlled malaria in children in Nigeria (1951); success was achieved with this agent subsequently in group treatment in Haute Volta.⁵⁸ In a two-year study using prophylaxis in 277 Nigerian children aged five to 10 years (1956) also identified benefits related to better general health, as average weight gain in treated children was significantly higher than that of untreated children.⁵⁹ Unpublished data included in a 1955 report by Colbourne indicates that chloroquine proved to be an effective suppressive agent in a group of adolescents in the Gold Coast in 1952.⁶⁰

Colbourne also used a combination of amodiaquine and pyrimethamine to suppress malaria in seven-year-old children in an Accra school. At the beginning of each term, 176 children received amodiaquine (to clear parasitemia), and they weekly received pyrimethamine (to suppress malaria). Seventy-six 'controls' received dummy tablets.⁶¹ Interestingly, this study included the first observation that freedom from malaria resulted in the reduction of school absenteeism due to sickness by approximately 50 per cent. Reduction in the duration of absence from school is now an accepted surrogate measure for morbidity from malaria. Of note, Colbourne's initial estimate that five-six school days were saved per child

56 Colbourne, M.J. 1955. The effect of malaria suppression in a group of Accra school children. *Transactions of The Royal Society of Tropical Medicine and Hygiene*, 49(4):556-569. [https://doi.org/10.1016/0035-9203(55)90058-4].

57 Magill, E.M. 1924. *Report on medical inspection of school children in Accra during 1923*. Government Sessional Paper No. 11 of 1924-5. Accra: Government Printers, 5.

58 Masseguin, A. & Palinacci, A. 1953. First Results of Chemoprophylaxis of Malaria with Malocide (Pyrimethamine) in Children in Upper Volta. *Bulletin de la Société de Pathologie Exotique*, 46(5):673-676.

59 Archibald, H.M. & Bruce-Chwatt, L.J. 1956. Suppression of malaria with pyrimethamine in Nigerian schoolchildren. *Bulletin of the WHO*, 15(3-5):775-784. [https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2538299/].

60 Colbourne, 1955.

61 Ibid.

with malaria suppression, is directly comparable to the finding 60 years later of a mean reduction in absence from 6.5 to less than one school day(s) when the effects of rapid diagnosis and prompt treatment were followed in school-based studies in Uganda.⁶²

School-based intervention

Health education

The WHO has always placed community participation at the centre of its 'health for all' strategies.⁶³ It is often teachers who identify health issues that warrant attention and seek to initiate education or skills teaching in school to address them.⁶⁴ An important construct, as it makes cooperation and long-term commitment by teachers to health promotion realistic. The literature shows teachers have collaborated in programmes addressing a range of health issues; evidence which is important in the necessary dialogue about whether teachers will be motivated enough to invest the time required to help initiate and then sustain any school-based intervention.

Schools can be an effective and efficient way to reach a large segment of the population, as globally, more than one billion children have the potential to benefit from school-based health delivery.⁶⁵ The WHO's Health-Promoting School model is an innovative approach to health promotion, and also towards attaining the UN's 17 Sustainable Development Goals; as these have the overarching aim of addressing poverty worldwide, they have relevance in the context of reducing the burden of malaria. Goals 1-6 directly address factors that contribute to health, disease and wellbeing in children (poverty, malnutrition, health, education, empowering women and girls, and water).⁶⁶ The Health-Promoting School model employs multi-disciplinary strategies to engage a school community; children

62 Macnab et al., 2016a.

63 Lasker, R.D. & Weiss, E.S. 2003. Broadening participation in community problem solving: a multidisciplinary model to support collaborative practice and research. *Journal of Urban Health*, 80(1):14-47. [https://doi.org/10.1093/jurban/jtg014].

64 Macnab, Stewart & Gagnon, 2014a.

65 WHO, 2013. *What is a health promoting school?* [https://bit.ly/311Ovnd] (Accessed 10 December 2018); Macnab, A.J. 2013. The Stellenbosch consensus statement on Health Promoting Schools. *Global Health Promotion*, 20(1):78-81. [https://doi.org/10.1177/1757975912464252].

66 Costanza, R., Daly, L., Fioramonti, L. & Giovannini, E., Kubiszewski, I., Mortensen, L.F., Pickett, K.E., Ragnarsdottir, K.V., De Vogli, R., Wilkinson, R. 2016. Modelling and measuring sustainable wellbeing in connection with the UN Sustainable

readily assimilate 'knowledge' and 'skills,' and the WHO's overarching objective is to generate life-long learning that positively influences the social determinants of health.⁶⁷ The WHO now endorses school programmes as a way to address specific health challenges worldwide.⁶⁸

In the author's opinion, the inclusion of education on malaria in all schools in endemic areas should be the norm. Educational and protective strategies can be delivered in parallel and are potentially synergistic. In the author's experience, children broadly educated about malaria are all the more likely to recognise the relevance of preventive strategies like indoor spraying and insecticide-treated bed nets. They can aid community adoption of vector control interventions (novel or non-insecticide-based approaches offer particular promise), and potentially become involved in malaria vaccine roll-out, rightly heralded as a paradigm shift with huge implications for the protection of school children.⁶⁹ Thus far, the programmes to immunise are not school-based.

Current data on the use of insecticide-treated bed nets suggest focused school-based education could impact prevention. In most low- and middle-income countries less than 50 per cent of households own a mosquito net despite promotional programmes; even when nets are present many are untreated with insecticide, and most children do not sleep under insecticide-treated bed nets.⁷⁰ A large cross-

sectional study in Malawi found that there were significant differences in net use based on age in areas where school-age children had the highest prevalence of malaria, with only 57 per cent of school children reported to use an insecticide-treated bed net, compared to 74 per cent of adults and 76 per cent of younger children.⁷¹ A study based on national survey data from 18 malaria-endemic areas in Africa identified similar net use patterns.⁷² Recognising that a reduction in all-cause mortality among children of up to 60 per cent has been realised when insecticide-treated bed nets are used in areas of stable endemic transmission, these data underscore the need for school-based programmes that improve knowledge and practices related to prevention.⁷³

Schools can also play a vital role in ensuring that pupils understand the importance of obtaining rapid access to correct diagnosis and effective treatment.⁷⁴ The author agrees with other authors that such knowledge must be regarded as essential and that there are many simple, effective and inexpensive ways to give children this knowledge through additions to the curriculum. However, health education must engage pupils for these messages to have an impact. The shared facts and how they are taught must resonate and have 'relevance' for the learner if what is learned is to lead to a behavioural change. The incentive to educate effectively is research showing that adolescents tend to retain knowledge that resonates culturally and which they perceive to be personally and socially relevant; that effective learning can translate into positive behaviours, and many of these persist into adult life.⁷⁵

Motivated teachers seek out novel approaches to engaging their pupils; for example, implementing a clean-up programme around the school where pupils collect discarded plastic bottles, bags and bottle caps, provides evidence-based learning

Development Goals. *Ecological Economics*, 130:350-355. [<https://doi.org/10.1016/j.ecolecon.2016.07.009>].

67 Macnab, 2013; Viner, R.M., Ozer, E.M., Denny, S., Marmot, M., Resnick, M., Fatusi, A. & Currie, C. 2012. Adolescence and the social determinants of health. *The Lancet*, 379(9826):1641-1652. [[https://doi.org/10.1016/S0140-6736\(12\)60149-4](https://doi.org/10.1016/S0140-6736(12)60149-4)].

68 WHO, 2008; Sachs & Malaney, 2002; Tang, K., Nutbeam, D., Aldinger, C. St Leger, L., Bundy, D., Hoffmann, A.M., Yankah, E., McCall, D., Buijs, G., Arnaout, S., Morales, S., Robinson, F., Torranin, C., Drake, L., Abolfotouh, M., Whitman, C.V., Meresman, S., Odete, C., Joukhadar, A.H., Avison, C., Wright, C., Huerta, F., Munodawafa, D., Nyamwaya, D. & Heckert, K. 2008. Schools for health, education and development: a call for action. *Health Promotion International*, 24(1):68-77. [<https://doi.org/10.1093/heapro/dan037>].

69 Miller, M.W. & Tren, R. 2012. Implications of public-health insecticide resistance and replacement costs for malaria control: challenges and policy options for endemic countries and donors. *Research and Reports in Tropical Medicine*, 3:1-19. [<https://doi.org/10.2147%2FRRTM.S30914>]; Greenwood, B., Dicko, A., Sagara, I., Zongo, I., Tinto, H., Cairns, M., Kuepfer, I., Milligan, P., Ouedraogo, J., Doumbo, O. & Chandramohan, D. 2017. Seasonal vaccination against malaria: a potential use for an imperfect malaria vaccine. *Malaria Journal*, 16(182). [<https://doi.org/10.1186/s12936-017-1841-9>].

70 Walldorf et al., 2015; Macnab et al., 2016b; Swana, E.K., Makan, G.Y., Mukeng, C.K., Mupumba, H., Kalaba, G.M., Luboya, O.N., Bangs, M.J. 2016. Feasibility and

implementation of community-based malaria case management with integrated vector control in the Democratic Republic of Congo. *Malaria Journal*, 15(413). [<https://doi.org/10.1186/s12936-016-1475-3>].

71 Walldorf et al., 2015.

72 Noor, A.M., Kirui, V.C., Brooker, S.J. & Snow, R.W. 2009. The use of insecticide treated nets by age: implications for universal coverage in Africa. *BMC Public Health*, 9(369). [<https://doi.org/10.1186/1471-2458-9-369>].

73 Nankabirwa et al., 2014a.

74 Brooker, S., Guyatt, H., Omumbo, J., Shretta, R., Drake, L., Ouma, J. 2000. Situation analysis of malaria in school-aged children in Kenya—what can be done? *Parasitol Today*, 16(5):183-186. [[https://doi.org/10.1016/s0169-4758\(00\)01663-x](https://doi.org/10.1016/s0169-4758(00)01663-x)].

75 Marmot et al., 2008; Viner et al., 2012; Airhihenbuwa, C.O., Makoni, S., Iwelunmor, J. & Munodawafa, D. 2014. Sociocultural Infrastructure: Communicating Identity and Health in Africa. *Journal of Health Communication International Perspectives*, 19(1):1-5. [<https://doi.org/10.1080/10810730.2013.868767>].

when pupils understand these items offer breeding habitat for mosquito larvae, and a way to encourage effective prevention practices.⁷⁶

Worldwide it is still commonplace to find children lack even the most basic knowledge about malaria. In a recent survey in Ugandan primary schools, only one in five children knew what caused malaria, or if it can be prevented, what signs and symptoms suggest infection, and what can be done to treat an infection.⁷⁷

Evidence that the broader community also lacks essential knowledge comes from data showing how small a proportion of sick, febrile children with presumptive malaria are taken for appropriate care. Simba and colleagues (Warsame, Kakoko, Mrango, Tomson, Premji and Petzold, 2010) identified that less than half (44.8 per cent) were taken to government facilities, and only 37.6 per cent had prompt access to artemisinin combination therapy.⁷⁸ The author's experience is similar – only one in four children (26 per cent) sent home from schools with a febrile illness compatible with malaria, received management meeting the WHO criteria. The majority (42 per cent) were only given an anti-pyretic, and care of the remainder included local herbal remedies (19 per cent), being taken to church (eight per cent), or visiting a traditional healer (six per cent).⁷⁹

There is growing evidence that where children receive sufficient guidance, they can act as agents for change in both the school and their local community.⁸⁰ Knowledge and skills learned from effective school-based health education 'ripple' out to involve siblings and parents.⁸¹ Importantly, this willingness to share learned

concepts and practices indicates acquisition of higher levels of health literacy.⁸² A Ghanaian study evaluated the impact of malaria-related participatory health education activities designed and led by teachers. Comparing communities with and without the school-based intervention, knowledge on malaria causation was significantly more accurate among pupils in the participating schools and adults in their communities; the prevalence of parasitaemia in pupils decreased from 31 per cent to 10 per cent and the number of adults who had treated a bed net with insecticide in the past six months doubled.⁸³ Similar findings in the community come from Lao People's Democratic Republic, where school-based education improved knowledge, attitudes, and practices towards malaria control.⁸⁴

In keeping with other authors, in the author's opinion, the following are key components where interventions to reduce morbidity from malaria among school children are to be offered:

Education

Aim for all children to have 'health literacy' about malaria. Include key facts in the curriculum of all schools in endemic areas about the cause, prevention and clinical features of malaria, and how and why diagnosis and prompt treatment are necessary.

Prevention

Promote the use of insecticide-treated nets, so that all school-age children in malarial areas sleep under one. Children should understand vector control and contribute to local measures to clean-up garbage that provides a breeding habitat for mosquitoes.

Accurate diagnosis and prompt treatment

Advocate for the use of the WHO-approved methods employing rapid diagnostic testing and artemisinin combination therapy, and facilitate effective intervention; in rural areas or where access to clinics and/or alternative points of care providing such services are limited, 'task-shifting' is valid, by training teachers to provide rapid diagnostic testing and artemisinin combination therapy as a school-based health service.

76 De Silva, P.M. & Marshall, J.M. 2012. Factors contributing to urban malaria transmission in sub-Saharan Africa: a systematic review. *Journal of Tropical Medicine*, 2012(819563). [https://doi.org/10.1155/2012/819563].

77 Macnab et al., 2016a.

78 Simba et al., 2010.

79 Macnab, A.J., Mutabazi, S., Mukisa, R., Eliab, A., Kigozi, H. & Steed, R. 2016. The impact on absence from school of rapid diagnostic testing and treatment for malaria. *International Journal of Learning, Teaching and Educational Research*, 15(7):20-37. [https://bit.ly/3jaiQS1].

80 Tang et al., 2008; Simovska, V. & Carlsson, M. 2012. Health-promoting changes with children as agents: findings from a multiple case study research. *Health Education*, 112(3):292-304. [https://doi.org/10.1108/09654281211217803].

81 Ayi, I., Nonaka, D., Adjovu, J.K., Hanafusa, S., Jimba, M., Bosompem, K.M., Mizoue, T., Takeuchi, T., Boakye, D.A. & Kobayashi, J. 2010. School-based participatory health education for malaria control in Ghana: engaging children as health messengers. *Malaria Journal*, 9(98). [https://doi.org/10.1186/1475-2875-9-98]; Macnab, A.J., Gagnon, F. & Stewart, D. 2014a. Health Promoting Schools: Consensus, challenges and potential. *Health Education*, 114(3):170-185. [https://bit.ly/34szNmL].

82 St Leger, L. 2001. Schools, health literacy and public health: possibilities and challenges. *Health Promotion International*, 16(2):197-205. [https://doi.org/10.1093/heapro/16.2.197].

83 Ayi et al., 2010.

84 Nonaka, D., Kobayashi, J., Jimba, M., Vilaysouk, B., Tsukamoto, K., Kano, S., Phommasack, B., Singhasivanon, P., Waikagul, J., Tateno, S. & Takeuchi, T. 2008. Malaria education from school to community in Oudomxay province, Lao PDR. *Parasitology International*, 57(1):76-82. [https://doi.org/10.1016/j.parint.2007.09.005].

Policy

Establish local and national programmes, inter-sectoral collaboration and leadership. These are needed to highlight current epidemiological findings and research data on malaria in school-age children, and give communities specific recommendations and direction on how to address the problems faced.

Malaria control strategies

Prophylaxis: regular administration of preventive drugs

Chemoprophylaxis involves the regular administration of antimalarial drugs to those at risk of infection to maintain protective levels within the bloodstream. Prophylaxis is generally not recommended for children in malaria-endemic areas for multiple reasons; these include problems with adherence to prescribed regimens, compliance due to cost, and the significant risk of emergence, or increased risk of drug resistance.⁸⁵ Over time, side-effects also preclude the use of chemoprophylactic drugs in children, particularly chloroquine.

Intermittent protective treatment

This treatment involves the periodic administration of a full therapeutic dose of an antimalarial drug or combination of drugs at predefined intervals to those at high risk of malaria, regardless of their infection status.⁸⁶ For children, intermittent protective treatment is now considered a preferable alternative to chemoprophylaxis.

Three trials have involved two main approaches; seasonal malaria chemoprevention and intermittent parasite clearance. Intermittent protective treatment is one of several possible malaria control strategies which could be delivered through schools. A study reported (Fernando, De Silva, Carter, Mendis and Wickremasinghe, 2006 from Sri Lanka) is an example of comprehensive school-based intervention. In a randomised, double-blind placebo-controlled trial weekly chloroquine or placebo was given to school children (six to 12 years) for nine months. Besides a reduction

in malaria incidence in the treated group, this study also documented a significant difference in absenteeism between those receiving chloroquine versus placebo, and a marked improvement in school performance.⁸⁷

Seasonal malaria chemoprevention is a control strategy recommended by the WHO targeting children living in areas of seasonal malaria transmission. Seasonal malaria chemoprevention is recommended for children under five years of age in countries where more than 60 per cent of the burden of malaria occurs in the months of the rainy season (which coincide with peak malaria transmission), a single curative dose of sulphadoxine-pyrimethamine is administered with a three-day course of amodiaquine.⁸⁸

In an alternative approach in older children (six to 15 years), Thera and colleagues (Kone, Tangara, Diarra, Niare, Dembele, Sissoko and Doumbo, 2018) tested the efficacy and safety of artesunate-amodiaquine in a randomised open-label trial in Mali.⁸⁹ Two hundred pupils received either a three-day course of artesunate-amodiaquine during four consecutive months or no intervention. Twenty cases of uncomplicated malaria occurred in controls and three cases in the artesunate-amodiaquine arm, showing a protective efficacy of 85 per cent. The authors concluded that artesunate-amodiaquine is effective and well-tolerated, and a feasible and accepted school-based seasonal malaria chemoprevention strategy. Teachers were not involved in drug administration but did facilitate contact between investigators and pupils; a close partnership was established, which added confidence that all cases of illness were captured.⁹⁰ Evidence from several African countries has also shown that seasonal malaria chemoprevention using sulphadoxine-pyrimethamine-amodiaquine is highly effective, eradicating most severe malaria, and leading to a strong reduction in *Plasmodium falciparum* prevalence, the incidence of uncomplicated clinical malaria, and malaria anaemia.⁹¹

87 Fernando et al., 2006.

88 WHO, 2012. *WHO policy recommendation: Seasonal malaria chemoprevention (SMC) for Plasmodium falciparum malaria control in highly seasonal transmission areas of the Sahel sub-region in Africa*. Global Malaria Programme Policy Recommendation. [https://bit.ly/2UjIOA].

89 Thera, M.A., Kone, A.K., Tangara, B., Diarra, E., Niare, S., Dembele, A., Sissoko, M.S. & Doumbo, O.K. 2018. School-aged children based seasonal malaria chemoprevention using artesunate-amodiaquine in Mali. *Parasite Epidemiology and Control*, 3(2):96-105. [https://doi.org/10.1016/j.parepi.2018.02.001].

90 Thera et al., 2018.

91 Cairns, M., Roca-Feltrer, A., Garske, T., Cairns, M., Roca-Feltrer, A., Garske, T., Wilson, A.L., Diallo, D., Milligan, P.J., Ghani, A.C. & Greenwood, B.M. 2012. Estimating the potential public health impact of seasonal malaria chemoprevention in African children. *Nature Communications*, 3:881. [https://doi.org/10.1038/ncomms1879].

85 Temperley et al., 2008; Brooker et al., 2000.

86 Greenwood, B., Dicko, A., Sagara, I., Zongo, I., Tinto, H., Cairns, M., Kuepfer, I., Milligan, P., Ouedraogo, J., Doumbo, O. & Chandramohan, D. 2017. Seasonal vaccination against malaria: a potential use for an imperfect malaria vaccine. *Malaria Journal*, 16(182). [https://doi.org/10.1186/s12936-017-1841-9]; White, N.J. 2005. Intermittent presumptive treatment for malaria. *PLoS Medicine*, 2(1):e3. [https://doi.org/10.1371%2Fjournal.pmed.0020003]; Greenwood, B. 2006. Intermittent preventive treatment—a new approach to the prevention of malaria in children in areas with seasonal malaria transmission. *Tropical Medicine & International Health*, 11(7):983-991. [https://doi.org/10.1111/j.1365-3156.2006.01657.x].

Combining intermittent protective treatment with the expanded programme on immunisation in schools has been suggested, but data do not show significant benefit.⁹² Studies, where seasonal, intermittent protective treatment has proved effective in older children, include:

- An open randomised controlled trial of seasonal, intermittent protective treatment among school children (six to 13 years) in Mali; 296 were randomised to one of three study arms – sulphadoxine-pyrimethamine amodiaquine or vitamin C, with two full treatment doses, given two months apart during the season of high transmission. The incidence of clinical malaria in the sulphadoxine-pyrimethamine and amodiaquine arms was reduced by 66.6 per cent and 46.5 per cent, respectively, versus vitamin C. These intermittent protective treatment regimens also reduced all-cause acute clinic visits, asymptomatic parasitaemia and anaemia.⁹³
- A stratified, cluster-randomised, double-blind, placebo-controlled trial in 30 primary schools in Kenya involving 2 604 children (five to 18 years) who received sulphadoxine-pyrimethamine and 2 302 dual placebos. At 12 months, the prevalence of anaemia averaged 6.3 per cent (intermittent protective treatment) and 12.6 per cent (placebo); significant improvement was evident in two measures of cognitive ability.⁹⁴
- A randomised trial in children (six months to ten years) in Mali; 262 received either sulphadoxine-pyrimethamine twice with an eight-week interval or no intermittent protective treatment. In treated subjects, the annual incidence rate of clinical malaria was reduced by 42.5 per cent in an area with intense seasonal transmission.⁹⁵

92 Chandramohan, D., Webster, J., Smith, L., Awine, T., Owusu-Agyei, S. & Carneiro, I. 2007. Is the Expanded Programme on Immunisation the most appropriate delivery system for intermittent preventive treatment of malaria in West Africa? *Tropical Medicine & International Health*, 12(6):743-50. [<https://doi.org/10.1111/j.1365-3156.2007.01844.x>]; Maltha, J., Gillet, P. & Jacobs, J. 2013. Malaria rapid diagnostic tests in endemic settings. *Clinical Microbiology and Infection*, 19(5):399-407. [<https://doi.org/10.1111/1469-0691.12151>].

93 Barger et al., 2009.

94 Clarke, S.E., Jukes, M.C., Njagi, J.K. & Khasakhala, L., Cundill, B., Otido, J., Crudder, C., Estambale, B.B. & Brooker, S. 2008. Effect of intermittent preventive treatment of malaria on health and education in schoolchildren: a cluster-randomised, double-blind, placebo-controlled trial. *The Lancet*, 372(9633):127-138. [[https://doi.org/10.1016/S0140-6736\(08\)61034-X](https://doi.org/10.1016/S0140-6736(08)61034-X)].

95 Dicko, A., Sagara, I., Sissoko, M.S., Guindo, O., Diallo, A.I., Kone, M., Toure, O.B., Sacko, M. & Doumbo, O.K. 2008. Impact of intermittent preventive treatment with

- A randomised, double-blind, placebo-controlled trial in schoolchildren (six to 14 years) in Uganda; 740 were randomised to dihydroartemisinin-piperaquine given once a month, once a school term (four treatments over 12 months), or placebo, and followed for 12 months. Monthly intermittent preventive treatment with dihydroartemisinin-piperaquine offered remarkable protection; reducing the incidence of malaria by 96 per cent, the prevalence of asymptomatic parasitaemia by 94 per cent and the prevalence of anaemia by 40 per cent in schoolchildren living in a high-malaria-transmission setting.⁹⁶

Nankabirwa and colleagues (Wandera, Amuge, Kiwanuka, Dorsey, Rosenthal, Brooker, Staedke and Kanya, 2014b) summarised eight intermittent protective treatment studies from Africa.⁹⁷ Trials data, including a 2011 systematic review and meta-analysis on efficacy and safety of 12 trials (seven controlled, five controlled) generally indicate intermittent protective treatment regimens provide significant benefit for school-age children, achieving reduced rates of infection, improved health, a decrease in absence from school, enhanced academic achievement, and improved cognitive ability.⁹⁸ The consensus is that intermittent protective treatment is a safe, simple strategy offering remarkable protection in schoolchildren

sulphadoxine-pyrimethamine targeting the transmission season on the incidence of clinical malaria in children in Mali. *Malaria Journal*, 7(123). [<https://doi.org/10.1186/1475-2875-7-123>].

96 Nankabirwa, J.I., Wandera, B., Amuge, P., Kiwanuka, N., Dorsey, G., Rosenthal, P.J., Brooker, S.J., Staedke, S.G. & Kanya, M.R. 2014b. Impact of intermittent preventive treatment with dihydroartemisinin-piperaquine on malaria in Ugandan schoolchildren: a randomized, placebo-controlled trial. *Clinical Infectious Diseases*, 58(10):1404-1412. [<https://doi.org/10.1093/cid/ciu150>].

97 Nankabirwa et al., 2014b.

98 Ibid.; Bundy, D.A.P., Shaeffer, S., Jukes, M., Beegle, K., Gillespie, A., Drake, L., Lee, S.F., Hoffman, A., Jones, J., Mitchell, A., Barcelona, D., Camara, B., Golmar, C., Savioli, L., Sembene, M., Takeuchi, T. & Wright, C. et al. 2006. School Based Health and Nutrition Programs. In: Breman, J.G., Measham, A.R., Alleyne, G., Jamison, D.T., Claeson, M., Evans, D.B., Jha, P., Mills, A. & Musgrove, P. (eds). *Disease Control Priorities for Developing Countries*. Breman JG, Measham AR, Alleyne G et al. (eds). Oxford: Oxford University Press. 2006:1091-1108; Clarke et al., 2004; Clarke et al., 2008; Dicko et al., 2008; Clarke, S.E., Rouhani, S., Diarra, S., Saye, R., Bamadio, M., Jones, R., Traore, E., Traore, K., Jukes, M.C.H., Thuilliez, J., Brooker, S., Roschnik, N. & Sacko, M. 2017. Impact of a malaria intervention package in schools on Plasmodium infection, anaemia and cognitive function in schoolchildren in Mali: a pragmatic cluster-randomised trial. *BMJ Global Health*, 2:e000182. [<http://doi.org/10.1136/bmjgh-2016-000182>]; Wilson, A.L. & IPTc Taskforce. 2011. A systematic review and meta-analysis of the efficacy and safety of intermittent preventive treatment of malaria in children (IPTc). *PLoS One*, 6(2):e16976. [<https://doi.org/10.1371/journal.pone.0016976>].

in high-malarial-transmission settings, and also appears to have a substantial protective effect against all-cause mortality. Clarke and colleagues (Brooker, Njagi, Njau, Estambale, Muchiri and Magnussen, 2004) concluded that effective malaria intermittent protective treatment interventions could be a valuable addition to school health programmes.⁹⁹

While the optimal regimen remains unclear, a 2015 systematic review of five studies assessing efficacy concluded:¹⁰⁰

- Sulphadoxine-pyrimethamine may not be a promising regimen in areas where resistance to this drug is high.
- Artemisinin combination therapies (dihydroartemisinin-piperaquine, sulphadoxine-pyrimethamine + amodiaquine) provided acceptable protective efficacy against clinical malaria, parasitaemia and anaemia.
- Dihydroartemisinin-piperaquine administered monthly demonstrated the highest protective efficacy.
- Combining at least two long half-life drugs such as piperaquine plus sulphadoxine-pyrimethamine may be, at present, the most promising option.

However, in a cluster randomised trial, Halliday and colleagues (Okello, Turner, Njagi, Mcharo, Kengo, Allen, Dubeck, Jukes and Brooker, 2014) failed to show benefit from an intermittent screening and treatment programme. Kenyan primary schools were randomly assigned as intervention or control sites, and 5 233 children randomly selected by public health workers were screened using rapid diagnostic testing. The 17.5 per cent rapid diagnostic testing-positive (with or without malaria symptoms) were then treated with artemether-lumefantrine.¹⁰¹ Follow up at 12 and 24 months showed no impact for the prevalence of anaemia, or on the prevalence of *Plasmodium falciparum* infection, or scores of classroom attention. The authors concluded that in this setting, as implemented, intermittent screening and

treatment is not effective in improving the health or education of school children. Possible reasons given included:

- marked geographical heterogeneity in transmission;
- the rapid rate of reinfection following artemether-lumefantrine;
- variable reliability of rapid diagnostic testing; and
- the relative contribution of malaria to anaemia.

In a review examining why this trial failed to show benefit, Von Seidlein emphasised the results cannot be attributed to methodological uncertainty (the trial was conducted in a large sample of schools, to the highest procedural standards, with excellent adherence and follow-up).¹⁰² The author concluded that children found to be parasitaemic most likely did benefit from early treatment; however, this was not an outcome the investigators measured. Also, that individual beneficial effects probably did not translate to school-wide outcomes because the trial did not involve treatment of all infections, only those of sufficiently high density to be detectable by rapid diagnostic testing. This author's review of alternative approaches and presumptive treatments extends beyond the school-based scope of this chapter but contains excellent science.

Concerns with seasonal malaria chemoprevention are that it does not provide complete protection and is demanding to deliver for both families and healthcare providers. Furthermore, as sulphadoxine-pyrimethamine selects rapid drug-resistant parasites, malaria burden may increase in older children where seasonal malaria chemoprevention is implemented. Also, a risk exists of future emergence of resistance to the drugs currently being used for seasonal malaria chemoprevention.¹⁰³ Although intermittent protective treatment with sulphadoxine-pyrimethamine has reduced malaria episodes by 20 to 59 per cent across Africa, the protective efficacy may also be affected by co-existing malnutrition. In 1 200 Ghanaian infants who received sulphadoxine-pyrimethamine or placebo at three, nine and 15 months of age the protective efficacies of intermittent protective treatment in malnourished children were roughly half or less of those observed in non-malnourished children.¹⁰⁴

99 Clarke et al., 2017.

100 Matangila, J.R., Mitashi, P., Da Luz, R.A., Lutumba, P.T., Van Geertruyden, J.P. 2015. Efficacy and safety of intermittent preventive treatment for malaria in schoolchildren: a systematic review. *Malaria Journal*, 14(450). [<https://doi.org/10.1186/s12936-015-0988-5>].

101 Halliday, K.E., Okello, G., Turner, E.L., Njagi, K., Mcharo, C., Kengo, J., Allen, E., Dubeck, M.M., Jukes, M.C.H., Brooker, S.J. 2014. Impact of intermittent screening and treatment for malaria among school children in Kenya: a cluster randomized trial. *PLoS Medicine*, January 28. [<https://doi.org/10.1371/journal.pmed.1001594>]; Halliday et al., 2014.

102 Von Seidlein, L. 2014. The failure of screening and treating as a malaria elimination strategy. *PLoS Med*, 11(1):e1001595. [<https://doi.org/10.1371/journal.pmed.1001595>].

103 Greenwood et al., 2017.

104 Danquah, I., Dietz, E., Zanger, P., Reither, K., Ziniel, P., Bienzle, U. & Mockenhaupt, F.P. 2009. Reduced efficacy of intermittent preventive treatment of malaria in malnourished children. *Antimicrobial Agents and Chemotherapy*, 53(5):1753-1759. [<https://doi.org/10.1128/AAC.01723-08>].

Mass drug administration

Mass drug administration is a WHO endorsed a strategy to control Neglected Tropical Diseases, a group of 13 major disabling conditions among the most common chronic infections in the world's poorest people; seven of these are now targeted using mass drug administration – ascariasis, trichuriasis, hookworm infection, schistosomiasis, lymphatic filariasis, trachoma, and onchocerciasis.¹⁰⁵ A key component of current Neglected Tropical Diseases control policy is at least annual preventive chemotherapy distributed through school-based mass drug administration initiatives; hence, these policies offer the opportunity to deliver school-based malaria strategies conjointly.¹⁰⁶ The positive impact of combining intermittent protective treatment of malaria with mass drug administration to control intestinal soil-transmitted helminths was evaluated in Ghana in a three-arm, open-label intervention study using artemether-lumefantrine; measures of anaemia, sustained attention, and recall in the schoolchildren improved.¹⁰⁷ The potential and safety of teachers' involvement in mass drug administration were confirmed in Malawi when artemether-lumefantrine as an intermittent protective treatment for malaria was combined with school-based mass drug administration for schistosomiasis and helminths using praziquantel and albendazole.¹⁰⁸ When this same mass drug combination was administered in Zimbabwe to treat children infected with any of the schistosome species and soil-transmitted helminths, those confirmed to also have malaria via thick blood film microscopy were treated using a combination of chloroquine, sulphadoxine and pyrimethamine according to local case management guidelines.¹⁰⁹

105 Hotez, P.J., Molyneux, D.H., Fenwick, A., Kumaresan, J., Sachs, S.E., Sachs, J.D. & Savioli, L. 2007. Control of neglected tropical diseases. *The New England Journal of Medicine*, 357(10):1018-27. [https://doi.org/10.1056/NEJMra064142].

106 Cohee et al., 2018; WHO. 2013. *Schistosomiasis: Progress Report 2001–2011, Strategic Plan 2012–2020*. [https://bit.ly/3kkUnJS].

107 Opoku et al., 2016.

108 Cohee et al., 2018.

109 Midzi, N., Mtapuri-Zinyowera, S., Sangweme, D., Paul, N.H., Makware, G., Mapingure, M.P., Brouwer, K.C., Mudzori, J., Hlerema, G., Chadukura, V., Mutapi, F., Kumar, N. & Mduluza, T. 2011. Efficacy of integrated school based de-worming and prompt malaria treatment on helminths-Plasmodium falciparum co-infections: A 33 months follow up study. *BMC International Health and Human Rights*, 11(1):9. [https://doi.org/10.1186/1472-698X-11-9]; Mphwatiwa, T., Witek-McManus, S., Mtali, A., Okello, G., Nguluwe, P., Chatsika, H., Roschnik, N., Halliday, K.E., Brooker, S.J. & Mathanga, D.P. 2017. School-based diagnosis and treatment of malaria by teachers using rapid diagnostic tests and artemisinin-based combination therapy: experiences and perceptions of users and implementers of the Learner Treatment Kit, southern Malawi. *Malaria Journal*, 16(318). [https://doi.org/10.1186/s12936-017-1964-z]; Anaba, M.K.,

The addition of antimalarials to these routine annual mass drug administration programmes to control Neglected Tropical Diseases was well-tolerated, safe, beneficial and well-received by parents, and is logical as current national malaria control interventions do not specifically target school-age children, despite evidence that they bear the highest burden of infection.¹¹⁰ Hence, combining intermittent protective treatment with mass drug administration strategies is an appealing model; adding malaria treatment to already established platforms for Neglected Tropical Diseases control may also increase the cost-effectiveness of both interventions, leading to increased sustainability.

Rapid diagnostic testing and Artemisinin combination therapy

A major advantage of rapid diagnostic testing kits is that they provide point-of-care diagnosis, which in turn makes immediate treatment feasible. Rapid diagnostic testing is especially useful where health facilities are scarce and/or operate using staff with minimal skill levels, and when introduced, were quickly shown to be more cost-effective than diagnostic microscopy.¹¹¹ Overall, research confirms that “RDTs represent a cheap diagnostic approach in school malariometric surveys, and can be used to estimate infection prevalence at low and high prevalence categories reliably”.¹¹²

The sensitivity and specificity of rapid diagnostic tests are good enough for them to replace conventional testing for malaria.¹¹³ However, their usefulness is linked to the accuracy of the diagnoses they provide; while simple to use and the principles of how they work are similar, rapid diagnostic testing kits do vary, and accuracy is user-dependent. Maltha, Gillet and Jacobs (2013) reviewed design limitations and

Ibisomi, L., Owusu-Agyei, S., Chirwa, T., Ramaswamy, R. 2019. Determinants of health workers intention to use malaria rapid diagnostic test in Kintampo North Municipality, Ghana-a cross-sectional study. *BMC Health Services Research*, 19(1):491. [https://doi.org/10.1186/s12913-019-4324-6].

110 Clarke et al., 2008.

111 Wongsrichanalai, C., Barcus, M.J., Muth, S., Sutamihardja, A., Wernsdorfer, W.H. 2007. A review of malaria diagnostic tools: microscopy and rapid diagnostic test (RDT). *The American Journal of Tropical Medicine and Hygiene*, 77(Supplement 6):119-127. [https://doi.org/10.4269/ajtmh.2007.77.119]; FIND, TDR & WHO. 2009. *Malaria rapid diagnostic test performance*. Results of WHO product testing of malaria RDTs: Round. [https://bit.ly/36sOntE].

112 WHO, 2015.

113 Abba, K., Deeks, J.J., Olliaro, P.L., Naing, C.M., Jackson, S.M., Takwoingi, Y., Donegan, S. & Garner, P. 2011. Rapid diagnostic tests for diagnosing uncomplicated P. falciparum malaria in endemic countries. *Cochrane Systematic Review*, (7): CD008122. [https://doi.org/10.1002/14651858.CD008122.pub2].

end-user errors.¹¹⁴ In the context of employing school-based diagnosis, minimising mistakes is crucial; it has been shown that job aids (step-by-step instructions) that supplement manufacturer's instructions can improve performance.¹¹⁵

While the positive impact of rapid diagnostic testing on malaria management has been widely demonstrated, field trials have indicated that adherence to test results is sometimes poor, especially in public health settings. However, appropriate training and protocol design improve adherence.¹¹⁶ Importantly data from Senegal indicate high adherence to rapid diagnostic testing results in anti-malarial prescribing practice following a national programme to introduce rapid diagnostic testing into public health facilities. Parasite-based diagnosis increased nationally from 3.9 per cent of reported malaria-like febrile illness to 86 per cent over a three-year period, which was also associated with a large reduction in artemisinin combination therapy consumption, demonstrating that effective roll-out and use of malaria rapid diagnostic testing is achievable on a national scale through well planned and structured implementation.¹¹⁷ This is relevant to the up-scale of programmes for rapid diagnostic testing use by appropriately trained teachers in schools. The potential for up-scaling was identified in studies that showed:

- kits can be stocked and used appropriately outside formal health facilities; and

114 Afenyadu et al., 2005; Maltha, Gillet & Jacobs, 2013.

115 Rennie, W., Phetsouvanh, R., Lupisan, S., Vanisaveth, V., Hongvanthong, B., Phompida, S., Alday, P., Fulache, M., Lumagui, R., Jorgensen, P., Bell, D. & Harvey, S. 2007. Minimising human error in malaria rapid diagnosis: clarity of written instructions and health worker performance. *Transactions of The Royal Society of Tropical Medicine and Hygiene*, 101(1):9-18. [https://doi.org/10.1016/j.trstmh.2006.03.011].

116 Manyando, C., Njunju, E.M., Chileshe, J., Siziya, S., Shiff, C. 2014. Rapid diagnostic tests for malaria and health workers' adherence to test results at health facilities in Zambia. *Malaria Journal*, 13(166). [https://doi.org/10.1186/1475-2875-13-166]; Burchett, H.E., Leurent, B., Baiden, F., Baltzell, K., Björkman, A., Bruxvoort, K., Clarke, S., DiLiberto, D., Elfving, K., Goodman, C., Hopkins, H., Lal, S., Liverani, M., Magnussen, P., Mårtensson, A., Mbacham, W., Mbonye, A., Onwujekwe, O., Roth Allen, D., Shakely, D., Staedke, S., Vestergaard, L.S., Whitty, C., Wiseman, V. & Chandler, C.I. 2017. Improving prescribing practices with rapid diagnostic tests (RDTs): synthesis of 10 studies to explore reasons for variation in malaria RDT uptake and adherence. *BMJ Open*, 7(3): e012973. [https://doi.org/10.1136/bmjopen-2016-012973].

117 Thiam, S., Thior, M., Faye, B., Ndiop, M., Diouf, M.L., Diouf, M.B., Diallo, I., Fall, F.B., Ndiaye, J.L., Albertini, A., Lee, E., Jorgensen, P., Gaye, O. & Bell, D. 2011. Major reduction in anti-malarial drug consumption in Senegal after nation-wide introduction of malaria rapid diagnostic tests. *PLoS One*. 6(4):e18419. [https://doi.org/10.1371/journal.pone.0018419].

- basic training programmes enable teachers and other individuals without a formal health care background to use rapid diagnostic testing reliably and effectively.¹¹⁸

Artemisinin combination therapy is the first-line treatment for *Plasmodium falciparum* malaria recommended since 2001 by the WHO for use worldwide in all countries with endemic disease.¹¹⁹ Artemisinin combination therapies are partly gametocytocidal, so widespread deployment can be expected to affect the transmission of malaria in communities where a high proportion of infected individuals have symptoms and seek treatment.¹²⁰ Benefits of genuine artemisinin combination therapies include high efficiency, fast action, few adverse effects, low cost and the potential to lower the rate at which resistance emerges and spreads.¹²¹ Care must be taken in low- and middle-income countries over the choice of the preparation used as sub-standard and counterfeit products with little or no

118 Kyaabayinze, D.L., Asiimwe, C., Nakanjko, D., Nabakooza, J., Counihan, H., Tibenderana, J.K. 2010. Use of RDTs to improve malaria diagnosis and fever case management at primary health care facilities in Uganda. *Malaria Journal*, 9(200). [https://doi.org/10.1186/1475-2875-9-200]; Macnab et al., 2016a & 2016b; Mbonye, A.K., Magnussen, P., Lai, S., Hansen, K.S., Cundill, B., Chandler, C. & Clarke, S.E. A cluster randomized trial introducing rapid diagnostic tests in registered drug shops in Uganda: Impact on appropriate treatment of malaria. *PLoS One*, 10(7):e0129545. [https://doi.org/10.1371/journal.pone.0129545]; Visser et al., 2017; Halliday et al., 2014; Kyaabayinze et al., 2010; Counihan, H., Harvey, S.A., Sekeske-Chinyama, M., Hamainza, B., Banda, R., Malambo, T., Masaninga, F. & Bell, D. 2012. Community health workers use malaria rapid diagnostic tests (RDTs) safely and accurately: results of a longitudinal study in Zambia. *The American Journal of Tropical Medicine and Hygiene*, 87(1):57-63. [https://doi.org/10.4269/ajtmh.2012.11-0800]; Witek-McManus, S., Mathanga, D.P., Verney, A., Mtali, A., Ali, D., Sande, J., Mwendu, R., Ndau, S., Mazinga, C., Phondiwa, E., Chimuna, T., Melody, D., Roschnik, N., Brooker, S.J. & Halliday, K.E. 2015. Design, implementation and evaluation of a training programme for schoolteachers in the use of malaria rapid diagnostic tests as part of a basic first aid kit in southern Malawi. *BMC Public Health*, 15(1):904. [https://doi.org/10.1186/s12889-015-2228-x].

119 WHO, 2019; Adjui, M., Babiker, A., Garner, P., Olliaro, P., Taylor, W., White, N. & International Artemisinin Study Group. 2004. Artesunate combinations for treatment of malaria: meta-analysis. *The Lancet*, 363(9402):9-17. [https://doi.org/10.1016/s0140-6736(03)15162-8]; Benjamin, J., Moore, B., Lee, S., Senn, M., Griffin, S., Lautu, D., Salman, S., Siba, P., Mueller, I. & Davis, T. 2012. Artemisinin-naphthoquine combination therapy for uncomplicated pediatric malaria: a tolerability, safety, and preliminary efficacy study. *Antimicrobial Agents and Chemotherapy*, 56(5):2465-2471. [https://doi.org/10.1128/AAC.06248-1].

120 O'Meara et al., 2010.

121 WHO, 1992; Adjui et al., 2004.

efficacy are unfortunately widespread, and continue to pose severe threats to human health. Estimates indicate that in 2013 more than 100 000 deaths in sub-Saharan Africa in children under five years of age were associated with poor quality antimalarials.¹²² In addition to risking the health of the patient because of limited or absent efficacy, falsified medicines also contribute significantly to the risk of drug resistance developing. It is also important to note recent concerns that the efficacy of artemisinin combination therapy has declined on the Thai-Cambodian border (a site of historically emerging antimalarial-drug resistance); resistance is characterised by slow parasite clearance in vivo without corresponding reductions on conventional in vitro susceptibility testing.¹²³

Since the efficacy of artemisinin combination therapies is high, more could be achieved if their potential was optimised through effective coverage and increased availability; the major challenge is finding effective ways to deliver these drugs to those who need them most.¹²⁴ Evaluation of a community case management approach, where a variety of trained providers delivered artemisinin combination therapy to children in five African cities, found this model feasible and acceptable, but that innovation was required to overcome the struggle of competing against sources using established healthcare providers.¹²⁵ Other exploratory avenues included deployment through trained agents in drug stores, pharmacies and private medical clinics, and teachers in school programmes.¹²⁶

122 Brooker et al., 2008.

123 Dondorp, A.M., Nosten, F., Yi, P., Das, D., Phyo, A.P., Tarning, J., Lwin, K.M., Ariey, F., Hanpithakpong, W., Lee, S.J., Ringwald, P., Silamut, K., Imwong, M., Chotivanich, K., Lim, P., Herdman, T., An, S.S., Yeung, S., Singhasivanon, P., Day, N., Lindergardh, N., Socheat, D. & White, N.J. 2009. Artemisinin Resistance in *Plasmodium Falciparum* Malaria. *The New England Journal of Medicine*, 361(5):455-467. [<https://doi.org/10.1056/NEJMoa0808859>].

124 Mutabingwa, 2005; Whitty, C.J.M., Chandler, C., Ansah, E., Leslie, T., Staedke, S.G. 2008. Deployment of ACT antimalarials for treatment of malaria: challenges and opportunities. *Malaria Journal*, 7(S7). [<https://doi.org/10.1186/1475-2875-7-S1-S7>].

125 Akweongo, P., Agyei-Baffour, P., Sudhakar, M., Simwaka, B.N., Konaté, A.T., Adongo, P.B., Browne, E.N., Tegegn, A., Ali, D., Traoré, A., Amuyunzu-Nyamongo, M., Pagnoni, F. & Barnish, G. 2011. Feasibility and acceptability of ACT for the community case management of malaria in urban settings in five African sites. *Malaria Journal*, 10(240). [<https://doi.org/10.1186/1475-2875-10-240>].

126 Macnab et al., 2016a; Mbonye et al., 2015; Halliday et al., 2014; *President's Malaria Initiative (PMI)*. 2006. Uganda: Malaria Country Action Plan, February. [<https://bit.ly/3aPCYWy>] (Accessed 6 December 2019).

Developing a model for teacher-driven school-based care

If teachers could be trained to promptly detect and adequately treat uncomplicated malaria promptly, and promptly refer severe forms of the disease, improved access to this critical service would be achieved. For example, school absenteeism and man-hours lost to the disease would be reduced, especially in these rural communities.¹²⁷

These words were written in 2005 in a review on how to improve access to early treatment.¹²⁸ Afenyadu, Agyepong, Barnish and Adjei (2005)'s concept that teachers should be trained to intervene presaged the calls for innovative solutions to the health burden of malaria in school-children from the WHO, and other experts.¹²⁹ The authors also identified that decentralisation to the district level, and collaboration between the health and education sectors were required to improve the health status of school children in rural communities.

In an early exploratory trial, 12 Ghanaian schools trained teachers to diagnose and treat uncomplicated malaria and recognise and refer severe forms of the disease for appropriate treatment. The five-day training included:

- Instruction in diagnosis using an adaptation of the WHO diagnostic algorithm designed for training Community Health Workers,¹³⁰ and
- Chemotherapy with chloroquine (the drug of choice at the time).

Of the fevers diagnosed as presumptive malaria by teachers, 93 per cent met the case definition. The proportion adequately treated initially (75 per cent) was improved by pre-packaging the antimalarials to simplify correct dosing. The authors concluded that primary school teachers in rural communities are willing partners in bringing early case detection and adequate management closer to the people.¹³¹

Findings were similar in a contemporaneous study in Tanzania where the clinical diagnostic algorithm included measurement of body temperature, although training in diagnosis and treatment only involved headteachers and selected 'health' teachers.¹³² Treatment outcome was measured using a thick blood smear examination rather than prescriber compliance.

127 Afenyadu et al., 2005.

128 Ibid.

129 WHO, 2008; Sachs & Malaney, 2002; Agyepong et al., 2017; Temperley et al., 2008; Hounghbedji et al., 2015; Khatib et al., 2013.

130 WHO, 1992.

131 Afenyadu et al., 2005.

132 Magnussen, P., Ndawi, B., Sheshe, A.K., Byskov, J. & Mbwana, K. 2001. Malaria

In Malawi, teachers were taught to use pupil-treatment kits containing sulphadoxine-pyrimethamine tablets dispensed according to national guidelines. The authors concluded school-based interventions could play a part in mitigating malaria based on comparison of overall and malaria-specific mortality rates; these were calculated for the three years before and two years after the intervention, with rates dropping from 2.2 to 1.44 deaths/1 000 student-years, and 1.28 to 0.44 deaths/1 000 student-years respectively.¹³³

In a second Malawian school-based programme, teachers were trained to identify and treat children suffering from malaria. Intervention and comparison schools were matched; retrospective evaluation used school administrative records. Significant reductions in general absenteeism and grade repetition by students were noted.¹³⁴

The first model combining teacher-administered rapid diagnostic testing with artemisinin combination therapy was developed as a community-outreach health-education project by a local non-governmental organisation after teachers had identified the unacceptable health burden malaria was creating among their pupils.¹³⁵ The decision to introduce school-based rapid diagnostic testing/artemisinin combination therapy was made collaboratively during community-based dialogue. Up to that time all pupils sick at school were sent home devolving care to parents, however many of those presumed to have malaria never received timely diagnosis and treatment, so morbidity and the duration of absence from school were high.

Macnab and colleagues (Mukisa, Mutabazi & Steed, 2016a; Mutabazi, Mukisa, Eliab, Kigozi & Steed, 2016b) evaluated this two-year intervention trialling teacher-driven rapid diagnostic testing/artemisinin combination therapy in 2016; four rural schools in Uganda were involved.¹³⁶ All teachers were trained broadly on malaria causation, prevention and treatment; two volunteer teachers in each school were specifically trained to collect the required data, conduct rapid diagnostic testing in

children falling sick at school and administer artemisinin combination therapy to those testing positive. The effect on absenteeism was evaluated as a surrogate for morbidity. A year of baseline pre-intervention data was compared to the subsequent year when all sick children had a teacher-administered rapid diagnostic testing and prompt artemisinin combination therapy if they tested positive. A single dose artemisinin combination therapy preparation was used to ensure a full course of treatment was completed, and eliminate any partial treatment bias.

Pre-intervention 953/1 764 pupils were sent home due to presumed infectious illness; parental management only approached the WHO standards for malaria diagnosis and treatment in 1:4 children, and the mean duration of absence from school was 6.5 school days. During school-based teacher-administered rapid diagnostic testing/artemisinin combination therapy, 1 066/1 774 pupils were identified as sick, 765/1 066 were rapid diagnostic test positive and received artemisinin combination therapy, and duration of absence fell to 0.6 days. (Table 14.1). After being promptly treated, many children felt well enough to ask to return to class within hours, and consequently had no days when they were absent from school.

Overall, absence from school was reduced by 60.8 per cent during this intervention. If the same percentage of children sent home in year one had malaria as were diagnosed using rapid diagnostic testing in year two, this would equate to 1 358 cases in 1 775 children over the two years – a malaria incidence rate of 79 per cent across the four schools. No children died from malaria during the intervention year. Delivery was readily implemented and sustained; teachers participated willingly.

diagnosis and treatment administered by teachers in primary schools in Tanzania. *Tropical Medicine & International Health*, 6(4):273-79. [<https://doi.org/10.1046/j.1365-3156.2001.00720.x>].

133 Pasha, O., Del Rosso, J., Mukaka, M. & Marsh, D. The effect of providing fansidar (sulfadoxine-pyrimethamine) in schools on mortality in school-age children in Malawi. *The Lancet*, 361(9357):577-578. [[https://doi.org/10.1016/s0140-6736\(03\)12511-1](https://doi.org/10.1016/s0140-6736(03)12511-1)].

134 Simwaka, B.N., Simwaka, K. & Bello, G. 2009. Retrospective analysis of a school-based malaria treatment programme demonstrates a positive impact on health and education outcomes in Mangochi district. *Malaria Journal*, 1(4):492-506. [<https://doi.org/10.1080/19439340903342336>].

135 Macnab et al., 2016a.

136 Ibid.; Macnab et al., 2016b.

Table 14.1 Composite data from the school-based teacher-driven rapid diagnostic testing (RDT) or artemisinin combination therapy (ACT) malaria intervention programme in four Ugandan schools, comparing a pre-intervention year with a year of project intervention followed by three years of independent school-sustained delivery.

	Year 1	Year 2	Year 3	Year 4	Year 5
	Pre-intervention Baseline	Intervention	Independent conduct year 1	Independent conduct year 2	Independent conduct year 3
Children	1764	1774	1798	1797	1791
Age years	5-13	5-13	5-14	5-14	5-14
Sick at school	Sent home	Teacher assessed	Teacher assessed	Teacher assessed	Teacher assessed
Total	539	1066	957	1317	632
RDT + ve		715 (68%)	597 (62%)	819 (62%)	819 (62%)
Rx ACT		715	597	819	819
Absence School days mean (SD)	All illnesses	Malaria	Malaria	Malaria	Malaria
(p = significance compared to pre-intervention Year 1)	6.5 (3.17)	0.59 (0.64) p=<0.001	0.49 (0.38) p=<0.001	0.37 (0.35) p=<0.001	0.59 (0.64) p=<0.001
Project action	Baseline data Teacher Training re. RDT/ACT	Project data	f/up data Refresher training	f/up data	f/up data Refresher training
Oversight	Monthly visits	Weekly visits	Site visit/term	Site visit/term	Site visit/term

In 2017, Mphwatiwa and colleagues (Witek-McManus, Mtali, Okello, Nguluwe, Chatsika, Roschnik, Halliday, Brooker and Mathanga) reported on a similar approach in Malawi. The experiences and perceptions of users and implementers from 6/29 primary schools, where teachers were trained to test and treat were evaluated from eight focus groups and 20 in-depth interviews.

Findings included:

- Positive outcomes

Trained teachers were trusted providers of malaria testing and treatment; access to treatment by children increased; absenteeism decreased.

- Potential barriers

Increased teacher workloads and the need for supervision from health workers are potential barriers.

- Concerns

Lack of incentives and concerns for the sustainability of drug supply; an impressive element was that this trial was established following intersectoral collaboration between the Ministry of Health and Ministry of Education Science and Technology.¹³⁷

Both Macnab et al. and Mphwatiwa et al. concluded that training teachers to ‘test and treat’ was well-received, supported national health and education policies and was seen to be a worthwhile intervention.¹³⁸ Importantly, sustainability is demonstrated by ongoing data from Uganda shown in Table 14.1. For three years post-intervention the target schools have independently continued rapid diagnostic testing and artemisinin combination therapy, and the significant reduction in malaria morbidity (reduction in absenteeism) was sustained; there is also robust evidence of greater knowledge about many aspects of malaria among the school-children and in the broader community.¹³⁹ Even during restricted schooling necessitated by the Covid-19 pandemic, teachers were motivated to continue to offer scaled back diagnostic and treatment services; these were modified to comply with infection control measures to limit spread of Covid-19.

Training

Schools present an obvious opportunity to improve the access of children to health services; a key question in the context of malaria is can teachers be trained to provide appropriate diagnostic and treatment services for school children.

Witek-McManus and colleagues (Mathanga, Verney, Mtali, Ali, Sande, Mwenda, Ndau, Mazinga, Phondiwa, Chimuna, Melody, Roschnik, Brooker and Halliday, 2015) evaluated the training and performance of teachers in Malawi. Training materials were first piloted in a four-day workshop; assessment data informed the design of the definitive seven-day training. Fifteen teachers were evaluated at four stages: pilot training, two weeks post-pilot, following final training and seven months later. Conclusions were that appropriately trained teachers could use rapid diagnostic testing and artemisinin combination therapy competently to test and

¹³⁷ Mphwatiwa et al., 2017.

¹³⁸ Macnab et al., 2016b; Mphwatiwa et al., 2017.

¹³⁹ Macnab et al., 2016a.

treat children at school for uncomplicated malaria. They do so safely and accurately, demonstrating a comparable skill level to other non-health professional users of rapid diagnostic testing.¹⁴⁰ Teacher training in Uganda was via a one-day workshop; two trained laboratory staff and two nurses included instruction on:

- evaluation of a child for a presumed infectious illness;
- theory and practice for the conduct of rapid diagnostic testing and administration of artemisinin combination therapy;
- record-keeping; and
- needle safety and waste disposal techniques.¹⁴¹

Practical competencies were re-evaluated during project implementation, and at a refresher course given two years later. Importantly, in both projects, all teachers correctly performed safe blood collection and handling, accurate interpretation of rapid diagnostic testing, correctly dispensed artemisinin combination therapy and sustained this competency for the duration of the evaluation.¹⁴²

All evaluative literature stresses that effective training and comprehensive instructions on rapid diagnostic testing and artemisinin combination therapy are essential.¹⁴³ Learning points from training for personnel other than teachers warrant inclusion, including the systematic review of six published and six unpublished studies by Visser and colleagues (Bruxvoort, Maloney, Leslie, Barat, Allan, Ansah, Anyanti, Boulton, Clarke, Cohen, Cohen, Cutherell, Dolkart, Eves, Fink, Goodman, Hutchinson, Lal, Mbonye, Onwujekwe, Petty, Pontarollo, Poyer, Schellenberg, Streat, Ward, Wiseman, Whitty, Yeung, Cunningham and Chandler, 2017). Factors deemed to have a positive effect on rapid diagnostic testing uptake and provider adherence to test results included the length of provider training and adequacy of support or supervision. Common challenges were the disposal of medical waste and referral of complicated patients to public facilities.¹⁴⁴ A problem

140 Witek-McManus et al., 2015.

141 Macnab et al., 2016b.

142 Ibid.; Witek-McManus et al., 2015.

143 Visser et al., 2017; Burchett, H.E., Leurent, B., Baiden, F., Baltzell, K., Björkman, A., Bruxvoort, K., Clarke, S., DiLiberto, D., Elfving, K., Goodman, C., Hopkins, H., Lal, S., Liverani, M., Magnussen, P., Mårtensson, A., Mbacham, W., Mbonye, A., Onwujekwe, O., Roth Allen, D., Shakely, D., 2017. Improving prescribing practices with rapid diagnostic tests (RDTs): synthesis of 10 studies to explore reasons for variation in malaria RDT uptake and adherence. *BMJ Open*, 7(3):e012973. [https://doi.org/10.1136/bmjopen-2016-012973].

144 Visser et al., 2017.

of retained preference for clinical diagnosis was often seen to persist in public health workers; this will not compromise teacher performance as they will only gain experience with the rapid diagnostic testing diagnostic pathway.¹⁴⁵

Training approaches need to emphasise how to minimise common errors, and periodic performance appraisals to monitor user behaviour should be a basic component of rapid diagnostic testing implementation.¹⁴⁶ Learning points on how errors are made and practical ways to avoid them are necessary as even simple diagnostic tests can be poorly performed and interpreted; examples include ensuring the correct volume of buffer is added to the test cassette, and the appropriate wait time elapses before reading the result.¹⁴⁷ Trainers must be flexible and responsive to learner's priorities, expectations and capacities, and trainee providers learn from being involved in the exploratory community dialogue necessary before programme implementation.¹⁴⁸ A proper understanding of the aims and expected benefits of testing, opportunities to learn from experienced staff, and exposure to 'champions' for the intervention, were three training fundamentals identified as lacking where the use of rapid diagnostic testing by trained health workers remained low.¹⁴⁹

Cost

The cost and cost-benefit of any school-based health intervention, including rapid diagnostic testing/artemisinin combination therapy, are relevant to their deployment. Rapid diagnostic testing has the potential to be cost-effective in most parts of sub-Saharan Africa; the cost of artemisinin combination therapies is a potential barrier to scale-up of initiatives that use them,¹⁵⁰ but substantial cost-benefit will accrue from improving the health of school-aged children in ways that

145 Manyando et al., 2014; Burchett et al., 2017.

146 Rennie et al., 2007.

147 Ibid.; Counihan et al., 2012.

148 Witek-McManus et al., 2015; Burchett et al., 2017; Macnab et al., 2016b; Mbonye et al., 2015; Macnab, Stewart & Gagnon, 2014; Macnab, 2013.

149 Manyando et al., 2014; Anaba et al., 2019; Onwujekwe, O., Mangham-Jefferies, L., Cundill, B., Alexander, N., Langham, J., Ibe, O., Uzochukwu, B. & Wiseman, V. 2015. Effectiveness of provider and community interventions to improve treatment of uncomplicated malaria in Nigeria: a cluster randomized controlled trial. *PLoS One*, 10(8):e0133832. [https://doi.org/10.1371/journal.pone.0133832].

150 Shillcutt, S., Morel, C., Goodman, C., Coleman, P., Bell, D., Whitty, C.J. & Mills, A. 2008. Cost-effectiveness of malaria diagnostic methods in sub-Saharan Africa in an era of combination therapy. *Bulletin of the WHO*, 86(2):101-10. [https://doi.org/10.2471/blt.07.042259]; Mutabingwa, 2005.

aid cognitive development and promote educational achievement; future research is needed to establish cost benefits accrued in this way.

In 2000, programmes to provide diagnosis and treatment in schools were deemed an affordable approach after cost analysis of options in Kenyan schools concluded that delivery of chemoprophylaxis would be prohibitively expensive; school health models where teachers implement programmes providing deworming and micronutrients had already shown reduced delivery costs.¹⁵¹

In 2008, studies comparing presumptive treatment and rapid diagnostic testing use in rural health facilities in sub-Saharan Africa deemed the intervention cost-effective, if it proved less costly and more effective, or an incremental cost per disability-adjusted life year of less than 150 US dollars was averted.¹⁵² In the same year, cost of teacher-delivered intermittent protective treatment in Kenya was estimated to be 1.88 US dollars per child treated per year. The largest components were drug and teacher training costs. Set-up accounted for 13.2 per cent of overall costs (equivalent to 0.25 US dollars per child) and recurrent costs 86.8 per cent (1.63 US dollars per child per year). Cost-benefit analysis equated each anaemia case averted to 29.84 US dollars and each *Plasmodium falciparum* parasitaemia case averted to 5.36 US dollars.¹⁵³

In 2009 benefits far outweighed costs where teachers were trained to identify and treat children with malaria in Malawi; cost-benefit accrued from significant reductions in both general absenteeism and grade repetition by students.¹⁵⁴

In 2011 the estimated cost of school-based intermittent screening and treatment, again from Kenya, was 6.61 US dollars per child screened. Key components were salaries 36 per cent and rapid diagnostic testing kits 22 per cent, and almost half the intervention cost (47 per cent) comprised redeployment of existing resources, including health worker time and use of hospital vehicles. The authors estimated that costs would likely reduce by 40 per cent with changes in delivery, including the use of alternative rapid diagnostic testing kits and removal of supervised treatment.¹⁵⁵

In 2016 the reported cost for school-based rapid diagnostic testing kits and artemisinin combination therapy supplies in Uganda was 0.50 and 2.20 US dollars, respectively. For every three sick/febrile children tested, two were rapid diagnostic testing positive. Cost savings were subsequently made when the single dose artemisinin combination therapy formulation used to eliminate any partial treatment bias was replaced with a conventional three-day six dose preparation costing one US dollar. Training and supervision costs were not included as the programme was delivered as part of aid provided by a medical charity.¹⁵⁶

Affordability and cost-effectiveness are important determinants of the long-term sustainability of school-based treatment; here, a key issue will be drug choice. Drugs best suited to mass treatment programmes should be cheap, easy to administer, preferably as a single dose, and well-tolerated with minimal side-effects; for intermittent protective treatment, a long half-life is also advantageous.¹⁵⁷ A global artemisinin combination therapy subsidy would significantly increase usage of artemisinin combination therapies and reduce retail price; in rural Tanzania, a 90 per cent subsidy increased the proportion of consumers purchasing artemisinin combination therapies from one per cent to 44.2 per cent one year later, and purchasing for children rose considerably.¹⁵⁸

Importantly, effective programme rollout offers potential overall savings. In Senegal, a major reduction in anti-malarial drug consumption occurred after nation-wide introduction of rapid diagnostic testing, and considerable cost-savings were achieved through centralised artemisinin combination therapy procurement; half of the global demand for antimalarials has been estimated to be due to overuse in patients without malaria.¹⁵⁹

156 Macnab et al., 2016a.

157 Temperley et al., 2008.

158 Sabot, O.J., Mwita, A., Cohen, J.M., Ipuge, Y., Gordon, M., Bishop, D., Odhiambo, M., Ward, L. & Goodman, C. 2011. Piloting the global subsidy: the impact of subsidized artemisinin-based combination therapies distributed through private drug shops in rural Tanzania. *PLoS One*. 4(9):e6857. [https://doi.org/10.1371/journal.pone.0006857].

159 Thiam et al., 2011; Cohen, J.M., Woolsey, A.M., Sabot, O.J., Gething, P.W., Tatem, A.J. & Moonen, B. 2012. Optimizing investments in malaria treatment and diagnosis. *Science*, 338(6107):612-614. [https://doi.org/10.1126/science.1229045].

151 Brooker et al., 2000; Clarke et al., 2004; Brooker et al., 2008; Fernando, S.D., Rodrigo, C. & Rajapaske, S. 2010. The 'hidden' burden of malaria: cognitive impairment following infection. *Malaria Journal*, 9(366). [https://doi.org/10.1186/1475-2875-9-366].

152 Shillcutt et al., 2008.

153 Temperley et al., 2008.

154 Simwaka, Simwaka & Bello, 2009.

155 Drake et al., 2011.

Future directions

In Africa, there is increasing evidence of the dramatic reductions in malaria mortality and morbidity in early childhood due to recent up-scaling of malaria control efforts.¹⁶⁰

Coincident with this epidemiologic change reported in 2008 by Temperley and colleagues (Mueller, Njagi, Akhwale, Clarke, Jukes, Estambale and Brooker), there was increased recognition of the consequences of malaria in children of school-age, including the detrimental effects on haemoglobin levels, and on learning and educational achievement. As a result, interest grew about the control of malaria in older children who attend school and calls followed for innovative concepts as to how this could be achieved.¹⁶¹ In response, models were developed that provide school-children with access to accurate diagnosis and treatment in endemic areas, reduce morbidity, and increase the capacity of children to benefit from their education. We now have evidence from many useful trials of ‘what works and why’ to guide future directions.

What school-based malaria testing and treatment is undertaken in future will depend on priorities set nationally, which in turn require vision beyond the conventional political time frame, but the benefits that are there to be achieved for school-children at risk for malaria are now explicit. While funding agencies tend to call for bold, novel and disruptive thinking, there are strong grounds to argue that substantive investment in proven school-based models is needed in parallel.

160 Temperley et al., 2008.

161 Ibid. Kurtzhals, J.A., Addae, M.M., Akanmori, B.D., Dunyo, S., Koram, K.A., Appawu, M.A., Nkrumah, F.K. & Hviid, L. 1999. Anaemia caused by asymptomatic *Plasmodium falciparum* infection in semi-immune African school children. *Transactions of The Royal Society of Tropical Medicine and Hygiene*, 93(6):623-627. [[https://doi.org/10.1016/s0035-9203\(99\)90073-1](https://doi.org/10.1016/s0035-9203(99)90073-1)]; Koukounari, A., Estambale, B.B.A., Njagi, J.K., Cundill, B., Ajanga, A., Crudder, C., Otido, J., Jukes, M.C., Clarke, S.E., Brooker, S. 2008. Relationships between anaemia and parasitic infections in Kenyan school-children: a Bayesian hierarchical modelling approach. *International Journal for Parasitology*, 38(14):1663-1671. [<https://doi.org/10.1016/j.ijpara.2008.05.013>]; Holding & Snow, 2001; Lalloo, D.G., Olukoya, P. & Olliaro, P. 2006. Malaria in adolescence: burden of disease, consequences and opportunities for intervention. *The Lancet Infectious Diseases*, 6(12):780-793. [[https://doi.org/10.1016/S1473-3099\(06\)70655-7](https://doi.org/10.1016/S1473-3099(06)70655-7)]; Brooker et al., 2008; Bundy, D.A.P., Lwin, S., Osika, J.S., McLaughlin, J. 7 Pannenberg, C.O. 2000. What should schools do about malaria? *Parasitology Today*, 16(5):181-2. [[https://doi.org/10.1016/s0169-4758\(00\)01658-6](https://doi.org/10.1016/s0169-4758(00)01658-6)]; Bundy, D.A.P., Lwin, S., Osika, J.S., McLaughlin, J. 7 Pannenberg, C.O. 2000. What should schools do about malaria? *Parasitology Today*, 16(5):181-2. [[https://doi.org/10.1016/s0169-4758\(00\)01658-6](https://doi.org/10.1016/s0169-4758(00)01658-6)].

The efforts of major agencies have made rapid diagnostic testing and artemisinin combination therapy more affordable and hence more accessible; the benefits of now making teacher-driven diagnosis and treatment broadly available in endemic areas would be considerable. Arguably there is still no consensus as to the optimal intervention approach, and more evidence on the costs and cost-effectiveness for school-based malaria control is needed, but individual region-specific programmes can be tailored from the evidence now available to provide viable interventions for at-risk populations.

Many malaria-endemic countries are considering scaling up rapid diagnostic testing use in a variety of locations; it is not overstated to say, “that when well used, rapid diagnostic testing can transform fever management, reform understanding of malaria transmission, and have even made malaria elimination look achievable.”¹⁶² There is a need for intersectoral collaboration at a national level, and only when this is realised is it likely that the effective upscaling of rapid diagnostic testing/artemisinin combination therapy availability will be achieved; legislative changes and investment in support programmes and infrastructure will be required in parallel.¹⁶³ However, it is significant that effective rapid diagnostic testing rollout on a national scale has already been achieved in Senegal through well-planned policies and structured implementation.¹⁶⁴

In addition to being simple to implement and low cost, the rapid diagnostic testing/artemisinin combination therapy model uses WHO-endorsed testing and treatment methods, so has broad relevance and is applicable to low-resource settings worldwide where the school-age population is at risk. Such models already meet calls from the WHO Commission on Social Determinants of Health to adopt a community empowerment approach, use ‘non-traditional outlets’ and ‘improved tools’ to address health challenges faced by young people, and seek longer and healthier lives for Africans. Future models that use novel ways to engage and train teachers to deliver health education and elements of care will also meet recommendations from the Lancet Commission on the future of health in sub-Saharan Africa to extend population access to services, by using ‘people-centred approaches’ and innovative education and training of personnel that correspond to local needs.¹⁶⁵

162 Thiam et al., 2011.

163 Afenyadu et al., 2005; Akweongo et al., 2011; Visser et al., 2017.

164 Thiam et al., 2011.

165 WHO, 2008; Sachs & Malaney, 2002; Agyepong et al., 2017.

Conclusion

Initiatives are needed to address the current epidemic of non-communicable diseases, but to be effective, when school-based health education programmes on DOHaD are implemented, they must be delivered to children who are healthy enough to be able to attend school and well enough to learn. Hence the importance of providing measures that address the negative impact of malaria, and other remediable social determinants of health that negatively impact a child's ability to benefit from education, in parallel with DOHaD-related school programs.

Growing awareness of the negative impact of malaria on school-age children has stimulated the search for interventions that can be delivered through schools to address mortality and morbidity. However, what agent(s) and mode of delivery constitute the optimal regimen in a given population, or endemic area is as yet undefined. A broad selection of literature now describes the rationale, therapeutic options, design, delivery, training, effectiveness, cost, challenges and future research priorities for interventions applicable to school-based delivery. The argument for universal, parasite-based diagnosis is clear; rapid diagnostic testing can provide poorly resourced, malaria-endemic populations with access to diagnosis, with a comparable level of accuracy to hospital-based diagnostics; and artemisinin combination therapies are effective and affordable therapy. Innovative ways are called for to make these WHO-endorsed entities more available to those in need, and globally schools offer more than one billion children the potential to benefit from school-based healthcare delivery.

Teachers can be effective agents for change. Innovative school-based models that engage and train teachers to deliver health education and elements of care are advocated by the WHO as a means to address all aspects of disease, and creative school-based interventions are sanctioned as a way to tackle health challenges faced by young people. Such models also meet recommendations from the Lancet Commission on the future of health in sub-Saharan Africa to extend population access to services by using 'people-centred approaches' and innovative education and training of personnel that correspond to local needs.

However, community interventions to educate and promote health in the context of the developmental origins of health and disease must also encompass diagnosis and treatment strategies for malaria where the disease is endemic, as the reduction in morbidity obtained will translate into improved school attendance and a higher capacity to learn, which will greatly increase the probability of any DOHaD-related education strategy being effective.

Acknowledgements

The author thanks the Stellenbosch Institute for Advanced Study for the invitation to work at the Wallenberg Research Centre in Stellenbosch as a Fellow in Residence. The school-based teacher-driven rapid diagnosis and treatment project in Uganda central to this chapter was funded by the Hillman Medical Education Fund, Canada, and our teams gratefully acknowledge the dedication of the teachers, parents and children who participated. Literature searches included in this chapter were part of related research publications on malaria, and invited presentations at the International Pediatric Association, Canadian Pediatric Society, International Conference(s) on Applied Science and Health, and the STIAS seminar series.



15

INTERSECTORAL APPROACHES TO HEALTH AND NON-COMMUNICABLE DISEASE PREVENTION IN AFRICA

Tolu Oni¹

This chapter grounds efforts to achieve optimal population health in Africa, within the context of global and regional aspirations for health as part of the sustainable development agenda. The author highlights the important role that the rapidly growing urban centres in Africa are playing in the ongoing epidemiological transition, with an emerging non-communicable disease epidemic alongside a high burden of infectious disease. Far from seeing this only as a challenge, the author of this chapter explores the opportunity to harness this changing environment for health creation, propose a re-thinking of accountability for health towards a more inclusive definition of health services, and the role that adolescents can and should play both as important targets for non-communicable disease prevention and as agents of change, advocating for an all of government, all of society's approach to health.

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No sustainable development without health

Emerging global policies and aspirations, including the New Urban Agenda and the United Nations (UN)' 17 'Sustainable Development Goals', encourage governments to 'leave no one behind', promote sustainable urban development, and to reduce inequalities.²

Two policy agendas for development at the global and Africa regional levels have raised awareness of the importance of understanding the interdependencies and interactions between different developmental challenges and the goal of improving population health and wellbeing, generating some momentum on the need for integrated approaches to addressing these.

The Sustainable Development Goals cover a broad range of social and economic development issues to be improved by 2030, from poverty, gender equality and health, to urbanisation, education and water.³ In the context of rapidly urbanising settings, meeting Goal 3, aimed to improve health and wellbeing, will require strategies focused on addressing the urban built environment exposures that drive ill health but could be harnessed to contribute positively to creating health. Such intersectoral strategies are an opportunity to re-think city development and planning processes, contributing to the achievement of Goal 11, which seeks to build resilient and sustainable cities, obtainable by the reinvention of human settlement.

The importance of incorporating non-communicable diseases into the broader global development policy agenda was underscored by the high-level meeting on non-communicable diseases at the United Nations General Assembly in September 2018. The draft political declaration submitted to heads of member states at this meeting underscored the importance of the interdependencies between sectors and the need for a life-course approach calling for a "scaling up of multi-stakeholder and multisectoral responses to the prevention and control of non-communicable diseases in the context of the 2030 Agenda for Sustainable Development".⁴

2 United Nations (UN). 2016. *The New Urban Agenda*. Habitat III, the United Nations Conference on Housing and Sustainable Urban Development, 17-20 October. [https://bit.ly/2Qk4S3B]; UN Sustainable Development Goals (SDGs). 2020. *About the Sustainable Development Goals*. [https://bit.ly/3j9HToq]; UN, 2018. *Time to Deliver: Accelerating our response to address NCDs for the health and well-being of present and future generations*. UN General Assembly, September 27. Draft Political Declaration. [https://bit.ly/2YvkXYO].

3 Ibid.

4 UN. n.d. *Overview of aspirations, goals and priority areas of Agenda 2063*. Africa Union. [https://bit.ly/32x8d64].

This draft text recognises the importance of conducive environments for non-communicable disease prevention and identifies the planning and development of cities as important to promote physical activity and sustainable healthy consumption and food production. The draft further includes the call for member states to:

Reaffirm the primary role and responsibility of Governments at all levels in responding to the challenge of non-communicable diseases by developing adequate national multisectoral responses for their prevention and control, and promoting and protecting the right of everyone to the enjoyment of the highest attainable standard of physical and mental health; and underscore the importance of pursuing whole-of-government and whole-of-society approaches, as well as health-in-all-policies approaches, equity-based approaches and life-course approaches.⁵

At a regional level, the Africa Union's Agenda 2063 sets out the development aspirations, goals and targets for 'the Africa we want' by 2063. In particular, the first aspiration for a prosperous Africa, based on inclusive growth and sustainable development, includes the interdependent goals for 'a high standard of living, quality of life and wellbeing for all citizens' ("including a priority for modern, affordable, and liveable habitats"), and for 'healthy and well-nourished citizens'.⁶ This long-term agenda is underpinned by a 10-year Science Technology and Innovation Strategy for Africa to accelerate Africa's transition to a knowledge-based economy. This strategy also recognises the prevention of non-communicable diseases in Africa as one of the six priorities.⁷

These global and regional goals highlight the importance of population health to achieve sustainable, inclusive development. However, as the next section discusses, these health needs are changing, driven by meso- and macro-level factors.

Figure 15.1 highlights key meso- and macro-level characteristics of the African context, that influence changing health needs and should inform efforts to improve health. These include the socio-political context of colonial history, migration, insufficient regional data-sharing platforms, and insufficient disaggregated data on health determinants and outcomes. This figure further highlights the consequences

5 UN, 2018.

6 African Union. n.d. *Agenda 2063: The Africa We Want*. [https://au.int/en/agenda2063/overview].

7 United Nations Population Fund (UNPF). 2007. *State of world population 2007 – Unleashing the potential of urban growth*. [https://bit.ly/3aSl4CB]. (Accessed 27 December 2017).

of this context and the role that research can play in improving health through place-based science.

For this chapter, the author will focus on two of these characteristics, rapid urbanisation, and the demographics to illustrate how the notion of health creation could be re-conceptualised.

Africa's urbanisation threatens health gains

Urbanisation is one of the most important demographic shifts worldwide, during the past century, and represents a substantial change from how most of the world's population has lived for the past several thousand years.⁸ It is a result of population migration from rural areas in addition to natural urban demographic growth. Many aspects of urban change in recent decades are unprecedented, including not only the world's level of urbanisation and the size of its urban population but also the number of countries becoming more urbanised and the size and number of huge cities.⁹ Since 1950, many urban changes have been dramatic – with the populations of dozens of major cities growing more than ten-fold, and many growing more than twenty-fold. Some of them sprawl for thousands of square kilometres. In 2007, the world's population living in towns and cities reached 50 per cent, and this proportion is growing.¹⁰ Today, more than half of the world's population resides in urban areas, more than the world's total population in 1960.¹¹

African countries are rapidly urbanising. This urban transition is unfolding rapidly, with urban dwellers projected to exceed 50 per cent around 2035.¹² In addition to the impact on the environment, unplanned and unmanaged growth across Africa, and high rates of poverty (62 per cent of urban dwellers live in slum conditions), are associated with exposures that contribute to and exacerbate, inequities in the burden of disease.¹³

8 Annual Reviews. 2005. Urban Health: Evidence, Challenges, and Directions. *Annual Review of Public Health*, 26:341-365. [https://doi.org/10.1146/annurev. pubhealth.26.021304.144708].

9 Satterthwaite, D. n.d. *The scale of urban change worldwide 1950-2000 and its underpinnings*. [https://bit.ly/3lcNxIa].

10 UN. 2011. *World Urbanization Prospects: The 2009 Revision*. UN Population Division.

11 UN. 2014. *World Urbanization Prospects: The 2014 Revision*, Highlights. [https://bit.ly/2FTbynq]. (Accessed 22 May 2018).

12 UN Habitat. 2014. *State of African Cities Report 2014: Re-imagining sustainable urban transitions*. [https://bit.ly/2YuZOxJ].

13 UN Department of Economic and Social Affairs & Population Division. 2011. *World Urbanization Prospects: The 2009 Revision*. [https://bit.ly/3gphS2z].

As two-thirds of the world's population will live in cities by 2050,¹⁴ it will pose numerous challenges for African countries in meeting the needs of their growing urban populations, including housing, infrastructure, transportation, and basic services such as education and healthcare. Thus, more intriguing than these global figures are the ecological and socio-environmental conditions often associated with this urbanisation process.¹⁵ Rapid, unplanned and unsustainable patterns of urban development in Africa are making developing cities focal points for many emerging environmental and health hazards.¹⁶

The pace of change and the complex nature of urbanisation is contributing to this epidemiological transition across African cities.

The urban poor increasingly faces a 'triple threat' of injuries, infectious diseases, and non-communicable conditions (diseases) like diabetes and heart disease.¹⁷ In particular, residents of informal settlements typically face multiple risks due to:

- hazardous shelter and local environmental conditions;
- limited or non-existent access to safe water, sanitation, public transport, and clean energy;
- insecure tenure and unsafe housing;
- exclusion from affordable, high-quality healthcare, education, refuse collection, and other vital services;
- spatial segregation; and
- violence and insecurity.

Multi-faceted intersectoral efforts are crucial to respond to these interrelated challenges. There is also a plausible connection between urbanisation and the rising levels of non-communicable diseases in those countries. These exposures – individual, household and neighbourhood-level – influence behaviours (what people eat, their physical activity, whether they smoke or drink, isolation or

14 Fotso, J.C. 2006. Child health inequities in developing countries: differences across urban and rural areas. *International Journal for Equity in Health*, 5:9. [https://doi.org/10.1186%2F1475-9276-5-9].

15 Galea, S. & Vlahov, D. *Urban health: evidence, challenges, and directions*. Annual Review of Public Health, 26:341-365. [https://bit.ly/2FSGuUR].

16 WHO & UN Habitat. 2016. *Global report on urban health: equitable healthier cities for sustainable development*. World Health Organization. [https://bit.ly/31lZ8Na].

17 WHO. 2015. *Non-communicable diseases prematurely take 16 million lives annually: WHO urges more action*. [https://bit.ly/31oymnp].

connection) and disease burden (water and air pollution-related diseases), lie largely outside the health sector.

These behaviours are exemplified by the rise in obesity, hypertension, and diabetes, associated with the increasing exposure of urban dwellers to unhealthy food, and human settlement environments that limit physical activity in cities. Furthermore, a rise in dense unplanned settlements with inadequate urban infrastructure, increased exposure to air, water, and noise pollution and unhealthy home environments are contributing to the increasing prevalence of chronic respiratory, and cardiovascular disease.

The double burden of non-communicable and communicable diseases in Africa

Non-communicable diseases are emerging in the context of rapid urbanisation and globalisation in low- and middle-income countries, especially amongst the poor residing in urban settings.

Non-communicable diseases refer to a group of diseases not mainly caused by an acute infection, resulting in long-term health consequences and often creating a need for long-term treatment and care.¹⁸ The World Health Organization (WHO) reports non-communicable diseases to be by far the leading cause of death in the world, as non-communicable diseases kill 38 million people each year and disproportionately affect low- and middle-income countries where nearly three-quarters of non-communicable disease deaths – 28 million – occur. Cardiovascular diseases account for most non-communicable disease deaths, or 17.5 million people annually, followed by cancers (8.2 million), respiratory diseases (four million), and diabetes (1.5 million).¹⁹ These four groups of diseases account for 82 per cent of all non-communicable disease deaths. Of these ‘premature’ deaths, 82 per cent occurred in low- and middle-income countries in Asia and Africa.²⁰

18 Mozaffarian, D., Fahimi, S., Singh, G.M., Micha, R., Khatibzadeh, S., Engell, R.E., Lim, S., Danaei, G., Ezzati, M., Powles, J. and the Global Burden of Diseases Nutrition and Chronic Diseases Expert Group. 2014. Global sodium consumption and death from cardiovascular causes. *The New England Journal of Medicine*, 371(7), August:624-634. [<https://doi.org/10.1056/NEJMoa1304127>].

19 Ibid.

20 Hunter-Adams, J., Nguendo Yongsi, B., Dzasi, K., Parnell, S., Boufford, J.I., Pieterse, E. & Oni, T. 2017. How to address non-communicable diseases in urban Africa. *The Lancet Diabetes & Endocrinology*, 5(12), December:932-934. [[https://doi.org/10.1016/S2213-8587\(17\)30220-6](https://doi.org/10.1016/S2213-8587(17)30220-6)].

Risk factors such as a person’s background, lifestyle and environment are known to increase the likelihood of non-communicable diseases.

The high burden of infectious disease in Africa has, for many years, been the focus of attention for interventions to improve health in the region. However, alongside this persisting infectious disease burden, African countries are experiencing a simultaneous growth in the burden of non-communicable diseases.²¹ For example, the burden of diabetes in Africa is expected to increase by 110 per cent between 2013 and 2035.²²

This rising burden of non-communicable diseases places an ever-increasing burden on government resources already strained by efforts to manage infectious diseases such as HIV/Aids, tuberculosis and malaria, with an ever-increasing budget required for the healthcare sector to treat and manage diseases adequately. At the level of the individual and household, the higher burden of these diseases in low-income households is associated with catastrophic healthcare expenditure and loss of income, making addressing this emerging non-communicable disease epidemic a priority in Africa.

Thus, though the growing problem of communicable and non-communicable diseases is a particular problem for the urban areas in Africa, and while studies have begun to measure this burden of disease, there is a paucity of research seeking to address these urban health challenges using a systems approach.

The need to harness Africa’s urbanisation for health

The scale and pace of urbanisation and the accompanying emerging non-communicable disease epidemic in Africa makes improving African health crucial for achieving global Sustainable Development Goals. Thus, there is a pressing need to prioritise non-communicable diseases and for innovative new approaches to create health and prevent disease at the population scale. As much of the change in Africa’s epidemiological profile is being influenced by the rapid rate of urbanisation, the built environment plays a significant role in non-communicable disease risk. It, therefore, can and should play an important role in the creation of health and prevention of non-communicable diseases.

21 Peer, N., Kengne, A.P., Motala, A.A. & Mbanya, J.C. 2014. Diabetes in the Africa region: An update. *Diabetes Research and Clinical Practice*, 103(2):197-205. [<https://doi.org/10.1016/j.diabres.2013.11.006>].

22 Patton, G., Coffey, C., Cappa, C., Currie, D., Riley, L., Gore, F., Mokdad, A., Degenhardt, L., Richardson, D., Astone, N., Sangowawa, A.O. & Ferguson, J. 2012. Health of the world’s adolescents: a synthesis of internationally comparable data. *The Lancet*, 379(9826):1665-1675. [[https://doi.org/10.1016/S0140-6736\(12\)60203-7](https://doi.org/10.1016/S0140-6736(12)60203-7)].

African countries are urbanising largely into conditions of informality, characterised by high poverty rates, and poor housing conditions. The increasing availability of processed foods high in sugar, trans-fats and salt, accompanied by poor access to spaces for transport- and leisure-related physical activity, rising outdoor and noise pollution are contributing to rising prevalence of obesity and diabetes, hypertension and cardiovascular disease, injuries, and mental disorders. Unaddressed, this rising non-communicable disease burden will have significant resource implications for African countries, already unable to cope with healthcare and economic costs.

Strategies to address non-communicable diseases in Africa to date have predominantly focused on improving treatment and screening to detect disease. While these are important, there is a need for a greater focus on prevention strategies that act on the upstream determinants of non-communicable diseases in African cities, highlighting the importance of building a knowledge base for the development and implementation of population-level, sustainable, equitable non-communicable disease prevention strategies across the life-course.

Despite the obvious importance of health and wellbeing in sustainable urban development strategies, at local levels, health is largely not considered within these agenda, partly due to the siloed vertical nature of policymaking, resulting in a lack of policy coherence between health and health determinant sectors. Inequities in the exposure to health determinants that increase the risk for non-communicable disease, particularly in the urban poor are thus exacerbated by the disconnect between the public health and built environment sectors such as urban planning and food systems.

Cities can play a vital role in addressing health and social inequity; greater coordination across sectors could contribute to improving health outcomes. The rapidly evolving and growing nature of African cities is often cited as driving informality. Ill-health also represents an opportunity for innovative approaches to non-communicable disease prevention. This shift in approach requires shifting to a health creation paradigm across government and society.

Such interventions should target the physical and policy environments and societal norms that shape the conditions in which people live and work, requiring coordination across health and non-health sectors, given that the majority of exposures that influence non-communicable disease risk lie outside the health sector.

New approaches to health creation are needed to achieve this. Over and above individual-level interventions, population-level, long-term non-communicable disease prevention strategies are needed, engaging sectors that play an important role in the health and wellbeing of urban dwellers, particularly the urban poor.

The need for intersectoral approaches

Understanding the key factors and inter-related determinants, contributing to a healthy city is important to effectively impact on the inhabitants' and communities' health and wellbeing in a changing urban environment. Without intervention, these patterns of urbanisation will continue to have significant detrimental effects on the health of urban communities, their environments and the planet.

The global and regional goals and aspirations presented in the first section of this chapter will not be achieved unless national and local governments commit to translating global policies into practice. Furthermore, coordination and cooperation across sectors through local intersectoral action is essential, as the underlying factors determining health, largely fall outside the scope and reach of the health sector.

Despite Africa's pressing need for this approach, urban health and urban health equity have not emerged as major research and policy priorities on this continent; with many African countries lagging in the area of urban health equity and healthy city initiatives. There are significant knowledge gaps in how global policies for improving health and wellbeing can be implemented to promote intersectoral action for non-communicable disease control in the African urban context. Moreover, how the global agenda is intersectional reflected in the national and sub-national policies, particularly in Africa, is not yet fully understood, representing a major gap given the high and complex burden of disease and high levels of health inequity in the region. There is a need for all of Africa to shift to a paradigm of health creation, not just disease prevention and treatment while being responsible custodians of the planet.

Given these contexts, in addition to the conventional health systems designed to protect the health, there is a need for research into systems for health; creating knowledge on aligning urban systems and policies for the creation of health.

Figure 15.2 exemplifies this notion. While healthcare is traditionally considered a health service, the fact that the food, water, waste, habitation and transport services and sectors are vital determinants of health, means we could consider these as health services, working together with the healthcare sector to create population health and reduce the need for healthcare.

This work is starting to happen, with researchers in different parts of the continent starting to research urban health, including investigating changing patterns of disease in urban populations, and better characterising changing urban exposures. While these research activities have made great strides within their respective countries in generating evidence to inform public policies, the lack of collaborative

efforts has resulted in missed opportunities to accelerate the pace of knowledge generation and experimentation through shared learning and comparative research in different African city contexts.

There is, therefore, a need for multi-stakeholder dialogue platforms (involving the public, private and civil society sectors) and mechanisms to support intersectoral (transversal whole-of-government) policy action plans. Such spaces are vital to bridge the gap between those working to address the knowledge gaps (researchers), actors responsible for implementation at scale (policymaker and practitioners); and the potential beneficiaries of, and advocates for, these interventions (civil society). This collaboration would serve to share information including on lessons learned relating to the implementation of intersectoral policies and strategies, to identify priority areas for research and intervention, and to strengthen the evidence base on best practice to prevent non-communicable diseases.

What does this have to do with early life?

Adolescence as an important period in the life-course for non-communicable disease prevention

Cognisant of the demographic context of the region, given that most behaviours that drive non-communicable diseases are formed in this life period, the demographic youth bulge in Africa means adolescents and youth represent an important target population for non-communicable disease prevention.

Adolescence (10-24 years) is a transitory period accompanied by physical, psychological and social development, and by increasing socialisation with peers and independence outside of the family.²³

Unlike early childhood, exposures and experiences are not completely under the control of, or fully characterised by household characteristics, as adolescence start to explore their identity. Despite the tendency for adolescents to focus on immediate benefits, the health-related behaviours, such as diet and physical activity patterns, obesity, tobacco, and alcohol, that influence the risk of major non-communicable diseases in adulthood usually start or are reinforced during adolescence.

23 Patton, G.C., Sawyer, S.M., Santelli, J.S., Ross, D.A., Afifi, R., Allen, N.B., Arora, M., Azzopardi, P., Baldwin, W., Bonell, C., Kakuma, R., Kennedy, E., Mahon, J., McGovern, T., Mokdad, A.H., Patel, V., Petroni, S., Reavley, N., Taiwo, K., Waldfogel, J., Wickremarathne, D., Barroso, C., Bhutta, Z., Fatusi, A.O., Mattoo, A., Diers, J., Fang, J., Ferguson, J., Ssewamala, F. & Viner, R.M. 2016. Our future: a Lancet commission on adolescent health and well-being. *The Lancet*, 387(10036):2423-2478. [[https://doi.org/10.1016/S0140-6736\(16\)00579-1](https://doi.org/10.1016/S0140-6736(16)00579-1)].

Thus, adolescence is a critical window in which the behaviours that will promote and maintain health across the life course are established.²⁴ Also, adolescence offers an opportunity to improve preconception health, which may also lessen intergenerational non-communicable disease risk.

Health behaviours like diet and physical activity are shaped in part by structural factors including built and policy environments.²⁵ There is, however, a paucity of understanding of the potential levers for intervention to influence adolescent diet and physical activity across socio-ecological domains from the household and neighbourhood environments, to the school environment, highlighting why this is an important phase for intervention to prevent diabetes and associated risk factors. However, for many adolescents, the need to prevent non-communicable diseases is not perceived as relevant to adolescent life given the long time-lag from behaviour to disease; making it difficult to meaningfully and sustainably engage adolescents on this issue.

Focus on diet and physical activity

Non-communicable diseases share common, interrelated risk factors in particular tobacco use, harmful use of alcohol, an unhealthy diet and lack of physical activity. Risk factors and causes of premature death in adulthood develop during adolescence and possibly even earlier. There is currently a global epidemic of risk factors for subsequent non-communicable diseases, particularly in low- and middle-income countries with the highest rates of adolescent overweight and lowest rates of physical activity.²⁶

However, besides sexual and reproductive health, the majority of adolescents do not perceive a need for non-communicable disease prevention, nor do they routinely access health care or the health sector. There is, therefore, a need for strategies – seeking to identify levers to impact adolescent health – that are not purely within the contexts of either the health sector, the household, or even purely within school grounds. Innovative strategies are needed to understand better how adolescents experience and engage with their built environments. Novel strategies to involve adolescents in effecting healthy change in their built environments, and to spark an

24 Green, L.W., Richard, L. & Potvin, L. 1996. Ecological foundations of health promotion. *American Journal of Health Promotion*, 10(4), March-April:270-281. [<https://doi.org/10.4278/0890-1171-10.4.270>].

25 Patton et al., 2012

26 WHO. 2004. *Global Strategy on Diet, Physical Activity and Health*. Resolution WHA55.23, 57th World Health Assembly, Geneva, May. [<https://bit.ly/3goK9X3>].

interest in long-term strategies to improve their adult health. Such strategies would need to be multisectoral and participatory, recognising the interactions between environmental and economic factors, social norms and personal choice.

Urban levers to improve adolescent diet and physical activity

An increasing proportion of African adolescent resides in rapidly growing, often unplanned cities. The built environments they are exposed to are often not conducive for embracing health-promoting behaviour. Furthermore, many strategies focus on individual-level behaviour change interventions. However, the effectiveness of advice on changing individual behaviour for diabetes prevention is, therefore, limited by the ability to embrace these behaviours. With perceived low risk and relevance of diseases such as diabetes to adolescents, such individual approaches are likely to have even more limited effect. By contrast, the evidence presented in earlier sections of this chapter demonstrates the important role that these environments, meso- and macro-level determinants, largely outside the health sector, play in disease prevention through healthier environments. There is, therefore, an opportunity to harness these built environments to improve diet and physical activity of adolescents.

Obesity, unhealthy diets, and physical inactivity, for example, are universal issues for adolescents in both high and low-income countries. Introducing healthier behaviours and protective factors during adolescence can significantly change an individual's health trajectory into adulthood.

Beyond consideration of adolescents as a key population group in non-communicable disease prevention in the context of their health outcomes and urban exposures, there is an opportunity to engage adolescents in the process of research (Figure 15.3). As citizen scientists, adolescents could participate in the collection of data on their urban environments, and how these inform or restrict their behaviours. By involving adolescents in research, such approaches to research could also serve to increase their agency and support their roles as advocates for change in their communities. Intersectoral approaches to health will require re-thinking of accountability mechanisms for health; and informed, empowered adolescents can play an important role in advocating for this change.

Conclusion

This chapter situates efforts to improve population health in Africa within the broader context of strategies for sustainable development. The author highlights the rapid urban growth on the continent as a potential threat to achieving these

goals by contributing to the burden of disease and health inequity, but also an opportunity to re-think governance for health. Such re-conceptualisation is framed around re-thinking accountability for health as not just within the healthcare sector, but across all sectors and services that determine health. Lastly, given the demographic youth bulge of the continent, the importance of engaging adolescents in non-communicable disease prevention efforts cannot be overemphasised.

Figures

Africa is characterised by	Consequence	Role of research in improving understanding	Role of research in intervention to improve health
Rapidly growing cities; and growing prominence of private developers in placemaking Demographic youth bulge Built environments in flux	Engaging only public sector will be insufficient Paucity of public big datasets Youth lens required Tools to measure built environment and associated behaviours in other contexts not suitable Longitudinal studies needed to capture and characterise range, scale and temporality of change	Participatory systems dynamics to engage diverse stakeholders Participatory data collection engaging youth as citizen scientists	(co-)Design and evaluate intervention Experiments and quasi-experiments in environment and intersectoral governance
Urban mobility and circular migration	Longitudinal follow up using routine methods challenging	Develop innovative approaches to generate longitudinal data	Longitudinal studies Modelling studies
Inadequate disaggregated data on health outcomes and determinants Urban centres rooted to colonial legacies of sociopolitical exclusion	Paucity of evidence to inform hyper local intervention in environment and health impact evaluation Contemporary manifestation as spatial and health inequity alongside cultural beliefs	Innovative approaches to integrate existing intersectoral quantitative, qualitative & spatial data Investigate history of environment and policy interventions to improve food and physical activity	Epidemiology to identify knowledge gaps and inform & evaluate policy priorities
Little regional sharing/exchange	Missed opportunities to learn what works, in which setting, for whom, in what circumstances and why	Connect and coordinate research and researchers	Sharing results and experience through academic and non-academic output South-South and North-South collaboration

Policy Relevant Science

Figure 15.1 Place-based context for policy-relevant science.

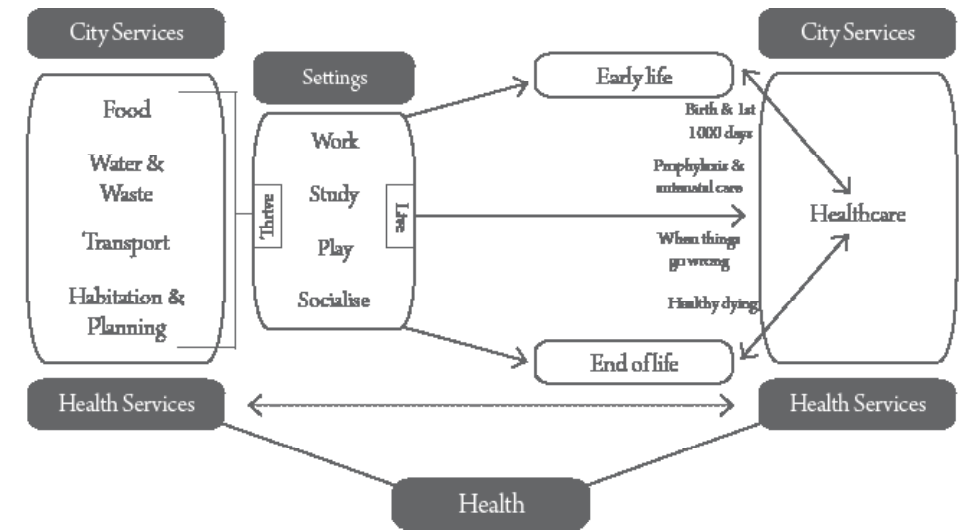


Figure 15.2 Re-thinking (urban) health services - reducing the need for healthcare.

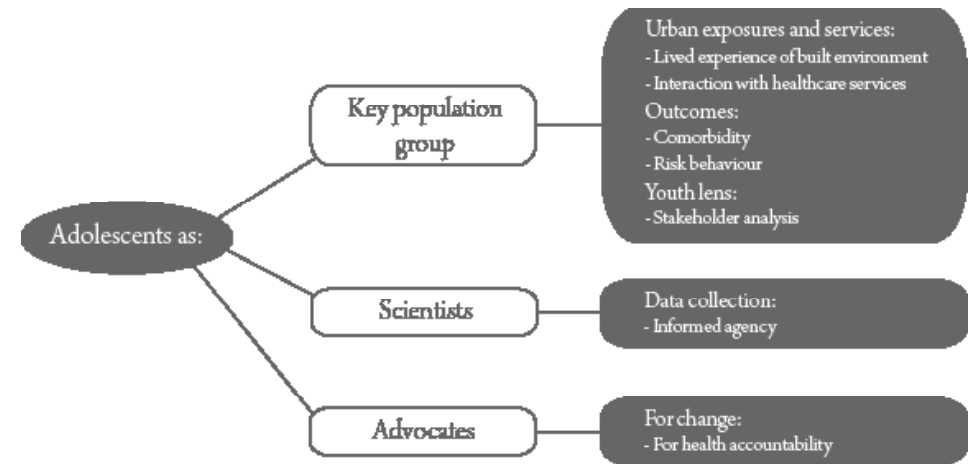


Figure 15.3 The roles of adolescents in non-communicable disease prevention.



16

CELEBRITY HEALTH PROMOTION MESSAGING: NOVEL OPPORTUNITIES TO ENGAGE YOUTH IN THE DEVELOPMENTAL ORIGINS OF HEALTH AND DISEASE

Andrew J Macnab¹ and Ronald Mukisa²

This chapter is a personal view seen from disparate viewpoints of age and culture. Two proponents of health promotion, one a Ugandan youth with first-hand experience of the burden of illness among African children and the other a Canadian academic with a lifetime spent treating sick children, speak to the place and potential of celebrity in the promotion of health among youth. Since 2011, school-based health promotion programmes conceived at the Stellenbosch Institute for Advanced Study (STIAS) have been introduced into many communities in Uganda. These initiatives are seen as an example of innovative health promotion with the potential to give the next generation health knowledge and skills that will translate into an important measure of ‘health independence’ for them in

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- 1 Stellenbosch Institute for Advanced Study (STIAS), Wallenberg Research Centre at Stellenbosch University, Stellenbosch, South Africa; Faculty of Medicine, Department of Paediatrics, University of British Columbia, Vancouver Canada.
 - 2 STIAS; Health and Development Agency, Uganda.

their future lives. A regular component of these programmes enables schools to introduce new topics through teacher-guided in-class discussions about health; in this way, pupils were introduced to elements of the developmental origins of health and disease (DOHaD) agenda, and then asked to discuss which ‘messages’ they saw as most relevant to them, and which ‘messengers’ could deliver these messages with the greatest impact.

Amongst the messengers, celebrities were identified as particularly influential; young people said they would listen to what a celebrity said about health, lifestyle and behaviour. Expanding on these discussions, pupils quoted health and lifestyle messaging that they already knew from listening to celebrity-recorded music videos. Here we describe examples, from a Ugandan perspective, of this form of celebrity-endorsed health messaging contained in music videos; these are the songs young people told us they listened to and knew the promotional messages they contain. National music celebrities, whom these young people identify with, have recorded a variety of videos with content advocating specific health behaviours, endorsing physical, emotional or spiritual health and calling for individual and collective action to address challenges such as maternal deaths related to childbirth and infant mortality. Some artists even raise awareness of difficult but very important social issues such as gender inequity, sexual harassment and domestic violence through their music.

Music videos resonate with youth, and celebrity recordings appeal as they combine young people’s love of music with their fascination of the aura of celebrity. We review the production concepts, content and messaging that make these celebrity music videos particularly powerful, and also suggest future directions where the engagement of celebrity messengers could offer a conduit for innovative delivery of DOHaD-related messages, and an effective way to impart knowledge and impact health behaviours among youth.

Introduction

With links established between exposures during key developmental periods and later health and disease, the DOHaD-health promotion challenge now is how to engage the ‘at risk’ population. It is relatively straightforward to decide ‘who’ needs to be engaged – youth have to be the key target population because the ‘window of opportunity’ for intervention with DOHaD requires the influence of behaviours before conception, to optimize preconception health of both parents and early fetal micronutrient provision, and then maternal health during pregnancy and infant care and nutrition in the first years of life. Engagement must also include youth of

both genders, recognising the important direct and supportive roles for fathers as well as for mothers.³

Youth are not a sub-set of the population who traditionally prioritise or even seriously consider their future health or that of their potential partners, let alone their offspring.⁴ As health behaviours correspond strongly from adolescence to adult life, health knowledge, and positive behaviours learned during this period are vital because of their potential to have a sustained influence.⁵ Hence, engaging young people in the context of DOHaD is a relevant and essential investment, offering a real possibility that where effective behavioural change can be generated within the youth population, this will translate into a future reduction in non-communicable diseases. The Cape Town Manifesto also called for DOHaD to be presented as a new and exciting way to achieve a healthier life, so innovative solutions must be found to sow the seeds of learned behaviours in a way that can positively impact the next generation of parents appropriately to result in better health for their offspring.⁶

With innovation, health promotion messages that have ‘relevance’ and ‘resonance’ for youth can be generated. The health promotion literature contains robust methodology, and the concept of health promotion has given birth to ‘some bright ideas’, but there are calls to create new approaches, and to ‘innovate for health.’⁷ In addition to needing new messages, we must also explore new ways to

- 3 Pentecost, M., Macnab, A.J., Mayekiso, A. & Ross, F. 2018. Beyond the dyad: making intervention DOHaD interventions more inclusive. *Journal of Developmental Origins of Health and Disease*, 9(1), February:10-14. [<https://doi.org/10.1017/S2040174417000629>].
- 4 Davies, J.I., Macnab, A.J., Byass, P., Norris, S.A., Nyirenda, M., Singhal, A., Sobngwi, E. & Daar, A. 2018. Developmental Origins of Health and Disease in Africa – influencing early life. *Lancet Global Health*, 6(3), March:244-245. [[https://doi.org/10.1016/S2214-109X\(18\)30036-6](https://doi.org/10.1016/S2214-109X(18)30036-6)]; Macnab, A.J. & Mukisa, R. Priorities for African youth to engage in the DOHaD agenda. *Journal of Developmental Origins of Health and Disease*, 9(1), February:15-19. [<https://doi.org/10.1017/S2040174417000423>].
- 5 Viner, R.M., Ozer, E.M., Denny, S., Marmot, M., Resnick, M., Fatusi, A. & Currie, C. 2012. Adolescence and the social determinants of health. *The Lancet*, 379(9826), April:1641-52. [[https://doi.org/10.1016/S0140-6736\(12\)60149-4](https://doi.org/10.1016/S0140-6736(12)60149-4)].
- 6 International Society for Developmental Origins of Health and Disease (DOHaD). 2015. *The Cape Town Manifesto – November 2015: A healthy start builds a bright future*. International Society for DOHaD, Cape Town. [<https://bit.ly/3aJwzFD>].
- 7 Bandura, A. 2004. Health promotion by social cognitive means. *Health Education & Behaviour*, 31(2), April:143-164. [<https://doi.org/10.1177/1090198104263660>]; Rimer, B.K. & Glanz, K. 2005. Theory at a glance: a guide for health promotion practice. 2nd Edition. *National Cancer Institute*. [<https://bit.ly/3hp0GLL>]; Antonovsky, A. 1996. The salutogenic model as a theory to guide health promotion. *Health Promotion*

deliver the knowledge, concepts and approaches necessary to generate informed decision making by the targeted youth concerning pregnancy and the nurture of their infants. There is also a fundamental yet often overlooked need to learn from young people themselves how best to instil behavioural change, and promote their adoption of health behaviours that will benefit the future health of their progeny.

We suggest that a creative way to address this essential step in health promotion is to ask our target population how to frame effective 'messages', and to establish how, and by whom, the messages chosen can be shared most effectively. Messages need to be clearly understood by young people when first heard, and be presented so that they have the greatest potential to create an impact in the long-term. Hence, an important consideration is to look at who will be the best 'messengers', and what modes of delivery will be the most effective for youth to access and retain the core DOHaD concepts. While the health promotion literature provides the basic methodology and conventional approaches, because youth are our target population, it behoves us to engage young people actively in the process. Their input is central to future health promotion strategies having the highest potential to attract and interest youth, generating pertinent messaging, identifying the most effective messengers and exploring the most topical and up to date modes of delivery.

To initiate this form of youth-centred inquiry, we presented the concept of DOHaD to senior pupils in rural primary schools in Uganda at discussion groups held regularly as part of our school-based health promotion programmes. These programmes are based on the WHO 'Health-Promoting School' model,⁸ and such discussion sessions are a regular component of the school-based health promotion used to engage pupils in health-related topics, promote dialogue and identify avenues for constructive behavioural change.⁹ While the idea that early life events

strongly impact future health was unfamiliar to these pupils, they quickly came to understand the concept.

In the discussions that followed, it became clear that the main impetus for these young people to want to learn about DOHaD was coming to know that when they have healthy offspring, these children will be able to earn more in their lifetime than a child born to them who is not healthy. In contrast, other issues related to DOHaD and non-communicable diseases, usually seen as the most substantive rationale for action carried no weight for the pupils. Neither the prospect of reducing the epidemic of obesity, Type 2 diabetes and heart disease in the future nor financial arguments about reducing the burden for governments related to providing care for those with non-communicable diseases were persuasive.

It was also clear that these children had significant gaps in their DOHaD-related knowledge, especially about the importance of micronutrient provision and good maternal health and nutrition during pregnancy, and the significance of how an infant is nourished during the first two years of life. They were, however, amenable to learning more if this meant they could then contribute to their children being healthy. Significantly, there were clear opportunities to engage both genders, as boys saw relevance in having a role where they could actively support a mother in ways that promoted the health and wellbeing of their infant. Once again, the context of higher earning capacity for healthy offspring was of definite interest, and boys' questions showed their interest in what their roles might be and how they could learn to fill them.¹⁰

An unexpected insight came when these pupils shared how they have already become aware of health promotion messaging because of music videos popular amongst school-aged children. In these videos, health topics and positive actions and behaviours are promoted and endorsed by celebrities.¹¹ The impact on pupils of celebrities promoting health in this way was striking. It was clear that young people already know facts and concepts relevant to maternal and child health; pupils gave us examples of where such messaging could be found on social media and referred to music videos they regularly viewed on YouTube in particular. The majority of pupils indicated they were aware of videos of this type, the names of the celebrity recording artists were familiar to the group as a whole, and more than half the children indicated that they had heard and remembered messages from music videos of this type that they had watched. The boys, interestingly, even more than

International, 11:11-18. [<https://bit.ly/2Ec41Qd>]; Crisp, B.R., Swerissen, H. & Duckett, S.J. 2000. Four approaches to capacity building in health: consequences for measurement and accountability. *Health Promotion International*, 15:99-107. [<https://doi.org/10.1093/heapro/15.2.99>];

De Leeuw, E. 1999. Theory and policy innovation for health: where has the creativity and fun gone? *Health Promotion International*, 6(1), March:1-3. [<https://doi.org/10.1093/heapro/dar001>].

8 WHO. 1997. *Promoting health through schools: Report of a WHO Expert Committee on Comprehensive School Health Education and Promotion*. WHO Technical Report Series, 870. [<https://bit.ly/2EcBASg>].

9 WHO. 1997. *Promoting health through schools: Report of a WHO Expert Committee on Comprehensive School Health Education and Promotion*. WHO Technical Report Series, 870. [<https://bit.ly/2EcBASg>]; Macnab, A.J. & Mukisa, R. 2018. Celebrity endorsed music videos: innovation to foster youth health promotion. *Health Promotion*

International, 34(4), August:716-725. [<https://doi.org/10.1093/heapro/day042>]; Macnab & Mukisa, 2018.

10 Ibid.

11 Ibid.

the girls identified with music videos. If this applies broadly, celebrity music videos offer a rare avenue to preferentially engage boys, in a health promotion area that to date has predominantly addressed girls and women.¹² Both genders, however, need to learn the DOHaD-related links between causation of illness and the contribution of diet and lifestyle in early life.¹³

This familiarity and interest of African youth in YouTube is in keeping with the recognised popularity and widespread access of materials from this site in many other societies and the known attraction and central place of social media in the lives and lifestyles of today's youth.¹⁴ While the impact of some music videos is considered to be negative and potentially harmful in the context of issues such as gender equity, sexual behaviour, alcohol abuse, drug-taking and violent behaviour, the statements of the pupils we met, warrants more attention to celebrity music videos.¹⁵ Many pupils identified strongly with videos that they saw as promoting health and lifestyle messages, and could sing or quote familiar content from these videos. Hence, it was apparent that they had retained key health messages from hearing the lyrics and viewing the images, raising the question, do music videos represent an innovative avenue to educate youth about DOHaD?

What follows is an evaluation of music videos endorsing health promotion and gender equity selected from those identified by African youth. The evaluation included locating and viewing these recordings on YouTube, transcribing and translating the lyrics, and content coding the core concepts and technical elements they incorporate regarding the health promotion genre of Education-Entertainment. The overall conclusion was that celebrity-endorsed messaging in music videos is an innovative medium with real potential for the promotion of DOHaD and related health messaging among youth in Africa.

12 Pentecost et al., 2018.

13 Davies et al., 2018; Macnab & Mukisa, 2018.

14 Brown, J.D. & Witherspoon, E.M. 2002. The mass media and American adolescents' health. *Journal of Adolescent Health*, 31 (Supplement 6), December:153-170. [https://doi.org/10.1016/s1054-139x(02)00507-4]; Brodersen, A., Scellato, S. & Wattenhofer, M. 2012. *YouTube around the world: geographic popularity of videos. Behavioural Analysis and Content Characterization in Social Media*. Proceedings of the 21st International Conference on the World Wide Web, Lyon, France, April 16-20. pp.241-250. [https://bit.ly/34FCguf]; Chou, W.Y., Hunt, Y.M., Beckjord, E.B., Moser, R.P. & Hesse, B.W. 2009. Social media use in the United States: implications for health communication. *Journal of Medical Internet Research*, 11(4):48. [https://doi.org/10.2196%2Fjmir.1249].

15 Tapper, J., Thorson, E. & Black, D. 1994. Profile: Variations in music videos as a function of their musical genre. *Journal of Broadcasting & Electronic Media*, 38(1), April:103-11. [https://doi.org/10.1080/08838159409364249]; Brown & Witherspoon, 2002.

Celebrity messages in song

Positive motivation

When we first asked pupils to tell us about a health message they had learned from a celebrity music video, the song suggested spoke in general terms about knowing that "consequences follow from whatever we choose to do", probably because of the simple way we had introduced the DOHaD concept as a 'cause and effect' relationship. Health examples given by pupils that 'consequences follow' were that eating the right things will make you grow and that cleaning your teeth will keep the mouth healthy.

The message about consequences is contained in the music video, *Obuvubuka BWO (Your Youth)*, recorded by Bobi Wine.¹⁶

Young people

Enjoy your youth and be happy while you are still young

Do everything that you want to do

And follow your heart's desire.

But remember

For everything that you do

Judgement must come.

Ecclesiastes Chapter 11 Verse 9¹⁷

The principal reason why Bobi's message has an impact, the young people told us, is because he is a prominent celebrity; another factor mentioned was that his message must be right because he used words from the Bible. Analysis of why this video engages its audience shows that it uses visual cues, locations and an overall style similar to those employed in the production of Wine's other popular videos; he speaks to a broad audience by singing in English and Luganda (pupils in Uganda are taught English and Luganda) and includes the source of the biblical text in the lyrics to emphasise the message. Uganda is a country with a large Christian following, so a biblical quote or song recorded in a Gospel style likely has particular appeal.

16 Swalz. 2013. *Bobi Wine ft Nubian Li & Henry Tigan _ Obuvubuka BWO (*Swalz*)*, May 23. [https://www.youtube.com/watch?v=IHc73xKWOhE].

17 Ibid.

Messages on maternal and child health

An example of a music video where the message relates to maternal and child health concepts is 'Everyone' a song where the first line is "No child is born to die, no mother should die giving life".¹⁸ This popular song was written and recorded by a group of celebrity musicians in Uganda who were aware of the issue of maternal and infant morbidity and mortality; they came together to create a compelling message through their music, intended to promote awareness and prompt action to generate change. It is clear that this song resonates with youth because of the talent, popularity and stature of the artists involved in Ugandan society; but the message also has relevance and power because of the reality and emotional impact in Uganda of maternal and infant death.

The words of the song are transcribed in Table 16.1. They are a model of how to combine elements that make the impact and appeal of a health promotion message as broad as possible for a potential audience. The production of this video also employs the core elements of the education-entertainment genre model of health promotion.¹⁹ The group of celebrities has wide appeal, achieves gender equity by including male and female artists, and children also contribute as central protagonists. Three languages are included Luganda, Swahili and English. Performers bring their unique style and individual music genre to the messaging, including Ballad, Reggae, Rap, Hip Hop and Lugaflow so that individual celebrities can reach out to their fans as well as contributing to the collective impact of the work as a whole.²⁰ Rap, for example, is considered one of the most controversial of music genres. However, research indicates that it can have profound psychological

18 Swalz. 2014. *All Stars (Bobi, Radio, Weasel, Chameleone, Navio, Miles, Renam Gravity_ EVERYONE 2014 (Swalz)*, June 12. [https://bit.ly/3eO2IVn].

19 McGuire, W.J. 2001. Chapter 2: Input and output variables currently promising for constructing persuasive communications. In: Rice, R.E. & Atkin, C.K. (eds). *Public Communication Campaigns*, 3rd Edition. Thousand Oaks: Sage Publications, pp.22-48. [http://doi.org/10.4135/9781452233260.n2]; Singhal, A. & Rogers, E.M. 2006. A theoretical agenda for Entertainment-Education. *Communication Theory*, 12(2), January:117-135. [https://doi.org/10.1111/j.1468-2885.2002.tb00262.x]; Piotrow, P.T. & De Fossard, E. 2004. Entertainment-education as a Public Health Intervention. In: Singhal, A., Cody, M. J., Rogers, E. M. & Sabido, M. (eds). LEA's communication series. *Entertainment-education and social change: History, research, and practice*. Mahwah, New Jersey: Lawrence Erlbaum Associates Publishers. pp.39-60; Porter, B. 2006. Beyond words: The craftsmanship of digital products. *Learning & Leading with Technology*, 33:28-31. [https://bit.ly/38xflO]; Storey, D. & Sood, S. 2013. Increasing equity, affirming the power of narrative and expanding dialogue: The evolution of entertainment education over two decades. *Critical Arts Journal*, 27(1):9-35. [https://doi.org/10.1080/02560046.2013.767015]; Rimer & Glanz, 2005.

20 Tapper, Thorson & Black, 1994.

and educational effects on the listener, and it has been utilised effectively with adolescents in fields such as education, risk reduction, and counselling psychology.²¹

In this video, the health issues promoted are not just delivered through words or in song; the music conveys emotion, the images are compelling, and text messaging is used like subtitles to deliver specific health messages; these include:

- When pregnant, visit a health facility as soon as possible.
- Make at least four antenatal clinic visits during pregnancy.
- Give birth in a health facility under the care of a skilled healthcare worker.
- Seek medical care immediately if the mother or newborn is unwell.
- Everyone has a role to play in ensuring that maternal, newborn and child health is prioritised, funded and delivered effectively at community and national level.
- Together we can end the preventable death of mothers and newborns.²²

Pupils recalled many of these messages from 'Everyone', and quoted key elements when describing what they had learned from the videos they liked to watch.

The English lyrics of the introduction and chorus of 'Everyone' are:

No child is born to die
And no mother should die giving life.
We need to come together
To make a difference
Everyone²³

The song continues with English lyrics that speak to the issue of mothers dying during childbirth and babies dying in infancy being urgent and of public concern. Numbers are given to quantify the problem; resources needed are listed; the preventable nature of these deaths is emphasised, and everyone is called upon to take responsibility and generate change. The phrases in Luganda and Swahili each reinforce these messages or challenge the listener to be responsible and become

21 Iwamoto, D.K., Creswell, J. & Caldwell, L. 2007. Feeling the beat: The meaning of rap music for ethnically diverse midwestern college students – A phenomenological study. *Adolescence*, 42:337.

22 Swalz, 2014.

23 Ibid.

involved. In Verse 4, Judith sings: “Everyone has their own experience of death, and wherever you are my friend, you can start to make a difference.” In his verse, David asks each of us: “Who do you think is going to help this young blood if not you?” and Bobi goes further, with the challenge: “Whose responsibility is it, yours or mine?” Jose repeats the theme of collective responsibility; “Me and you and everyone are responsible for all the young ones; how can a child be born and quickly die? Saving the children of the future is the responsibility of all of us.” Then Gravity calls; “Don’t sleep – wake up. Let us all fight for the young blood and the mothers not to die. Children must not be left alone without mothers.” Mike asks: “Mothers die when they are giving birth, but why?” and brings a new thought; “We just say the government should help, but me and you, and you and me, let’s combine our energy now to save the future.” Finally, Chagga describes the ideal all should strive for; “Children’s lives are lovely when they can laugh with their mothers, celebrate their birthdays year by year and live in a peaceful country.”

Messages of importance identified by girls

When asked about a particularly important message to them, girls spoke of liking certain celebrities because of what they sang about. When they described songs recorded by these artists, the ballads had three main themes where ‘hopes’ or ‘wanted realities’ predominated:

- Hopes for fidelity, lasting relationships and true love
- Hopes for greater gender equality and opportunity for girls
- Calling for or giving validation of the roles, actions and lives of women

An example of a song on the first theme is Mukyaala Mwami (wife and husband), where Khalifa Aganaga sings:

The way that you love ...
 Don’t feel frightened, don’t feel shy ...
 You have made me forget other ladies.
Chorus: Wife and husband – that is always good when you are loving each other, and the relationship is fine.²⁴

An example of the second theme is the song, *Woman*,²⁵ sung in English by Juliana Kanyomozi. Key verses and the chorus are summarised in Table 16.2. *Woman’s*

24 Aganaga, K. 2016. *Kalifah AgaNaga – Mukyaala Mwami (Official Video)*, 23 Aug. [<https://www.youtube.com/watch?v=m7UYaXRysuU>].

25 Sly Musik. 2015. *Woman – Juliana Kanyomozi {SHAMAC} Ugandan music*, February 12.

words are a celebration of the strengths and virtues of women, and so are worth listening to in full.

An example of the third theme is *Superwoman*, sung in Luganda and English.²⁶ It is notable that the artists in this video are both male (Bobi Wine and Nubian Lee) as the lyrics validate the role and positive impact of mothers; the key messages are:

Respect your mama, love your mama.
 I became what I am because of my mother
 She is a superwoman.
 It was because of you,
 Because of all your work
 All the time when I was weak,
 That I am who I am.
 Everything can be possible when you have a mother’s love.
 Superwoman.²⁷

Messages of importance identified by boys

Interestingly, many boys identify with messaging about HIV/Aids. One video given as an example has a dark storyline portraying adult characters, with one exception; a girl of school age is also portrayed. The video is *Togwamu Suubi (Don’t lose hope), Keep Uganda alive*.²⁸

The key messages in the song (recorded in Luganda) are:

Keep Uganda alive.
 We are not running away because you are affected (with HIV)
 Do not lose hope
 We are here for you
 Educate our youth
 Use protection (condoms)
 Get tested (for HIV)
 Stay faithful, do not cheat (on your partner) and risk the danger (HIV)

[<https://www.youtube.com/watch?v=SuR3YEaMk5s>].

26 Ugandan Music Videos. 2017. *Bobi Wine & Nubian Li – Superwoman (Official Video)*, September 16. [<https://www.youtube.com/watch?v=5ueRpSLiDdI>].

27 Ugandan Music Videos, 2017; Swalz, 2013.

28 DeonMurrayPro. 2013. *Aids Song Togwaamu Ssuubi All Ugandan Stars New Uganda music 2013 DEONMURRAY PRO*, July 29. [<https://bit.ly/3piUUzD>].

Please, all pregnant mothers – get tested
If your husband has left you – don't fear,
Take your medicine and care for your children.

Those who are affected
Please do not hide your disease
You should know there is treatment.

Always have protection (condoms) available at your house.

Do not lose hope.

We as celebrities want to fight this disease, we are there for you and are
with you.

This video conveys important and direct health and behavioural messages. The song is particularly inclusive; the words speak to a broad audience – men and women, adults and youth, those who are HIV positive and negative, women who are pregnant, those who have been left by their partners, and youth thinking of starting sex. The celebrities effectively combine a message of hope with the importance of testing and treatment and include advice on how to avoid transmission through the use of condoms. They call for universal action to fight the disease and encourage tolerance towards those who have it.

The specific scenario central to this video is interesting from a health promotion, and cultural perspective as the central character is a young school-aged girl. She is portrayed dressed in her school uniform and shown entering a room with an older man. All the visual cues are that they are about to engage in sex. However, the girl catches sight of a TV where the celebrities' video is playing, and after seeing their message, her actions indicate that she decides not to have sex, and so gets up and leaves. The boys, who suggested this video, described this scene, indicating impactful messaging, received information, and that the intended behaviour promoted had been understood and retained.

Messaging in Africa related to gender equity

While industrialised countries came to view the emergence of the #MeToo movement as an opportunity to reconsider inappropriate behaviour and sexual stereotyping when it burst onto the scene in the autumn of 2017, #MeToo has not created the same public debate across Africa. Although the media in some sub-Saharan countries did pick up the theme, and report individual stories, the resulting public conversations were muted at best, even though globally more than one in three women fall victim to sexual harassment or gender-based physical or

sexual violence.²⁹ In Africa, such acts have significantly higher rates of prevalence compared to western countries. It is essential to address the endemic gender disparity in Africa to promote knowledge and behaviours conducive to advancing the DOHaD agenda and in the broader social context. Currently, in most sub-Saharan cultures women and girls are not seen to have the same value as boys, and in parallel, molestation, trans-generational sex and rape are still widely accepted as normative behaviour; so the support of mothers during pregnancy and the importance of their role while breastfeeding and caring for their infant's social and emotional development are currently undervalued.

Domestic violence is an inherent African plague, but, while the norm used to be just living through the pain inflicted because of the shame such violence engenders, today there are signs of improvement, because, with the advent of social media, celebrities are now coming out to tell their stories. Music and storytelling, always powerfully intertwined in Africa, can be seen in songs and videos relevant to the #MeToo issues from many parts of the continent. Endorsement by celebrities in the Nigerian music industry is particularly strong. As in other countries, performers there have often turned a blind eye to societal issues just to score a hit, but now, lyrics are written, and songs recorded that are directly relevant to #MeToo. These include five powerful examples with messages to help address domestic violence, and one, *Good man*, performed by Eldee, has a verse that could be adopted across Africa and beyond.³⁰

Three rules: never raise a hand to hurt a single hair;
Rule number two: listen to her like you care;
Rule number three is more important than the others
It's simple: respect every woman like your mother.³¹

Nigerians and South Africans have also released songs that celebrate the love of mothers, the significance of their presence, the strength of women, and songs celebrating female empowerment.³² The recording artist Manteiga is quoted as

29 O'Neil, A., Sojo, V., Fileborn, B., Scovelle, A.J. & Milner, A. 2018. The #MeToo movement: an opportunity in public health? *The Lancet*, 391(10140), June:2587-2589. [https://doi.org/10.1016/S0140-6736(18)30991-7].

30 Jonathan. 2018. *These five songs about mothers and women will get you emotional*. Pulse TV. [https://bit.ly/34FK9j].

31 Ibid.

32 Ohunyon E. 2017. *Five Nigerian songs inspired by domestic violence*. Net TV. [http://thenet.ng/five-nigerian-songs-inspired-by-domestic-violence/]; OkayAfrica. 2016. *South Africa's Boldest Women in Music on the Ultimate 'Girl Power Anthems*, Aug. 30. [https://www.okayafrica.com/womens-month-south-africa-girl-power-anthems/].

saying that when she hears the song, *Pride*, it “builds me up inside as it speaks of being proud, of being black, of being a woman, of being a goddess, a flower, a sun”. Another artist Yvonne Chaka says of the protagonist in her song simply titled, *Woman*:

... she is strong, she is vulnerable, she is assertive, and she is humble. Women are taking up more powerful spaces in our society, and as a woman, I am always inspired by the tenacity and strength of the many women who have gone against all the odds to make their voices known in the world.³³

All these sentiments are relevant to the promotion of the DOHaD agenda in Africa.

The genre of Education-Entertainment

This genre is a communication strategy suited to promoting the DOHaD message as it aims to alleviate a social issue or educate the public through custom-made forms of entertainment, where the production involves the use of various types of mass media to communicate messages intended to drive social and behavioural change.³⁴ All the videos identified by children as containing health messages they remembered met inclusion criteria for the entertainment-education genre of health promotion. Each video addressed locally relevant and current educational issues, including avoidable maternal and neonatal death, the contemporary challenge of HIV/Aids, and calls for gender equity, the celebration of women and the central role of mothers. They also incorporate multiple techniques and approaches used successfully to increase the impact of various forms of the education-entertainment health promotion model.

Education-Entertainment is a genre of health promotion that intentionally incorporates educational content into a variety of entertainment media to increase knowledge about an issue, create favourable attitudes, and change behaviours. Music videos represent one of the most popular Education-Entertainment media formats.³⁵ In their design, the central issue to be framed in the video is chosen first, and then layers of reference values are added to the lyrics that complement the central message; these layers come from multiple sources (e.g. the songwriter, lyricist, content experts or members of the intended target audience). Creative elements (images, sound, music, transitions, animations, text and special effects)

33 Ibid.

34 McGuire, 2001; Singhal & Rogers, 2002; Piotrow & De Fossard, 2004; Porter, 2006; Storey & Sood, 2013; Rimer & Glanz, 2005.

35 Singhal & Rogers, 2002; Storey & Sood, 2013.

are then employed and artfully mixed to attract, retain and impact, while informing, touching and influencing the viewer.

Compelling visual images are obviously central to good video, but this is also relevant as humans process visual information 60 000 times more quickly than narrative fact.³⁶ Good sound is also essential as this reinforces the message by establishing the tone, mood and emotional context. Watching videos involves verbal and non-verbal thinking and so engages both sides of the brain; the left-brain processes dialogue, plot, rhythm and lyrics in parallel with right-brain processing the visual images, sound effects, melodies and harmonic relationships from the video.³⁷

An important design component is the repetition of the health promotion content; repeated words, phrases, text and images, including multiple performers and using different languages within the song, multiplies the opportunities for the message to ‘connect’ with its target audience. Added impact comes with repeated playing; unlike a message heard only once, each time a video is viewed or a song heard, the educational message imprints that much more on the memory of the viewer/listener, and increases the probability that the message will be retained.³⁸ Subsequently, a glimpse of the visual images, hearing a phrase from the song or even seeing the celebrity in another video can then trigger recall of the core message.

We can only hypothesise that such imprinting translates into behavioural change, but the fact that African school children are aware of music videos with a health message, and many can sing a phrase or quote a message from a video that they have watched, warrants attention. Such awareness is an achievement in itself in health promotion terms, and we know that where positive behaviours evolve in adolescence, they tend to carry forward into adult life.³⁹ Of interest regarding the challenges of social engagement over DOHaD, boys identified with music videos more than girls; if this applies broadly, celebrity music videos offer a rare avenue to preferentially engage boys in DOHaD-related health promotion, where the emphasis to date has predominantly focussed on girls and women. Both genders need to learn the links between causation of illness and the contribution of diet

36 Porter, 2006.

37 Schlaug, G., Jäncke, L., Huang, Y., Staiger, J.F. & Steinmetz, H. 1995. Increased corpus callosum size in musicians. *Neuropsychologia*, 33(8), August:1047-1055. [https://doi.org/10.1016/0028-3932(95)00045-5]; Hébert, S. & Peretz, I. 1997. Recognition of music in long-term memory: Are melodic and temporal patterns equal partners? *Memory and Cognition*, 25(4), July:518-533. [https://doi.org/10.3758/bf03201127].

38 Singhal & Rogers, 2002.

39 Viner et al., 2012.

and lifestyle in early life to the adult onset of non-communicable diseases later.⁴⁰ In this way future parents will have similar awareness and can mutually support one another.

The potential for celebrity and music to impact DOHaD

In debating the merits and potential of celebrity music videos in the context of DOHaD, it must be acknowledged that only a tiny proportion contain robust health messaging or even follow the principles of Education-Entertainment. Also, that overall, most music videos cannot be considered to have positive social messaging or depict appropriate behaviours and role modelling; many are rightly seen to contain negative messages and portray important social issues inappropriately⁴¹ Consequently, it is refreshing to find the strong, positive messaging about women, stable relationships and motherhood in songs that the female pupils identified. And find evidence that the videos had commanded attention and provided knowledge and perspectives that had been retained.

Social media

The use of social media by modern youth does offer a powerful tool for delivering health promotion messaging. Internet access, even in Africa is already considerable. It will be a growing phenomenon, and the fact that many pupils in rural Uganda have sufficient access to view music videos like the ones described, remember key content and be familiar with the names of the celebrity recording artists is significant.

Trends in the USA will inevitably impact Africa; an average American youth currently spends one-third of each day with various forms of mass media, mostly without parental oversight.⁴² The mass media have been shown to affect a broad

- 40 Bradac, J.J., Hopper, R. & Wiseman, J.M. 1989. Message effects: Retrospect and prospect. In: Bradac, J. (ed). *Message effects in communication science*. Newbury Park, CA: Sage. 241-317; Kajee, N., Sobngwi, E., Macnab, A.J. & Daar, A. 2018. The Developmental Origins of Health and Disease and Sustainable Development Goals: Mapping the Way Forward. *Journal of Developmental Origins of Health and Disease*, 9(1):5-9. [https://doi.org/10.1017/S2040174417000630]; Pentecost et al., 2018; Macnab & Mukisa, 2018.
- 41 Ward, L.M., Hansbrough, E. & Walker, E. Contributions of music video exposure to black adolescents' gender and sexual schemas. *Journal of Adolescent Research*, 20:143-166. [https://doi.org/10.1177%2F0743558404271135]; Brown & Witherspoon, 2002; Tapper, Thorson & Black, 1994.
- 42 Kraak, V. & Pelletier, D.L. 1998. How marketers reach young consumers: implications for nutrition education and health promotion campaigns. *Family Economics and Nutrition Review*, 11:31-41. [https://bit.ly/2Qr5d4p].

range of adolescent attitudes and behaviours, including violence, eating disorders, and tobacco and alcohol use.⁴³

Celebrity endorsement

Research does validate a role for celebrities in health promotion and the potential effectiveness of their endorsement; "Heroes, heroines and role models can motivate children and teenage youth."⁴⁴ This aspect of social marketing has been identified as a way to design better health promotion campaigns and create more effective nutrition education in particular.⁴⁵ Celebrities are recognised to be effective in 'selling' health promotion messages; many are highly visible and already affect opinion in society, so readily assume the role of champions advocating for change, particularly where they share social and cultural bonds with their audience, or have had a 'life experience' related to the issue they champion.⁴⁶ The more their 'audience' identifies with their celebrity, the more they associate with the issues and causes advocated, and the higher the likelihood of them adopting the values modelled. In Africa, very few children ever see their celebrities perform in person, but the news, TV, radio, and the availability of their music videos on social media make them widely 'accessible' and hence influential. Two caveats are however necessary; media controversy exists around the ethics of payments required by some celebrities for endorsement, and there are legitimate concerns about the potential for negative impact to be generated where a high-profile celebrity falls from grace.⁴⁷

- 43 Valente, T.W. & Pumpuang, P. 2007. Identifying opinion leaders to promote behaviour change. *Health Education & Behaviour*, 34(6):881-896. [https://doi.org/10.1177/1090198106297855].
- 44 Erdogan, B.Z. 1999. Celebrity endorsement: A literature review. *Journal of Marketing Management*, 15(4):291-314. [https://doi.org/10.1362/026725799784870379].
- 45 Batras, D., Duff, C. & Smith, B.J. 2016. Organizational change theory: implications for health promotion practice. *Health Promotion International*, 3191, March:231-241. [https://doi.org/10.1093/heapro/dau098].
- 46 Chapman, S. & Leask, J.A. 2001. Paid celebrity endorsement in health promotion: a case study from Australia. *Health Promotion International*, 16(4), December:333-338. [https://doi.org/10.1093/heapro/16.4.333]; Roberts, D.F. 2000. Media and youth: access, exposure, and privatization. *Journal of Adolescent Health*, 27(Supplement 2), August:8-14. [https://doi.org/10.1016/s1054-139x(00)00128-2].
- 47 Escobar-Chaves, S.L., Tortolero, S.R., Markham, C.M., Low, B.J., Eitel, P. & Thickstun, P. 2005. Executive summary. *Pediatrics*, 116(Supplement 1):297-300. [https://doi.org/10.1542/peds.2005-0355B].

Celebrity engagement

Some celebrities, like Bobi Wine, create opportunities for engagement; in addition to being a musician, he is an elected member of parliament and a Save the Children Ambassador. The role of ambassadors of the United Nations Children's Fund also offers motivated celebrities' unique opportunities. Ambassadors have a wide range of talents and achievements, but all share a commitment to improving the lives of children worldwide. Sports celebrities have great appeal amongst youth and hence considerable potential. Bill and Melinda Gates advocate for change through their foundation, and the founder of Facebook and his wife have pledged to fund cutting edge initiatives to eradicate major diseases within their daughter's lifetime. Strategies to seek to engage celebrities and philanthropists to promote knowledge and lifestyles in line with DOHaD should be possible given the weight of scientific evidence and escalating burden of non-communicable diseases. Facebook has already made the issue of cyberbullying its own, and announced that it is to offer secondary schools in the UK a digital on-line ambassador to run safety workshops and share advice on how to address cyberbullying. There is no doubt that the pervasive nature and social impact of Facebook adds an element of celebrity to the lives of young people; hence it is also an obvious medium to explore in the context of health promotion. However, an obvious caveat is the inescapable challenge of the volume of unreliable and inaccurate content posted.

Musical styles

Musical styles need consideration. For instance, despite its national and international appeal, rap is considered one of the most controversial music genres. Given the political charge it generates, rap music has spawned research across the social and health sciences, but, the majority of the research has investigated its impact on African Americans, not native Africans, and tended to focus on negative aspects of the music. There is a dearth of in-depth qualitative studies that explore how rap impacts the listener. Iwamoto suggests that rap can have a profound psychological and educational effect and sees potential for rap music to be used in innovative ways with adolescents in fields such as education, risk reduction programmes, and counselling psychology.⁴⁸ This suggestion indirectly supports our hypothesis and the potential for music videos to be useful in DOHaD health promotion. Because rapping also often occurs in native tongues, it can be argued that this offers the advantage that messages will be understood better by local populations and those less familiar with mainstream lyric languages. Lugaflow, for example, is Uganda's definition of Hip Hop, and a form of music used to advocate

truth for the future of the youth and the people of Uganda. Similar variants of rap exist in other African countries, and again, the potential significance of specific musical styles resonating with youth should not be lost.

Conclusion

Youth must be the target audience for health promotion related to DOHaD. In Africa, schoolchildren have heard and retained important health messages because they have spontaneously listened to music videos recorded by celebrities that are available via social media and endorse health. Emerging empowerment songs are now promoting public awareness on the continent about the cultural differences that impact gender roles and the inherent risks of harassment faced by women; these appear capable of helping generate change. Music videos that incorporate principles fundamental to the health promotion genre Education-Entertainment can be made to address elements of the DOHaD agenda. Education-Entertainment is defined as the process of putting educational content into entertainment messages to increase knowledge about an issue, create favourable attitudes and change behaviour. Education-Entertainment has been advocated as an innovative approach particularly applicable for the developing world. We suggest Education-Entertainment music videos containing celebrity endorsement are a medium suited to innovative health promotion, and in particular, lend themselves to engaging youth in Africa in the context of DOHaD.

⁴⁸ Iwamoto, Creswell & Caldwell, 2007.

Table 16.1 The English lyrics of 'Everyone'- All stars, Uganda.

Introduction
No child is born to die And no mother should die giving life. We need to come together To make a difference Everyone.
Chorus (sung by the celebrity artists as an ensemble with children)
No child is born to die Born to die No mother should die giving life We need to come together you and I Everyone, everyone we all today.
Verse 1 (sung by Bobi Wine, in 'Ragga' in Luganda and English)
Imagine 282 children to die Why don't we wonder why they have to die Why don't we save them little babies cause everyday 16 mommas dem have to die Inna Uganda we simply cry If we just cry they'll continue to die They'll die and die till we try ooh why.
Verse 2 (sung by Radio)
Save a child and save a mother Every child deserves a mother A mother loves to see her daughter Find a man and become a mother. Have some sons or maybe some daughters Some could be nurses or some will ah ha Like a sweet lovely something along We can only do it if we want together.
Verse 3 (sung by Weasel in 'Rap')
Everybody stand up, come step alite No baby born to die No mother has to cry Everybody needs a life, We can make a future let me say. Together we can make a difference Put up resistance They need existence Everybody's assistance. Your presence, me want to let you know ooh oh.
Verse 4 (sung by Judith Babirye in Luganda)
Verse 5 (sung by David Lutalo in Luganda)

Verse 6 (sung Peter Miles who returns to 'Rap')
It's a bit big tragedy Why we have to sleep and wake up in agony That's why I don't mess with biology Make a discovery Follow me, follow to save the children generally. 20, 50, 60 get to 70 till to the infinity. Cause we have ability. Ability.
Verse 7 (sung by Jose Chameleone in 'Ragga')
(His lyrics includes questions and messages in Luganda, English and Swahili)
Verse 8 (sung by Navio in 'Hip Hop')
Back to the business, We need staff and equipment when it comes to health You all know my passion is endless Women walking miles to find a place to child birth. We're all responsible no matter how your mind works Too many kids dying that we have to save Other my change this But first it's me I thought it couldn't get worse but hey, 16 women died giving birth today.
Verse 9 (sung by Gravity Omutujju in 'Lugaflow' in Luganda)
Verse 10 (sung by Mike Wine in 'Ragga' in Luganda and English)
Let's combine the energy, we save the future.
Verse 11 (sung by Chagga in Luganda)
Verse 12 (sung by Rema Namakura)
Hey, You and I can change this, together You and I tokoolere wamu Everyone is me Everyone is you Hand in hand in, coz
Chorus (sung by the artists as an ensemble with children)
No child is born to die Born to die No mother should die giving life We need to come together you and I Everyone, everyone we all today.

Table 16.2 The English lyrics of 'Woman' - Juliana Kanyomozi

Verse 1
We don't know how she always finds her way. The mystery of a woman. A savior in a time of need The bravery of a woman. In your time of need she does the deed. The magic of a woman
Chorus
Woman, woman. A warrior is a woman. Woman, woman. A savior is a woman.
Verse 2
When a man will cry a woman smiles When her spirit's down She has no time to frown. A warrior is a woman.
Chorus
Woman, woman. A warrior is a woman. Woman, woman. A savior is a woman.
Verse 3
Bountiful, wonderful is her frame of mind Beautiful, colorful her style is one of a kind. Her womanhood and her motherhood Are her strength and pride. Her warmth and grace she cannot hide The wonders of a woman
Chorus
Woman, woman. A warrior is a woman. Woman, woman. A savior is a woman.

Acknowledgements



This chapter is dedicated to Ronald Mukisa: 25 November 1993 - 15 May 2020.

In his short life, Ronny helped improve the health and lives of many children in Uganda. He was a talented traditional drummer and gifted musician, and contributed immeasurably to the success of our school health promotion programs, where his imagination, charisma and warmth helped engage and encourage children and adults alike. He will be greatly missed.

This project was made possible by the opportunities and creative space provided by STIAS, where the authors were able to work together as a Fellow and Invited Scholar in residence. Data and concepts described have been published previously as referenced, and were included in a DOHaD seminar in the STIAS series, and by AM in lectures at the DOHaD Summer Schools at STIAS for invited African scholars. RM gave an invited presentation on his research at Mahidol University, Thailand at the 2019 International Conference of Applied Science and Health (ICASH) for which he received their Young Scientist Award.



INDEX

15-year reading test 73

A

abortion 148

spontaneous abortions 148

accurate diagnosis 265

acute malnutrition 105

addiction 57

adipose tissue 138

adiposity 18, 20, 21, 58, 99, 164, 169, 170,
172, 173, 175, 176, 178, 179, 182

adolescence 10, 16, 18, 21-23, 30, 109, 118,
122, 135, 140, 167, 173, 174, 179, 286,
300-302, 309, 321, 323

Africa 1, 7, 8, 10-13, 15-18, 21, 22, 24-31,
34, 36, 37, 38, 40, 43, 46-52, 67,
103-107, 112-115, 121, 125, 127-134,
141, 143-146, 153, 156-159, 161, 163,
175, 185, 194, 196, 197, 203, 204,
206-209, 212, 217, 218, 222, 223,
225-227, 229, 230, 233-245, 247-257,
263, 264, 267, 269, 271, 275, 276, 283,
286-288, 291-298, 302, 318, 319, 322

sub-Saharan Africa 8, 10, 13, 16, 17, 30,
31, 34, 48, 103, 105-107, 112-115,
121, 125, 129, 130, 132, 134, 145,
146, 153, 156-159, 194, 206, 218,
233-245, 247, 248, 250-254, 263,
264, 275, 276, 283, 284

African Academy of Sciences 12, 47

African Population and Health Research
Center 103, 107, 123

Africa Union's Agenda 2063 293

age

gestational age 4, 77, 87, 150

school-age children 13, 222, 249, 250,
251, 253-255, 257, 263, 265, 266,
269, 273, 278, 288

small-for-gestational-age births 165

Aids 53, 116, 158, 205, 213, 297, 317, 320

American Academy of Pediatrics 84

anaemia 18, 53, 174, 257, 267-272, 284, 286

antenatal care 42

anthropometry 58, 172, 174

antibodies 89

appetite regulation 140

arachidonic acid 74, 76

artemisinin combination therapy 252-254,
264, 265, 274-276, 278-282, 284-287

artemisinin combination therapy availability 287

atherosclerosis 91

Australia 26, 111, 214, 215, 219, 323

B

Baby-Friendly
Baby-Friendly Community Initiative 104, 121, 122, 124, 125
Baby-Friendly Hospital Initiative 104, 120, 121, 124, 125
Baby-Friendly Workplace Initiative 104, 124

Bangladesh 111

Bayley scales 86

beans 196

behavioural choices 24

Berlin Institute for Population and Development 206, 231

beta-cell islets 136

bioavailable nutrients 196

Birth to Twenty Plus cohort 21

birth weight 20, 21, 29, 45, 80, 87, 122, 132, 133, 135, 138-140, 154, 163, 165, 171, 179
low birth weight 21, 45, 122, 132, 133, 135, 139, 140

blindness 53, 197, 199, 233-237, 240, 241, 245

blindness burden 233, 235, 236, 240

BMI 58, 170

body mass index 21, 22, 109, 128, 133, 144, 154, 169, 173, 174

Bobi Wine 313, 317, 324, 326

bottle-fed babies 72, 74, 77, 78

breastfeeding 13, 26, 29-31, 33-36, 44, 67, 68, 72-74, 76-78, 80-88, 90-101, 103, 104, 106-125, 150
breastfed babies 72, 78, 85, 101
breastfeeding-friendly workplace 123, 124
cessation of breastfeeding 115, 116, 118
complementary feeding 42, 101, 106, 112, 114-116, 118, 119
duration of breastfeeding 77, 78, 80-87, 91-96, 101, 124

exclusive breastfeeding 68, 72, 84, 85, 99, 100, 106-108, 110, 112-114, 116, 119, 120, 122, 124
health effects of breastfeeding 95
lactation period 78, 79, 82
mammary glands 69-71, 88
optimal breastfeeding 104, 106-108, 112, 115-122, 125
suckling 67-72, 78-81, 88, 97

Breast is Best 97, 98

breech position 4

bridging strategies 229

building 13, 51, 195, 205, 298, 310
building networks 13

Burundi 36, 112

Byass, Peter ix, 10, 25

C

Cameroon 10, 37, 129, 143, 154

Canada 1, 10, 18, 37, 42, 43, 103, 174, 185, 222, 289

cancer
breast cancer 59, 92-94, 96, 97, 110
ovarian cancer 94-96, 110

capacity 13, 20-22, 42, 43, 49, 136, 146, 163, 210, 212, 214, 249, 310

Cape Town Manifesto 40, 201, 203, 309

casein 71

cataract-related blindness 236

celebrity/celebrities 13, 229, 307, 308, 311-314, 316, 318, 319, 321-326
celebrity endorsement 323
celebrity engagement 324

cellular phones 199

childhood 10, 16, 18, 21, 22, 25, 26, 30, 33, 36, 40, 42, 44, 49, 53, 83, 109, 112, 133, 135, 167, 169-174, 176, 178, 210, 217, 286, 300
childhood overweight 225
children of educated mothers 231
children as health-promoting agents 218

China 18, 62, 69, 96, 133

climate change 8, 39

coagulation 58

cognition 57, 60, 255
cognitive and fine motor function 258

cognitive behaviour 196
cognitive compromise 248
cognitive impairment 248, 258, 284

collaboration 16, 185, 216

colostrum 89, 114, 119

communication 13, 40, 87, 185, 215, 216, 220, 221, 224, 245, 312, 314, 320

community-based action 224

community 'ownership' of data 224

conception 1, 40, 80, 148, 177, 182, 183

congenital anomalies 148, 163, 169, 178

consensus statement 206, 211, 214, 219, 261

consent 189, 200

coordination across sectors 298

cost-benefit 176, 209, 256, 283, 284

Côte d'Ivoire 112, 251

Covid-19 12, 211, 281

creatinine clearance 60

cultural beliefs 114, 115, 118, 119

curriculum 48, 194, 214, 215, 224, 225, 249, 263

cyberbullying 324

D

Darwin, Charles 69

da Vinci, Leonardo 1-5
The Fetus 1-3
The Fetus in the Womb 1, 3

deaths 9, 16, 20, 29, 53, 94, 104, 105, 107, 108, 119, 120, 127, 128, 249, 257, 276, 278, 296, 308, 315

delinquent behaviour 119

dental caries 193

derivative analyses 26

developmental programming 20, 21, 135, 150

diabetes 9, 13, 16, 18, 20, 21, 40, 48, 53, 61, 62, 91, 92, 99, 109, 127, 128, 131-133, 136-138, 141, 143-158, 161-179, 182, 183, 225, 226, 249, 295-298, 301, 302
diabetes in pregnancy 146-149, 158, 161, 164
gestational diabetes mellitus 21, 53, 144-148, 150, 153-158, 161-170, 172, 173, 175-180

criterion for the diagnosis of gestational diabetes 147
screening algorithm for gestational diabetes in resource-limited settings 157

International Association of Diabetes and Pregnancy Study Group 145, 152-156, 165-167

pre-gestational diabetes 161

type 2 diabetes 16, 18, 20, 21, 40, 48, 61, 62, 109, 128, 131, 132, 137, 138, 145, 147-149, 152, 162, 167, 169, 170, 172

diarrhoea 106, 110, 112, 193
prevention of diarrheal diseases 213

diet 5, 47, 49, 58, 82, 81, 85, 147, 133, 134, 136, 138, 140, 141, 148, 174, 193, 300-302, 321
dietary diversity questionnaire 225
diets 17, 18, 53, 63, 129, 224, 302
unhealthy diet 147, 301

diseases 8, 9, 12, 13, 15-17, 19, 22, 24, 29, 40, 47-49, 52, 53, 61, 62, 67, 106, 108, 109, 127-135, 137, 141, 144, 158, 159, 167, 172, 174, 182, 183, 193, 203, 204, 208, 211, 213, 214, 225, 231, 232, 237, 247, 249, 250, 272, 292, 293, 295-298, 300, 301

cardiovascular disease 16, 18, 20, 40, 48, 59, 90, 91, 128, 129, 133, 149, 150, 159, 171, 182, 183

chronic degenerative diseases 52, 132

chronic non-communicable diseases 8

communicable diseases 8, 9, 12, 13, 15-17, 19, 22, 24, 40, 49, 62, 67, 127-132, 134, 135, 137, 141, 144, 158, 159, 167, 172, 174, 179, 182, 183, 203, 204, 208, 211, 225, 231, 232, 249, 292, 293, 295-298, 300, 301, 309, 311

disease prevention 15, 49, 129, 204, 209, 221, 226, 291, 293, 298-303, 305

heart disease 9, 10, 59, 92, 96, 128, 131, 132, 249, 295, 311

infectious diseases 8, 15, 17, 40, 106, 109, 127, 129, 143, 158, 159, 187, 223, 247, 248, 251, 291, 297, 295

long-term diseases 29
Neglected Tropical Diseases 241, 272, 273
non-communicable diseases 8, 9, 11, 13, 15-19, 21-24, 40, 47, 49, 62, 67, 127-132, 134, 135, 137, 141, 143, 144, 158, 159, 167, 171, 172, 174, 179, 182, 203, 204, 207, 211, 225, 231, 232, 248, 249, 288, 291-293, 295-303, 309, 311, 322, 324
non-communicable disease prevention 15, 291, 293, 298, 300-303, 305
non-communicable disease risk 18, 21, 47, 297-299
United Nations goals for non-communicable diseases 159
obstructive airways disease 60
water and air pollution-related diseases 296
Djibouti 36, 112
docosahexaenoic acid 74
DOHaD (Developmental Origins of Health and Disease) 3, 5, 9-13, 16, 18, 21, 25-30, 36-42, 44-50, 53, 54, 67, 132, 134, 144, 149, 151, 171, 180, 185, 186, 200-204, 221, 309, 321, 324
Africa chapter of the International DOHaD Society 11, 12
Cape Town DOHaD Manifesto 40, 41
DOHaD concepts 45, 49, 186, 200, 201
DOHaD Core Group 10-12
DOHaD exposure-disease dyads 29, 36
Journal of DOHaD 11
Young African Scientists dedicated to DOHaD research 12
domestic violence 319
donated human milk 122, 123
dopamine 46
Dutch famine 51-56, 58-62
E
early child development 10, 43
economic benefits of having healthy offspring 229
economic growth 37, 39, 44

education 13, 39, 42, 43, 48, 62, 77, 91, 117, 123, 154, 175, 192-194, 198, 203, 205-208, 210, 212-220, 222, 224, 225, 229-231, 234, 235, 239, 240, 243, 248, 249, 254, 256, 258, 261-265, 268, 270, 271, 277, 278, 281, 286-288, 292, 295, 314, 315, 322
education-entertainment 312, 320, 322, 325
education of girls 230, 248
educators 185, 191, 208, 221, 230
empowerment 39, 215, 228, 229
empowering women and girls 192, 261
empowerment songs 325
environment
environmental exposures 13, 26, 127, 128
environmental stewardship 37
environmental sustainability 39
epidemiological health data 17
epigenetic
epigenetic changes 138, 150
epigenetic reprogramming 177
epigenetic transgenerational inheritance 26
epigenetics 9, 137
Equatorial Guinea 36
ethics 186, 190, 191, 323
Ethiopia 237
ethos 210, 213, 216, 221
evaluation 49, 91, 133, 188, 189, 191, 206, 207, 213, 214, 216, 217, 220-222, 225-228, 240, 255, 275, 278, 282, 312
excessive weight gain 21, 67, 135, 148
exercise 3, 5, 37
exposure-disease dyads 28, 29, 36

F

family history 89, 91, 146, 154, 156, 163, 166
famine 12, 51-62, 64, 137
fathers 13, 42, 45, 46, 87, 172, 180, 309
fetal
Fetal Alcohol Syndrome 13
fetal growth restriction 20

fetal hyperinsulinism 21
fetal loss 148, 169
fetal macrosomia 165, 168, 169, 176
fetal overnutrition 21
fetal programming 132, 140, 162, 167, 174, 179, 181
fetal programming of non-communicable diseases 174
fetal undernutrition 20, 60, 180
foetus 1
multi-fetal pregnancy 148
first 1 000 days 3, 17, 26, 42, 43, 44, 63
folate 171, 174
food
access to food 51, 52
food-insecure households 118
food insecurity 18, 52, 104, 107, 114, 125
food insufficiency 223
food security 11, 13, 39, 44, 45, 195
processed foods 298

G

Gambia 27
gender
gender-based violence 221
gender equality 39, 292
gender equity 221, 312, 314, 318, 320
messaging related to gender equity 318
genetic polymorphisms 130
genetics 130
genome 71, 131, 137
Ghana 112, 113, 241, 255, 256, 260, 264, 272, 273
Global Burden of Disease programme 27, 29, 31
glucose 18, 21, 61, 62, 136, 140, 146, 147, 149-156, 158, 162-167, 169, 170, 172, 173, 175-180, 182
glucocorticoids 134, 139, 140
glucose intolerance 62, 147, 156, 162, 164, 167, 172, 175-178
glucose tolerance test 146, 152, 154-156, 164-167
oral glucose tolerance test 146, 152, 154-156, 164-167

plasma glucose 154-156, 158, 164, 166
fasting plasma glucose test 154, 155
random plasma glucose test 155
governance 37, 49
government agencies 185, 186, 253
Greece 86
growth 1, 20, 22, 37, 39, 40, 42, 44, 53, 54, 63, 67, 75, 88, 89, 105, 108, 110, 115, 132, 134-139, 150, 151, 163, 171-173, 175, 176, 182, 197, 222-225, 235, 236, 249, 302
H

health 3, 4, 8-13, 15-17, 21-29, 37, 38, 40-56, 59-63, 67, 85, 89, 95-97, 104-117, 119, 121-124, 129, 132-134, 140, 143, 144, 146, 153, 158, 162, 163, 171, 177, 180, 185-187, 192-196, 198-227, 229-235, 238-249, 252, 254-257, 259-278, 281-284, 287, 288, 291-295, 297-303, 305, 307-312, 321, 322, 324
emotional health 205, 210
healthcare policy 223
health care costs 52
health care professions 185
health care systems 15
health education 213, 261
health independence 247, 307
health indicators 9, 205, 211
health literacy 42, 45, 49, 208, 210, 265
health-promoting behaviours 194
health promotion 187, 203, 208, 209, 212, 214, 224, 232, 288, 309
health promotion strategies 186, 310
health systems 16, 144, 146, 159, 240, 299
innovate for health 309
mental health 3, 8, 10, 52, 140, 193, 207, 212, 221, 293
anti-social personality disorder 57
schizophrenia 57, 60, 62, 132
oral health 12, 193, 196, 213, 214, 217, 220-222, 226, 227

- population health* 9, 61, 291-293, 299, 302
preconception health 301
primary health care centres 233, 240-242, 244, 245
public health 21, 22, 26, 37, 38, 46, 50, 54, 63, 105, 162, 163, 186, 200, 201, 225, 226, 239, 264, 265, 270, 274, 283
global public health 186
public health hypotheses 26
reproductive health 301
sexual health 193, 194
social determinants of health 193, 198, 212, 247, 249, 256, 262
urban health 295, 297, 299
healthier trajectories 15
Health in Transition 7-10
healthy life expectancy 29
healthy lifestyle habits 205, 210
healthy practices 220, 222, 249
in-school health practices 220
higher earning capacity 311
high salt intake 129
HIV/Aids 11, 116, 131, 133, 158, 193, 194, 205, 211, 213, 297, 317, 318, 320
Honduras 111
Hong Kong 92, 207, 208, 214, 215, 228, 230
human capital 16, 38, 41, 51, 52
human capital development 16
human genome 131
Human Milk Banking 104, 123
hunger 39, 42, 44, 52, 53, 57, 58, 60
hygiene 43, 193, 213, 221
hand-washing 43
personal hygiene 213
hyperglycaemia 13, 144, 146, 148-152, 161-163, 165, 167-170, 172-175, 177-179
hyperglycaemia-hyperinsulinism hypothesis 163
hyperglycaemia in pregnancy 143, 144, 148
World Health Organization guidelines for categorizing hyperglycemia in pregnancy 162
hypoglycaemia 149, 151, 170, 176
hypertension 20, 62, 91, 128, 132, 133, 135, 136, 139, 141, 146, 150-152, 171, 296, 298
hypothalamic-pituitary-adrenal axis 138, 139
I
imaging studies of the brains 57
immunoglobulin 60, 89
inclusive development
inclusive economic development 39
inclusive social development 39
income
high-income countries 16, 105, 128
insufficient family income 118
low and middle-income countries 13, 63, 217, 218, 230, 244
low- and middle-income countries 9, 15-17, 21, 105, 106, 123, 127, 129, 187, 195, 197, 255, 256, 262, 275, 296, 301
low- and middle-income settings 143, 204
per capita income 52
India 10, 18, 133, 161, 163, 165-167, 169, 171-173, 175, 179, 233, 234, 242-245
infants 45, 46, 53, 55, 68-70, 72, 74-79, 82, 84, 85, 87-89, 92, 95-97, 100, 101, 104, 106, 108-110, 112-114, 122, 123, 136, 148, 149, 165, 223, 224, 243
infancy 16, 18, 21, 23, 40, 58, 73, 83, 139
infant care and nutrition in the first years of life 308
injuries 8, 17, 188, 232, 295, 298
injury prevention 221
Innocenti Declaration 120
innovative use of technology 228
insecticide-treated bed nets 262, 263
insulin 20, 61, 132, 133, 136, 137, 141, 148, 149, 151, 156, 163, 171-174, 176, 181
sensitivity to insulin 20
insulin resistance 133, 137, 141, 148, 156, 163, 171-173, 176
integration 216, 242, 243
intergenerational studies 26
intermittent screening and treatment 251, 256, 270, 284
internet access 234, 245
intersectoral approaches and partnerships 13
interviews 227
intrauterine growth restriction 105, 151
investment 10, 24, 80, 204, 205, 207-211, 214, 230-232, 286, 287, 309
K
Kangaroo Mother Care 13, 42, 45, 46
Kenya 11, 104, 105, 107, 113, 114, 116-118, 121-125, 130, 208, 239, 250, 251, 253, 254, 256-258, 263, 268, 270, 284
Kenya Demographic and Health Survey 107, 121
kidney 20, 136
knowledge 3, 25, 38, 45, 48, 49, 51, 104, 116, 119, 120, 125, 128, 194, 198-200, 204, 205, 208, 210, 211, 213, 218, 222, 227, 232, 247-249, 255-257, 261-265, 281, 293, 298-300, 307, 308, 310, 311, 319, 320
knowledge transfer 45
L
lack of physical activity 301
lack of stable employment 118
Lactivism 98, 100, 101
lactose 72, 82
Lancet 8, 11, 12, 16, 17, 21, 27, 38, 43, 44, 48, 61, 63, 92-94, 105, 106, 110, 120, 121, 128, 130, 133, 144-146, 153, 171, 177, 193, 198, 212, 230, 236, 248, 252, 254, 256, 258, 262, 275, 278, 286-288, 296, 297
Lancet Commission on the Future of Health in sub-Saharan Africa 8
Lancet Global Health 11, 12, 17, 43, 44, 230, 236
leadership and management 215
legislation 44
LENScience 48
life-course
life-course approach 15, 292
life-course frameworks 22
life-course perspective 16
life-course trajectories 22
life expectancy 8, 29, 129, 143, 223, 236
Linnaeus, Carl 69, 70
lipid profiles 58
literacy 10, 42, 45, 49, 208-210, 236, 243, 265
long-chain polyunsaturated fatty acids 74-77
longitudinal birth cohorts 26
M
macrosomia 21, 148-150, 154, 156, 163, 165, 168, 169, 176
magnetic resonance imaging 87
maize 196
malaria 13, 53, 106, 131, 158, 193, 213, 225, 231, 248-289, 297
cerebral malaria 257
delay in the treatment of fever 252
historic interventions for malaria 260
malaria health promotion 256
malaria prevention 213, 251, 256, 259
malaria-related absence 249
plasmodium falciparum malaria 251, 255, 257, 267, 275
residual malaise from sub-optimal treatment 249
seasonal malaria chemoprevention 267
temporary or permanent neurological complications 249
Malawi 112, 237, 239, 252, 263, 272, 275, 277, 278, 280, 281, 284
Mali 251, 258, 267-269
management 15, 31, 39, 124, 125, 129, 144, 149, 155, 156, 161-165, 176, 179, 203, 215, 234, 241, 242, 245, 252, 253, 262-264, 272, 274-277, 287
mass drug administration 272
maternal
maternal alcohol consumption 29
maternal-child bonding 42
maternal hyperglycaemia 146, 149, 151, 152, 161, 172, 174, 175

maternal nutrition 56, 61, 121, 171, 176
 maternal undernutrition 61, 132, 136
 messages on maternal and child health 314
 maternity leave 118, 124, 125
 medicine 5, 180, 254, 318
 metabolic capacity 20
 metabolic syndrome 132, 168, 169
 #MeToo movement 318, 319
 Mexico 244
 microalbuminuria 60
 microfinance 44
 micronutrients 182, 196, 198, 284
 micronutrient deficiencies 18, 105
 Millennium Development Goals 38
 mobile phones 234, 244, 245
 morbidity 9, 11, 13, 28, 40, 45, 105, 106,
 110, 112, 145, 148-150, 176, 193, 225,
 226, 231, 248-251, 254-257, 259, 260,
 278, 279, 285-288
 mortality 8, 9, 13, 18, 20, 27-29, 40, 43, 45,
 56, 57, 59, 85, 105, 109, 110, 112,
 119-121, 128, 145, 150, 163, 169, 188,
 197, 198, 225, 226, 231, 249-252,
 254-257, 263, 269, 270, 278, 286, 288
 annual child mortality 105
 child and maternal mortality 8, 197
 infant mortality 308
 mothers 9, 11, 20, 26, 42, 45, 46, 53, 54, 68,
 71-73, 77, 78, 82, 84, 85, 88, 89, 91,
 95-101, 104, 108, 114-116, 118-125,
 137, 144, 149, 163, 165, 170, 172, 173,
 175, 180, 181, 188, 197, 198, 231, 308,
 309, 315, 316, 319
 teenage mothers 116
 Mukisa, Ronald 185, 201, 307, 329
 multisectoral collaborations 24
 music videos 12, 200, 229, 308, 310-312,
 321-325

N

National Development Plan 207
 neonatal
 neonatal death 109, 320
 neonatal deaths 104, 107
 neonatal hypoglycaemia 170, 176

National Institute for Health and Clinical
 Excellence 145, 151, 152, 155, 217
 nephron 60, 136
 nephropathy 149
 Netherlands 55, 56, 103
 neuroendocrine disorders 132
 New Zealand 26, 48
 Nigeria 52, 62, 113, 121, 153, 156, 239, 245,
 258, 260, 283
 non-fatal birth asphyxia 29
 non-governmental organisations 46, 47
 numeracy 10
 nutrition 9, 13, 16-18, 20-22, 24, 31, 39,
 44-46, 49, 51, 53, 54, 56, 58, 59,
 61-63, 71, 73, 74, 76, 83, 89, 96, 99,
 103-107, 109-116, 118, 120, 121,
 123, 133-136, 138, 167, 171-173, 176,
 177, 179, 195-198, 208, 212-214,
 221-225, 322
 infant nutrition 13, 46
 malnutrition 8, 17, 18, 21, 49, 53,
 104-106, 112, 132-134, 138, 168,
 174, 182, 183, 192, 193, 196, 261
 protein-energy malnutrition 105
 nutrition-related risk factors 18
 undernutrition 9, 12, 17, 18, 20, 21,
 52-54, 56, 57, 60-63, 105, 106, 110,
 115, 132-134, 136-138, 140, 141,
 172-174, 180, 181
 prenatal undernutrition 52, 54, 56, 62

O

obesity 9, 10, 17, 18, 21, 22, 24, 26, 30-36,
 40, 53, 58, 91, 92, 106, 108, 109, 114,
 128, 129, 132, 133, 135, 140, 141,
 147-149, 151, 152, 154, 157, 161-163,
 166-168, 170, 175, 176, 178, 179, 181,
 182, 213, 217, 221-226, 296, 298,
 300, 301
 onchocerciasis 233, 237, 240, 272
 organogenesis 148, 176
 overweight 9, 17, 30, 31, 40, 62, 105, 109,
 110, 114, 141, 147, 154, 167, 225
 ownership and empowerment 215
 oxytocin 111

P

pancreatic beta-cell mass 137
 parents 43, 77, 86, 116, 198, 211, 212, 215,
 216, 223, 224, 249, 255, 272, 273,
 288, 289, 309
 peace and security 39
 peers 116, 300
 photographs 186, 191
 photo-essays 185, 186, 191
 photojournalism 186, 187, 191, 200
 photo-manipulation 190
 physical activity 47, 130, 133, 154, 157, 179,
 217, 222, 225, 293, 295, 296, 298,
 300-302
 placenta 4, 5, 89, 111, 134, 149, 151
 placental insufficiency 136
 policy interventions 13
 pollution 129, 296, 298
 polycystic ovarian syndrome 148, 178
 postnatal services 119
 poverty 9, 39, 42, 52, 53, 63, 64, 104, 113,
 115, 117-119, 125, 129, 134, 159, 179,
 192, 208, 235, 247, 249, 252, 254,
 257, 261, 292
 preconception 16, 22, 23, 155, 177, 301
 predictive adaptive responses 134
 preeclampsia 148, 149, 168
 pregnancy 16, 21, 23, 25, 29, 40, 53, 54,
 56, 61, 63, 74, 76, 77, 78, 80, 86,
 89, 92-95, 122, 132-134, 138, 140,
 143-152, 154, 155, 158, 161-165,
 167-178, 221, 179, 180, 182, 222,
 308, 310, 311
 stress during pregnancy 53
 premature deaths 296
 prenatal famine exposure 52, 57
 preterm 76, 87, 122, 168, 238
 prevention 9, 15, 16, 23, 24, 47, 49, 62, 109,
 128, 129, 133, 141, 145, 156, 179,
 193, 203-205, 209, 213, 214, 221, 226,
 238, 251, 254, 256, 262-266, 291-293,
 297-302
 prevention strategies 24, 213, 298
 prolactin 46
 prompt treatment 252, 261, 265

prophylaxis 266
 psychosocial resilience 205, 210
 PWIAS (Peter Wall Institute for Advanced
 Studies) 7, 201

Q

quantitative indices 226
 questionnaires 227

R

rap 315, 324, 325
 rapid diagnostic testing 188, 217, 250-254,
 264, 265, 270, 271, 273-275, 278-288
 upscaling of rapid diagnostic testing 287
 register-based national information
 systems 26
 reproductive education 42
 research 1, 7, 10, 12, 15, 18, 24, 25, 27, 37,
 43, 45, 51, 67, 103, 107, 109, 112, 115,
 123, 127, 130, 132, 139, 140, 143, 146,
 149, 157, 161, 164, 167-169, 171, 178,
 185, 192, 195, 203, 216, 224, 230, 231,
 233, 238, 240, 242, 247, 258, 262, 264,
 272, 273, 288, 289, 291, 297
 resilience 204, 205, 209, 210, 214, 221, 224
 retinopathy 149, 238, 245, 258
 retinopathy of prematurity 237, 238, 245
 Royal Horticultural Society Taskforce
 report 224
 Rwanda 36, 112, 113, 206, 239

S

Saving Brain initiatives 42
 school
 central role of teachers and learners 219
 school-based health promotion 204, 208,
 214, 230, 255, 307, 310
 school-based programmes 12, 48, 192,
 205, 221, 222, 230, 248, 256
 school food gardens 213
 school gardening 195
 Scotland 207, 214, 230
 scurvy 53

sedentary lifestyle 129
 self-efficacy 45, 49
 self-esteem 204, 205, 209, 224
 self-report 227
 Senegal 111, 274, 285, 287
 sex workers 119
 skill development 195
 skin-to-skin care 13
 social and emotional development 319
 social justice 37
 socio-environmental cues 24
 Somalia 52
 South Africa 1, 7, 10, 11, 15, 18, 21, 25, 37, 48, 51, 67, 103, 127, 133, 143, 156, 161, 185, 203, 206, 207, 233, 237-239, 247, 319
 South Sudan 52
 Sri Lanka 256, 258, 266
 Stellenbosch
 international colloquium in Stellenbosch 206
 Stellenbosch consensus statement on the Health-Promoting School model 214
 stress 11, 40, 53, 59, 80, 111, 116, 134, 136, 139, 140, 173
 stroke 9, 91, 173
 stunting 10, 53, 63, 67, 105, 223
 stunting of growth 67
 subsistence farming 52
 sweet potato 196, 197, 199
 Sudden Infant Death Syndrome 100
 sustainable
 sustainable agriculture 39, 44, 195
 sustainable cities 292
 sustainable development 37
 Sustainable Development Goals 8, 11, 12, 37-42, 44, 46-50, 198, 199
 Sweden 10, 25, 26

T

Tanzania 48, 113, 129, 217, 239, 242, 243, 252, 253, 277, 278, 285
 targeted advocacy 13
 target population 186, 217, 300, 308, 310

teacher-driven rapid diagnostic testing 278, 280
 technological innovation 204
 test and treat 280, 281
 Thailand 201, 257, 329
 thin-fat phenotype 174
 thrifty phenotype hypothesis 133
 tobacco smoking 47
 trachoma 233, 236, 237, 241, 272
 transgenerational inheritance 26, 138
 transgenerational transmission of risk 149
 tuberculosis 53, 131, 221, 297
 twins 3

U

Uganda 10, 48, 114, 127, 188, 206, 212, 217-219, 222, 223, 227, 250-253, 256, 257, 260, 261, 268, 269, 274-276, 278, 281, 282, 284, 285, 288, 289, 307, 310, 313, 314, 317, 322, 324-326
 uncorrected refractive error 233-236, 243, 245
 UNICEF (United Nations Children's Fund) 30, 31, 84, 105, 106, 111, 113, 120, 121, 133, 324
 United Nations
 Sustainable Development Goals 12, 30, 84, 105, 133, 187, 207, 324
 United Nations goals for non-communicable diseases 159
 United States of America 27, 44, 57, 103, 112, 137, 225
 University of the Witwatersrand
 MRC Developmental Pathways for Health Research Unit 12
 urban
 urban poor 107, 122, 295, 298
 urban slums 104, 125
 urban transition 17, 294
 urbanisation 52, 129, 130, 134, 172, 292, 294-298

V

vector control 221, 262, 263, 265

video 187, 191, 227, 313-315, 317, 318, 320-322
 video interview 227
 VISION 2020: The Right to Sight 235
 Vision Technicians 234, 241-245
 visual deprivation 236
 vitamin A deficiency 197, 199
 vitamin B12 89, 171, 174, 182
 vitamin D 171, 182

W

water 4, 39, 43, 52, 55, 71, 108, 193, 213, 214, 231, 241, 261, 292, 295, 296
 water and sanitation 39, 43, 213
 WHO (World Health Organization) 9-13, 16, 18, 23, 38, 42-45, 48, 53, 84, 90, 94, 95, 104-109, 112, 113, 120-123, 127, 129, 133, 134, 147, 152-156, 162, 164-167, 203, 187, 192-194, 197-200, 204-206, 208-213, 217, 220-223, 226-230, 232, 235, 238, 241, 248, 249, 251-257, 260-262, 264-267, 271-273, 275, 277, 279, 283, 287, 288, 295, 296, 301
 Health-Promoting School model 13, 203, 248
 Health-Promoting Schools 187
 WHO child growth standards 222, 223
 WHO criteria 155, 156, 264
 WHO-recommended diagnosis and therapy 252
 WHO's definition 155
 World Health Organization guidelines 162
 witchcraft 119
 women 58, 91, 95-97, 111, 168, 169, 176, 230, 319, 320, 327
 educated women 230
 women and girls 39, 43, 192
 workshops 228
 World Bank 30, 105, 196, 208, 236, 245
 worms 193

Y

Yemen 52
 young scientists 13
 youth 187, 204, 309, 313, 325
 YouTube 311, 312

Z

Zimbabwe 272

