BEHAVIOURAL LIFESTYLE FACTORS, PHYSICAL HEALTH-RELATED FITNESS AND CARDIOMETABOLIC DISEASE RISK IN WOMEN FROM A LOW SOCIO-ECONOMIC URBAN COMMUNITY IN STELLENBOSCH (WESTERN CAPE)

By Kasha Elizabeth Dickie

Dissertation presented for the degree of Doctor of Philosophy (Sport Science) in the Faculty of Medicine and Health Sciences at Stellenbosch University

Supervisor: Prof Elmarie Terblanche
Faculty of Medicine and Health Sciences

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Declaration

By submitting this dissertation electronically, I declare that the entirety of the work presented herein is my own original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe on any third-party rights and, that I have not previously in its entirety or in part submitted it for obtaining any qualification.

Ms Kasha Elizabeth Dickie

March 2020

Dedication

To the women of our rainbow nation and, to the special few whom I had the privilege of meeting while working on this research project. In keeping with our shared message which as a collective we sang and danced to:

"Break out of your shell and,
let the world know that you are coming out
- A healthier more powerful and
fitter version of the woman you were born to be!"

Student's contribution to the work presented in this Doctoral Dissertation

Under the leadership of my supervisor and principal investigator Prof Elmarie Terblanche, I was involved in the conceptualisation of the larger research project entitled: "*Relationships between lifestyle factors, cardiometabolic health, cognitive functioning and cardiorespiratory fitness in South African women from a low socio-economic community*". I played an active role in developing the research protocol with specific attention drawn to body composition, physical activity and sedentary behaviour measurement instruments selected and, presented herein.

Following this initial planning phase, I assisted with the formulation and submission of the larger research project protocol to the Human Research (Humanities) Ethics Committee of Stellenbosch University for ethical approval.

On receiving ethical approval in May 2017 (Appendix A), my actions and main responsibilities included the upskilling of a community champion to assist with participant recruitment, my own participant recruitment, the retrieval of informed consent and screening of participants, and the collection of data. I also took it upon myself to formulate a standardised testing schedule, given the requirement of two separate testing occasions for each participant, as well as the compilation of a monthly financial statement in line with the approved research project budget (Appendix B) and expenses incurred (Appendix C).

To conclude, I was directly involved in the management and quality control of all the data attained, as well as actively involved in formulating and providing the study participants with individualised feedback in the form of a written and confidential document.

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Dr Carla Coetsee, Ms Louise Engelbrecht and Dr Zarko Krkeljas

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Ms Kasha Dickie and Ms Sharné Nieuwoudt

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Abstract

Non-communicable diseases (NCDs), such as cardiovascular disease (CVD) and type 2 diabetes mellitus (T2DM), represent an ever-rising threat to the effective management of national health in South Africa. This especially among low versus high socio-economic urban communities as evidenced almost a decade ago. The results of which are likely to lead to an even higher demand for chronic public health care provision, and thus put immediate economic strain on the imminent South African (SA) National Health Insurance fund soon to be launched in 2026. However, one could argue that the evidence needed to reformulate the existing SA health policies, especially those directed at NCD-risk management and inclusive of modifiable behavioural/lifestyle factors, is either: i) not implemented and no action is taken; or ii) implemented, yet ineffective; or iii) limited and thus unable to detect a clinically significant effect to date.

Thus, the primary aim of this study was to characterise behavioural/lifestyle factors namely physical activity (PA) and sedentary behaviour, as well as physical health-related fitness and cardiometabolic disease risk profiles for CVD and T2DM in a group of urban women from an under-resourced Western Cape community. In addition, to determine whether physical inactivity, sedentarism and poor health-related fitness levels are important predictors of obesity and other cardiometabolic disease risk outcomes associated with CVD and T2DM.

Fifty-one (N=51) apparently healthy women (42 ± 13 yrs) underwent the following measurements: physical activity (PA) and sedentary time (ST), anthropometric, cardiovascular and physical-health related fitness (cardiorespiratory fitness [CRF] and muscular strength). Results from the study showed that less than a third of the women met the World Health Organisation (WHO) Global Health Recommendations for moderate to vigorous-intensity PA (MVPA) using accelerometry. Although overweight, women who accumulated ≥ 30-min of MVPA per day presented with more favourable body composition and regional body fat measures, compared to those who did not. In addition, women who were sufficiently active presented with reduced cardiometabolic disease risk. Although the associations between PA (intensities and volume) and CRF were not statistically significant, all were positive and showed clinically important associations. Independent of steps/day, higher CRF was associated with women who were younger and with reduced measures of total and central adiposity ($p < 0.001$). Whereas higher physical health-related fitness as opposed to ST and MVPA, was independently associated with reduced cardiometabolic risk but potentially mediated by adiposity.

In an attempt to combat cardiometabolic disease risk for CVD and T2DM among low socio-economic community urban-dwelling women, public health interventions should target domains in which time is already spent physically active. Such as walking briskly for travel- and/or occupational-related activities, while also aiming to increase public awareness of the health-enhancing benefits associated with meeting MVPA recommendations. Furthermore, intervention strategies also aimed at reducing cardiometabolic risk should target physical health-related fitness while also reducing ST especially among women who are already sarcopenic. Although the success of which will only be met once we understand the community's specific barriers to PA and healthy dietary habits.

Opsomming

Nie-oordraagbare siektes (NOS), soos kardiovaskulêre siektes (KVS) en tipe 2 diabetes mellitus (T2DM), verteenwoordig ’n steeds stygende bedreiging vir die effektiewe bestuur van nasionale gesondheid in Suid-Afrika (SA). Dit is veral so in die geval van lae versus hoë sosio-ekonomiese stedelike gemeenskappe, soos wat reeds ongeveer ‘n dekade gelede bevind is. Hierdie resultate gaan heel waarskynlik aanleiding gee tot ’n selfs hoër aanvraag na die voorsiening van kroniese openbare gesondheidsorg wat onmiddellik ekonomiese druk gaan plaas op die nuut voorgestelde Suid-Afrikaanse Nasionale Gesondheidsversekering (NGV) fonds wat in 2026 in werking tree. Daar kan egter geargumenteer word dat die nodige bewyse om die bestaande Suid-Afrikaanse gesondheidsbeleide te herformuleer, veral dié gerig op NOS-risikobestuur en die inklusiwiteit van aanpasbare gedrag-/leefstylfaktore is óf: i) nie geïmplimenteer en geen aksie vind plaas nie; óf ii) geïmplimenteer, maar oneffektief; óf iii) beperk en daarom nie in staat om ’n klinies betekenisvolle effek te bespeur nie.

Gevolglik was die primêre doel van die studie om die gedrag-/leefstylfaktore, naamlik fisieke aktiwiteit (FA) en sedentêre gedrag, asook fisieke gesondheidsverwante fiksheid en die risiko vir kardiometaboliese siekte profiele vir KVS en T2DM in ’n groep stedelike vrouens vanuit ’n voorheen benadeelde Wes-Kaaplandse gemeenskap, te bepaal. Daarmee saam het die studie ten doel gehad om te bepaal of fisieke onaktiwiteit, sedentêre gedrag en swak gesondheidsverwante fiksheidsvlakke belangrike voorspellers van vetsug en ander kardiometaboliese risiko’s wat met KVS en T2DM geassosieer kan word.

Een-en-vyftig (N=51), klaarblyklik gesonde vrouens (42 ± 13 jr) is aan die volgende metings onderwerp: fisieke aktiwiteit (FA) en sedentêre tyd (ST); antropometrie; kardiovaskulêre en fisieke gesondheidsverwante fiksheid (kardiorespiratoriese fiksheid [KRF] en spierkrag). Die resultate, soos bepaal met draagbare versnellingsmeters, het aangedui dat minder as ’n derde van die vroue aan die Wêreld Gesondheidsorganisasie (WGO) se Globale Gesondheidsaanbevelings vir matige tot hoë intensiteit FA (MHFA) voldoen het. Alhoewel oorgewig, het die vroue wat ≥ 30-min MHFA per dag geakkumuleer het, ’n meer gunstige liggaamsamestelling en liggamsvetmates getoon in vergelyking met vroue wat nie aan die vereiste MHFA per dag voldoen het nie. Daarmee saam het vroue wat voldoende aktief was ’n verminderde risiko vir kardiometaboliese siektes getoon. Alhoewel die assosiasies tussen FA (intensiteit en volume) en KRF nie statisties betekenisvol was nie, was almal

positief en het klinies belangrike assosiasies getoon. Uitsluitend die treë per dag, is hoër KRF in jonger vroue met verminderde mates van totale en sentrale adipositeit, geassosieer ($p < 0.001$). Alhoewel hoër fisieke gesondheidsverwante fiksheid, in teenstelling met ST en MHFA, onafhanklik met verminderde kardiometaboliese risiko geassosieer het, kon dit heel moontlik deur adipositeit bemiddel gewees het.

In ’n poging om die risiko vir kardiometaboliese siekte vir KVS en T2DM onder vrouens in ’n lae sosio-ekonomiese stedelike gemeenskap te beveg, moet openbare gesondheidsintervensies domeine teiken waarin tyd reeds spandeer word om fisiek aktief te wees - byvoorbeeld, aktiwiteite soos vinnig stap om by ’n bestemming uit te kom en/of beroepsverwante aktiwiteite. Die doel behoort ook te wees om openbare bewustheid van die gesondheidsvoordele wat gepaard gaan met die bereiking van die MHFA aanbevelings te verhoog. Verder moet intervensiestrategieë gerig op die vermindering van kardiometaboliese risiko’s veral fisieke gesondheidsverwante fiksheid teiken en terselfdertyd ST, veral onder vroue wie alreeds sarkopenies is, verminder. Sukses sal egter net bereik word wanneer gemeenskappe se spesifieke hindernisse tot deelname aan FA en gesonde dieetgewoontes verstaan word.

Acknowledgements

On behalf of my entire research group, we wish to thank the National Research Foundation (NRF) of South Africa for their financial support in making the larger research project and the research outputs contained in this dissertation possible.

Stellenbosch University: Thank you for the financial support in allowing me valuable time away from my teaching commitments to focus solely on my research efforts and dissertation composition.

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Professor Elmarie Terblanche (supervisor and principle investigator): Thank you for all your time, effort and motivational support. You have taught me that perseverance matched with willpower equal "progress and growth" not only in my work but also in my own life - as a whole. Thank you for your constant mentorship and valuable input towards the SUNWELL Community Health Programme as a whole, as well as this, my dissertation. I am not going to stop my chain of red "X" marks.

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To my giants whose shoulders I stand on: You inspire me to never stop learning, reading, writing, and sharing my knowledge with others. My promise to you all is to remain a scholar of life and to pass the skills you have taught me onto others. So that they too can influence the possibilities of tomorrow. I also promise to slow down and question the advancement of knowledge simply defined as a collision of ideas bundled into a homogenous theoretical framework.

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My parents: Thank you for all your love and support. Dad, as a little girl you always said to Tam and I, to use our initiatives. Thus, a considerable part of my passion for research is my recollection of early childhood memories. My desire to identify a problem, putting my initiative to the test (As I remember how you would point to your head while telling us to "give it a go") and finding out the hidden truths I manage to discover in my own unique way. Even if it was the "tuck-in triangular black bag" technique in helping you with Sunday chores in picking up the leaves in the garden… so many a season. Thank you for this and giving me everything I have ever wanted in life, and MORE. Mum, you are an inspiration and have taught me never to give up, even when I heard rumblings of "I will not" or "I cannot". Your success in life is a massive source of inspiration to me. From motherhood, to cancer survivor, to entrepreneur, to half-marathoner - four degrees which qualify you as simply OUTSTANDING! Your love and support fuel me with energy and drive - to live my dreams and, ultimately DO WHAT I LOVE. All of which I am ever so grateful and proud to share with those whose path I cross. To both of you: "You are my super-heroes and you POWER my world!"

List of Abbreviations and Acronyms

% :	Percentage
® :	Registered trademark
= :	Equals
± :	Plus or minus
> :	Greater than
≥ :	Greater than or equal to
< :	Lesser than
≤ :	Lesser than or equal to
ACC :	American College of Cardiology
ACSM :	American College of Sports Medicine
AHA :	American Heart Association
AFM :	Appendicular fat mass
ANCOVA :	Analysis of covariance
ANOVA :	Analysis of variance
Apo A :	Apolipoprotein A1
Apo B :	Apolipoprotein B
β :	Partial correlation coefficient
B :	Parameter estimate
BMI :	Body mass index
BP :	Blood pressure
Bt20 :	Birth to Twenty
CI :	Confidence interval
CCMRS :	Clustered Cardiometabolic Risk Score
cm :	Centimetre

cm^2 :	Centimetres squared
CFM :	Central fat mass
CDC :	Centers for Disease Control and Prevention
CO_2 :	Carbon dioxide
counts·min^{-1} :	Counts per minute
CPET :	Cardiopulmonary Exercise Testing
CVD :	Cardiovascular disease
DBP :	Diastolic blood pressure
DHDSS :	Dikgale Health and Demographic and Surveillance System
DVD :	Digital video disc
DXA :	Dual-energy x-ray absorptiometry
e.g. :	For example
etc. :	Et Cetera
ES :	Cohen's *d* effect size
EWGSOP :	European Working Group on Sarcopenia in Older People
FFM :	Fat-free mass
FFSTM :	Fat-free soft tissue mass
FPG :	Fasting plasma glucose
GoPA :	Global Observatory for Physical Activity
GPAQ :	Global Physical Activity Questionnaire
g·L^{-1} :	Grams per litre
HbA1c :	Glycated haemoglobin
HDL-C :	High-density lipoprotein cholesterol
HIV :	Human immunodeficiency virus
HR :	Heart rate
hr :	Hours

IDF :	International Diabetes Federation
i.e. :	That is
ISAK :	International Society for the Advancement of Kinanthropometry
IQR :	Interquartile range
kCal/day :	Kilocalories per day
kg :	Kilogram
kg/m^2 :	Kilogram per metres squared
$kg \cdot m^2$:	Kilogram per metres squared
L :	Litres
LDL-C :	Low-density lipoprotein cholesterol
Lp (a) :	Lipoprotein (a)
LPA :	Light-intensity physical activity
METS :	Modeling the Epidemiologic Transition Study
METs :	Metabolic equivalents
MetS :	Metabolic Syndrome
MET/day :	Metabolic equivalent per day
MET-min/week :	Metabolic equivalent minutes per week
min :	Minutes
min/day :	Minutes per day
$min \cdot day^{-1}$:	Minutes per day
min/week :	Minutes per week
MHO :	Metabolically healthy obese
mg/dL :	Milligrams per decilitre
$mg \cdot dL^{-1}$:	Milligrams per decilitre
mL :	Millimetres
$mL \cdot kg^{-1} \cdot min^{-1}$:	Millimetres per kilogram per minute

mm Hg :	Millimetres of mercury
mmol/L :	Millimoles per litre
$mmol \cdot L^{-1}$:	Millimoles per litre
MONW :	Metabolically obese normal weight
MRC :	Medical Research Council
MVPA :	Moderate to vigorous-intensity physical activity
n :	Number
N_2 :	Nitrogen
NCD :	Non-communicable disease
NCDs :	Non-communicable diseases
NCEP ATP III :	National Cholesterol Education Program Adult Treatment Panel III
O_2 :	Oxygen
OPACH :	Objective Physical Activity and Cardiovascular Health
p :	Probability of statistical significance
PA :	Physical activity
PAEE :	Physical Activity Energy Expenditure
PAI :	Physical Activity Index
PURE :	Prospective Urban and Rural Epidemiological
r :	Pearson's product moment correlation coefficient
R^2 :	Coefficient of determination
RQ :	Respiratory Quotient
SA :	South African
SANHANES :	South African National Health and Examination Survey
SBP :	Systolic blood pressure
SD :	Standard deviation
SEE :	Standard error of estimate

sec :	Seconds
SES :	Socio-economic status
steps/day :	Steps per day
steps·day^{-1} :	Steps per day
SSF :	Sum of skinfolds
ST :	Sedentary time
STEPS :	STEPwise approach to chronic disease risk factor surveillance
THUSA :	Transition and Health During Urbanisation of South Africa
T2DM :	Type 2 diabetes mellitus
TC :	Total serum cholesterol
TG :	Trigyceride
USA :	United States of America
WC :	Waist circumference
WHO :	World Health Organization
VAT :	Visceral adipose tissue
VO_{2max} :	Maximal aerobic capacity
VO_{2peak} :	Peak oxygen uptake
vs. :	Versus
yrs :	Years
ZAR :	South African Rand (currency)

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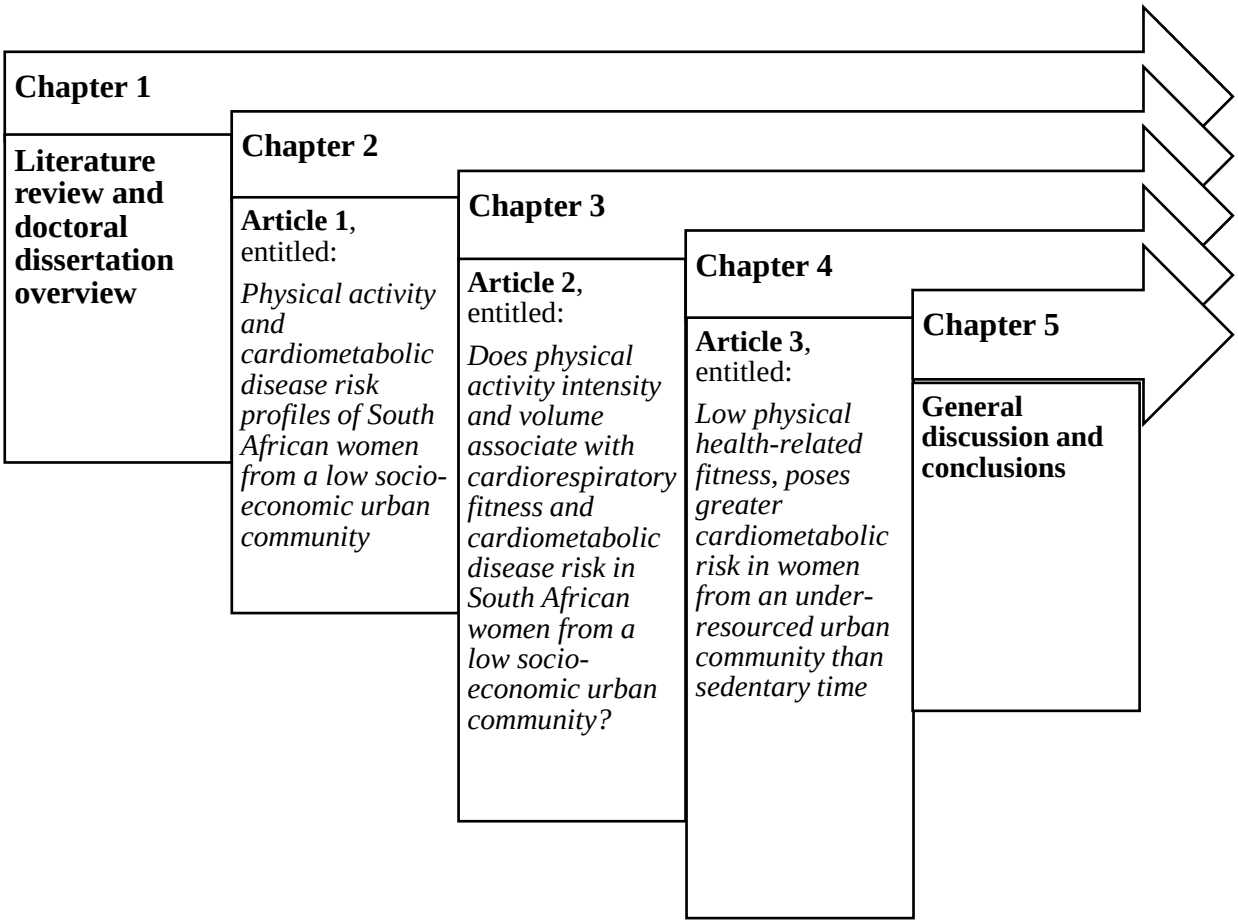
List of Tables

Structure of the Chapters presented in this Doctoral Dissertation

This doctoral dissertation follows the article by publication format, however prior to presenting each article (1, 2 and 3) a review of the literature and overview of the dissertation are provided in chapter 1.



The reference list for chapter's 1 and chapter's 5 are combined, and follow on from chapter 5 which includes the general discussion of the dissertation presented as well as conclusions. Alternatively, the reference lists for chapter's 2, 3, and 4, are separate and appear at the end of each chapter (article) according to the specified journal's referencing requirements.

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CHAPTER ONE

LITERATURE REVIEW:

1.1 Introduction

Non-communicable diseases (NCDs), such as cardiovascular disease (CVD) and diabetes mellitus, represent an ever-rising threat to the effective management of national health in all World Health Organization (WHO) member countries.[1] These countries are categorised according to gross national income per capita estimates and grouped together as either: low-income; lower to middle-income; upper to middle-income and high-income, respectively. South Africa, described as an upper to middle-income country, reported an estimated 44% of total NCD-related mortalities in 2014 alone.[1]CVD constituted the highest accountable cause (18%), compared to diabetes mellitus (6%) which ranked third (Figure 1.1).[1]

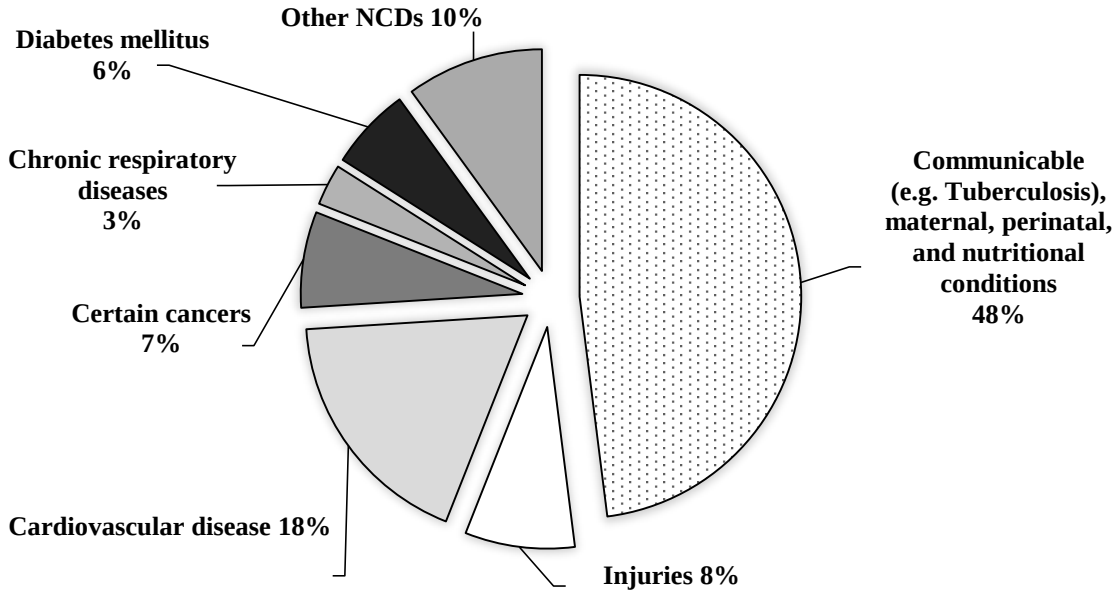

Figure 1.1 All-cause mortality among all South Africans (2014).[1]

A similar survey in 2016 reflects different findings and indicates a rise in mortality attributed to diabetes mellitus leading it to rank second (5.5%) in comparison to Tuberculosis (TB) (6.5%, ranked first) and CVD (5.1%, ranked third).[2] Of major concern to national health authorities was: i) the significantly higher estimate of diabetes mellitus-related mortalities among adult women (62.7%) compared to their male counterparts (37.3%) and ii) the notable increase in estimated NCD-related mortalities for both men and women in comparison to survey findings reported in 2014 (57.4% vs. 44.0%, respectively). Given the above, the aim to reduce the NCD-burden by 28.0% by the year 2030,

as written in the South African (SA) National Development Plan released in 2012, seems highly unattainable under its provisos. However, one could argue that the evidence needed to reformulate the existing SA health policies, especially those directed at NCD-risk management is either: i) not implemented and no action is taken; or ii) implemented, yet ineffective; or iii) limited and thus unable to detect a clinically significant effect to date. Either way, the WHO predicts NCD-related mortality to rise to new and unprecedented proportions, which is particularly alarming given South Africa's NCD-related mortality trend. Considering too the added significance of specific historical research inferences reported by Mayosi et al.[3] almost a decade ago, which have failed to bring about change in the way public health is addressed in South Africa. Notably identified by Mayosi et al.[3] was the steady overall rise in total NCD-burden among urban and rural communities, while at the same time identifying a disproportionate burden of NCDs affecting lower- versus higher-income urban community residents of South Africa. Both findings may in part, be explained by the influence of ongoing and rapid epidemiological transition in South Africa,[4,5] similar to other sub-Saharan African countries. This trend will likely lead to an even higher demand for chronic public health care provision,[3] and thus put immediate economic strain on the imminent SA National Health Insurance [6] fund, which is expected to be launched in 2026.

According to the WHO, any attribute, characteristic or exposure that predisposes an individual to disease or injury, is described as a risk factor.[7] However, unlike exposure to a harmful and transmissible virus (e.g. TB) resulting in communicable disease, NCDs are considered largely preventable. Factors, associated with behaviour or lifestyle, including physical inactivity, a poor diet, tobacco and alcohol use, are modifiable.[7] Arguably, some factors may be non-modifiable owing to aspects related to governance, economics, culture and the environment, and may in part, influence an individual's personal choice to modify his or her behaviour. Figure 1.2 shows that numerous factors have already been identified as key drivers for obesity within a SA setting.[8]

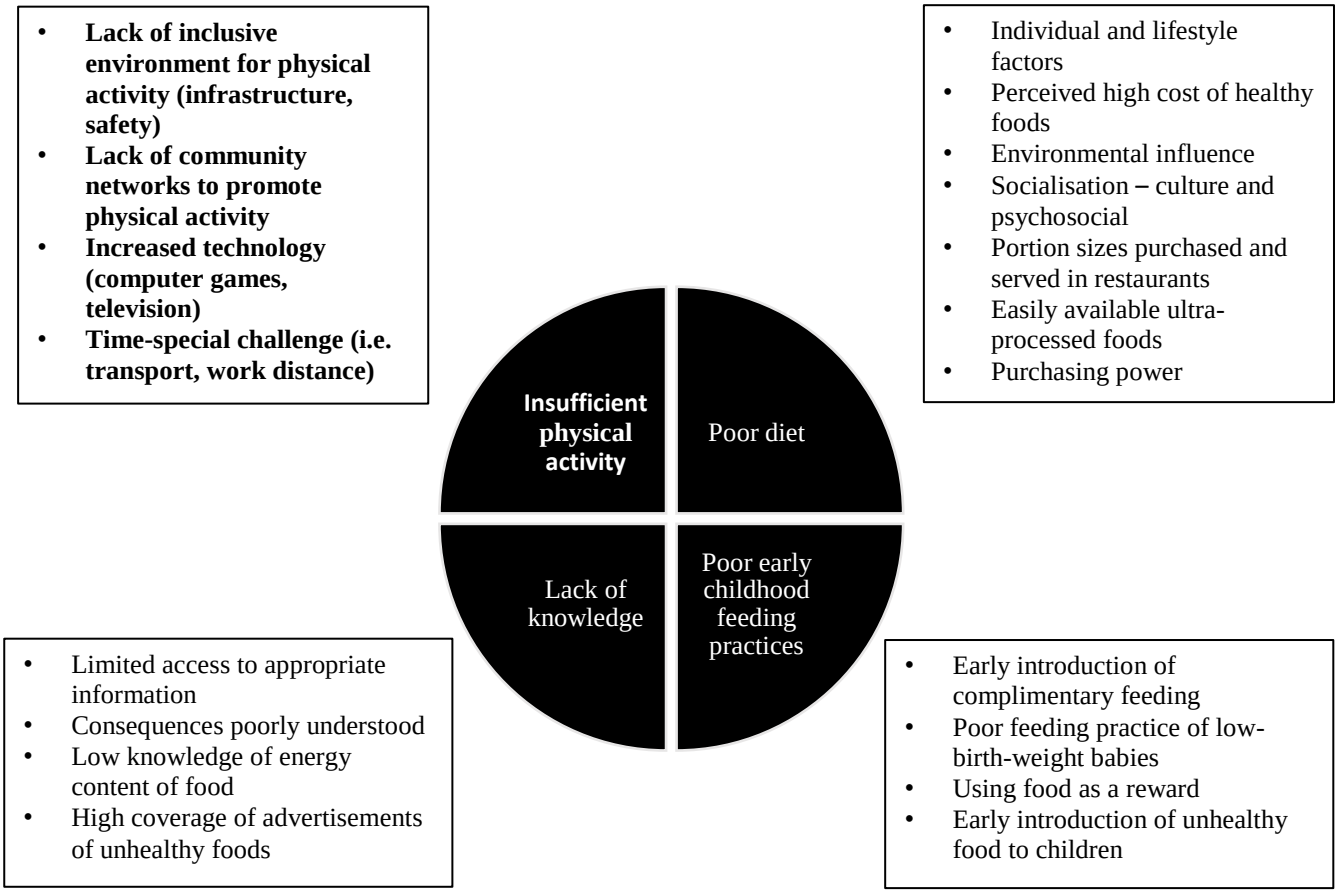

Figure 1.2 Drivers of obesity - a recognisable intermediate NCD risk factor in South Africa.[8]

Other recognisable intermediate NCD-risk factors include hypertension, dyslipidaemia and impaired glucose tolerance (IGT).[7] Alternatively, when clustered together with obesity, these are identified as the metabolic syndrome (MetS), or an indicator of cardiometabolic disease risk for CVD and diabetes mellitus.

To my knowledge, a dissonance exists in the evidence from large- and small-scale published SA studies,[9,10,11,12,13,14] with the majority of adult women shown to be obese (urban-dwellers)[9,11,12,14] and overweight (rural-dwellers),[10,12,13] yet sufficiently active in meeting health-enhancing physical activity (PA) guidelines.[15,16,17] Thus, the extent to which meeting current international PA guidelines, especially among adult women who are already obese or overweight, requires further investigation. In its policy, "*Strategy for the Prevention and Management of Obesity [2015 – 2020]*" the South African government draws upon the WHO 2010 Global Recommendations on PA for Health,[17] to reduce the national obesity problem.[8] The policy also highlights the need to investigate other

international PA recommendations, such as daily step counts, if South Africa is to assess PA and its effect on preventing obesity among its citizens.[18]

Independent of physical activity level, the associated risk of excess weight gain poses an even greater challenge in trying to curb the NCD-burden in South Africa, especially among adult women. Other behavioural/lifestyle factors (e.g. diet[19] or combining diet and exercise[20]) are probably of greater significance in weight loss efforts, bringing with it a relative reduction in obesity-related cardiometabolic disease risk for CVD and specifically type 2 diabetes mellitus (T2DM). Physical health-related fitness and specifically a moderate-to-high cardiorespiratory fitness (CRF) level has been shown to counteract the negative consequences associated with excess adiposity.[21,22] Although acknowledging the influence of diet and exercise on cardiometabolic disease risk, both fall beyond the scope of this descriptive study, which aims to characterise other behavioural/lifestyle factors (e.g. PA and sedentary behaviour) and physical health-related fitness components (e.g. body composition, muscular strength and CRF) as key influences.

In the context of South Africa's historical backdrop, it is important to highlight the references drawn to "racial categorisation" namely: "Black (African)", "White", "Coloured" and "Asian/Indian" reported herein. Although recognised as a non-biological and rather a social construct, racial categories are referenced according to the SA Demographic Health Survey statistics, as well as those reported by numerous small- and large-scale SA studies.[9,10,11,12,13,14] As such, I acknowledge the difficulties and complexities that surround the durability of their continued post-apartheid use. Notably, the use of "Coloured" and proposed alternatives, namely "mixed race" or "mixed ancestry", are all controversial as these terms imply that some people are racially pure when in reality all people are technically of mixed genetic origin. Furthermore, some people within the "Coloured" racial category consider themselves not of mixed race. They identify as being "Khoisan" or the equivalent of "First Nations South Africans", whose identity is said to have been violated by colonial rule.[162] Given these considerations, I have chosen to make use of the terminology currently used in the SA legislative system, namely the "*2019 Codes of Good Practice on Broad Based Black Economic Empowerment,"* which uses the term "Coloured".[163]

The subsequent sections of this literature review will firstly provide a brief overview and discussion of the prevalence of CVD and diabetes mellitus among SA adult women according to racial

categorisation. A more in-depth account follows in which the factors associated with cardiometabolic disease risk are highlighted, and in particular, as seen among "Coloured" SA adult women who have the highest prevalence of severe obesity compared to other SA women racial groupings (e.g. "Black [African]", "White" and "Asian/Indian").

This review also aims to include observational data on the associations between behavioural/lifestyle factors (e.g. PA and sedentary behaviour) and components of physical health-related fitness, with cardiometabolic disease risk. The former, along with the measurement methods are compared to data and methodologies from other sub-Saharan African countries' studies, including non-African low to middle-income and high-income countries, respectively. Lastly, it is important within the context of this study to highlight that, as in the case of diet (e.g. poor dietary practices[23,24,25] and food insecurity[26]) and exercise,[27,28] I also acknowledge the equal importance of genetic influences,[29,30,31] as well as other behavioural/lifestyle (e.g. poor eating practices,[23,24,25] food insecurity[26] and sleep deprivation[32]) and environmental risk factors (e.g. chemical and air pollutants[33]), that contribute towards the prevalence of cardiometabolic disease risk for both CVD and T2DM in adults. However, these factors are beyond the scope of the current doctoral dissertation.

1.2 Prevalence of cardiovascular disease and diabetes mellitus in South African adult women

Data from the first comprehensive National Health and Nutrition Examination Survey (SANHANES-1) (2011 – 2012),[34] show the prevalence of CVD (29.9%) to be higher compared to diabetes mellitus (6.0%) in SA women. Notably, the prevalence of CVD (39.6%) was the highest, and diabetes (8.0%) the second highest, among "Coloured" SA women, as compared to their age-matched "Black (African)", "White", and "Asian/Indian" SA counterparts (Figure 1.3).[34]

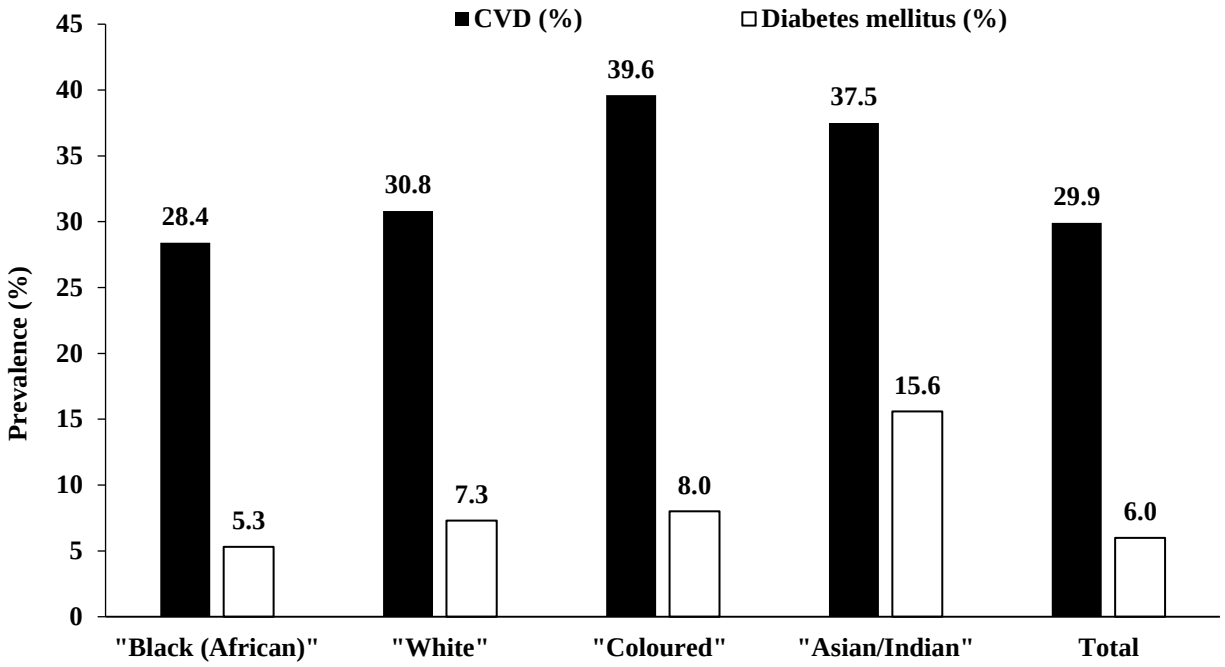

Figure 1.3 Prevalence (%) of cardiovascular disease (CVD) and diabetes mellitus among SA women (aged: 15 to 65+ yrs) and according to racial categories.[34]

In addition, more recent prevalence data from the 2016 SA Demographic Health Survey (SADHS) indicate that 46% of SA women aged ≥ 15 yrs are hypertensive.[35] On observation, only 9% of the women who reported their use of anti-hypertensive medication presented with normal BP.[35] Furthermore, the prevalence of hypertension was shown to increase with age, as well as to differ according to residential setting (urban: 46.5% vs. rural: 43.5%) and racial catergory.[35] In particular, "White" and "Coloured" women had the highest and second highest prevalence of hypertension (60.4% and 57.4%, respectively), compared to "Indian/Asian" and "Black (African)" women (43.8% and 46.4%, respectively).[35]

Similar to these SA inferences, the Centers for Disease Control and Prevention (CDC)[36] raises specific awareness of the importance of including non-behavioural NCD-risk factors, namely ethnicity, when analysing population data trends from the USA. Large historical datasets derived from nationally funded public health organisations, allowed the CDC to highlight the proportional differences in the prevalence of diabetes mellitus among adults from different racial and ethnic backgrounds.[36] Their use of "ethnic background" refers to shared cultural traditions which the "Hispanic (Latino American)" group ascribe to. According to Figure 1.4, the prevalence of diabetes

mellitus is highest among the “American Indian” or “Alaskan Native” group (15.9%), followed by the “African American” group (13.2%), “Hispanic (Latino American)” group (12.8%) and “Asian American” group (9.0%). All of these groups are at higher risk to develop diabetes mellitus compared to the “American (Non-Hispanic) White” group (7.6%).[36]

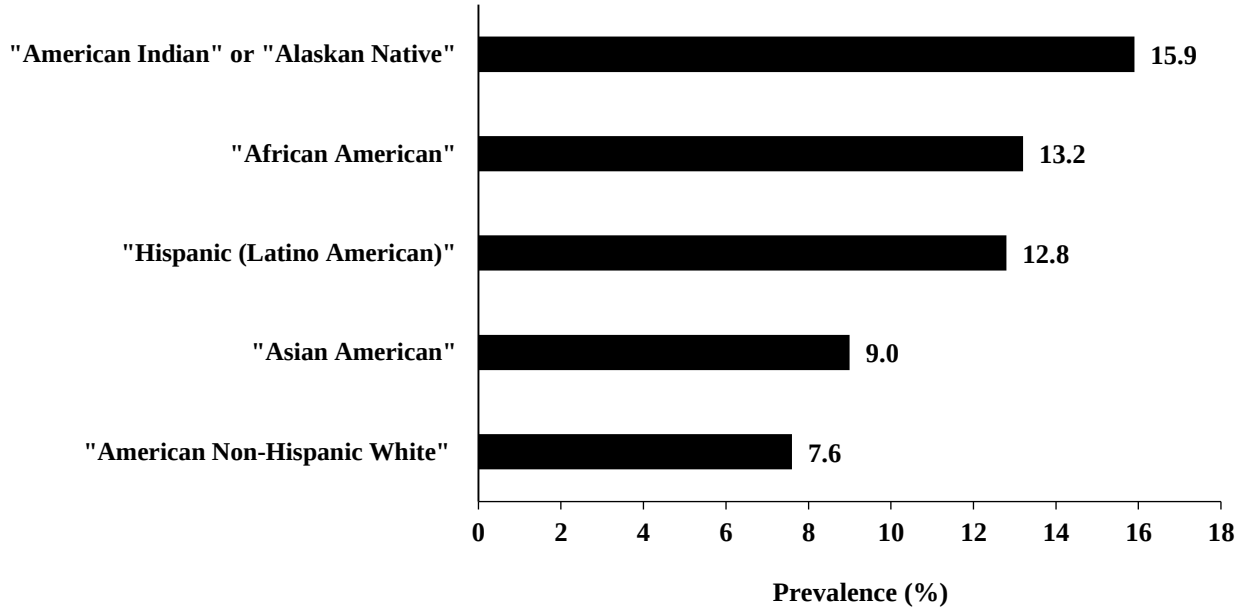

Figure 1.4 The prevalence (%) of diabetes mellitus in USA adults (both sexes and older than 20 yrs) according to race and ethnicity (2010 – 2012).[36]

Given this understanding, the need to explore factors associated with cardiometabolic disease risk for CVD and diabetes mellitus among SA women who are already overweight or obese is needed, and which the subsequent section will aim to discuss.

1.3 Intermediate cardiometabolic disease risk factors associated with cardiovascular disease and diabetes mellitus among South African adult women

A previous African study[37] and numerous SA studies[38,39] help in part, to explain possible reasons underpinning differences in the prevalence of CVD among SA adults. One particular reason being the relatively low prevalence of dyslipidaemia reported among “Black (African descent)” diagnosed CVD-patients compared to their age- and CVD-matched counterparts categorised according to three other racial categories groups in the Heart of Soweto cohort study (Figure 1.5).[40]

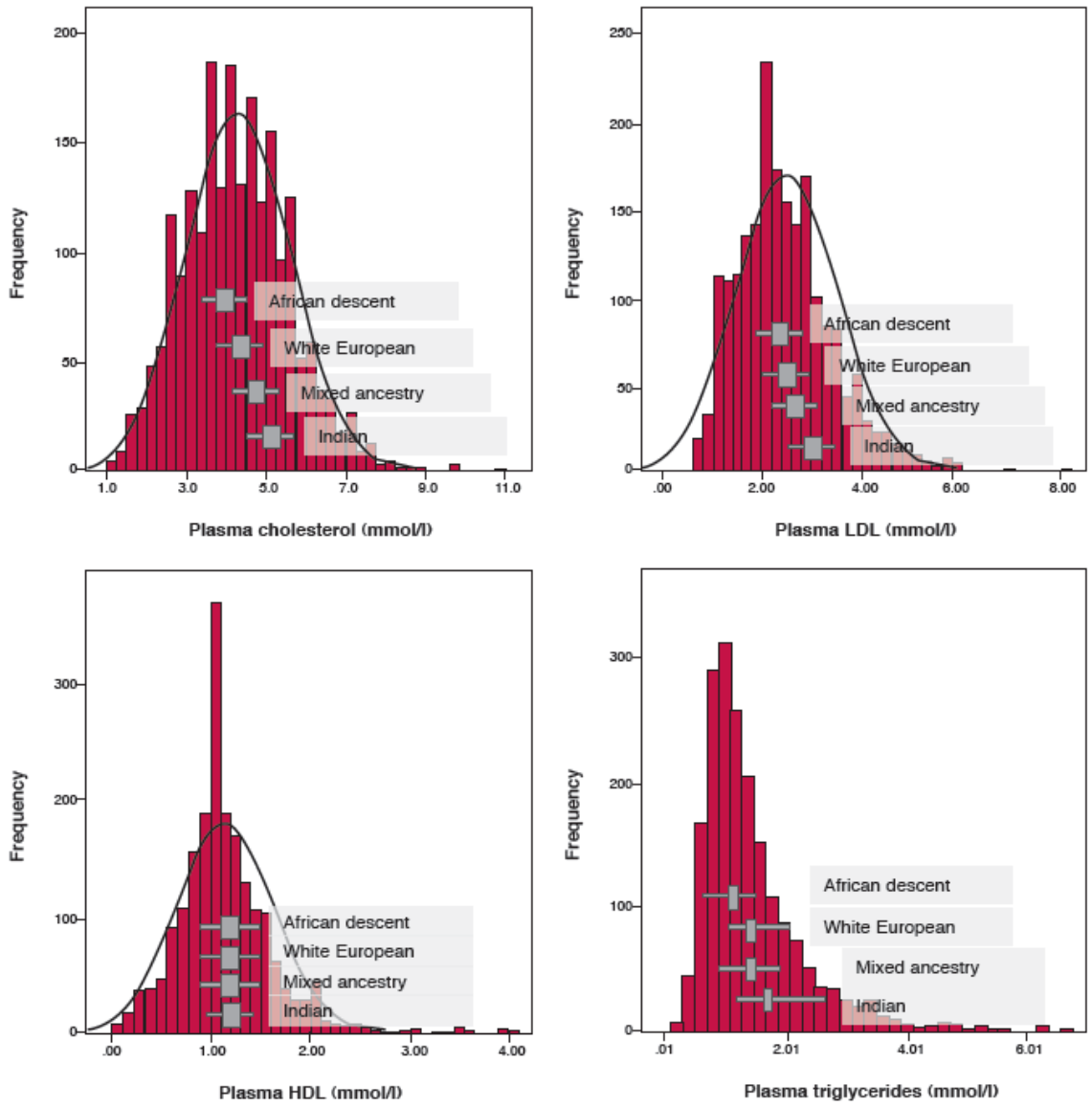

Figure 1.5 Frequency distributions (*n*) of plasma lipid levels among CVD-patients from the Heart of Soweto cohort study (2012).[40]

CVD-patients from the "Black (African descent)" group had the lowest plasma lipid levels (i.e. TC: < 5.0 mmol/L; LDL-C: < 3.0 mmol/L; and TG: < 1.7 mmol/L) compared to all other groups. Thus, contrary to the 1976 "lipid hypothesis" (or "cholesterol theory"), which postulates the link between hyperlipidaemia and CVD (e.g. hypertensive heart failure and coronary artery disease), this study suggests an unlikely causal link due to the relatively low circulating plasma lipid levels found among the "Black (African descent)" group. As suggested by the researchers of the Heart of Soweto cohort study[40] the steady increase in the prevalence of cardiometabolic disease risk for both CVD[37,38] and T2DM,[39] especially among "Black (African descent)" SA women, is most likely explained by other factors (i.e. behavioural/lifestyle and environmental).[40] However, notwithstanding the disparity in

additional CVD-associated risk which behavioural/lifestyle and environmental factors cannot account for in full, the findings also point to the concomitant influence of ongoing epidemiological transition in South Africa.[4,5] All of these factors go hand in hand, as a growing body of evidence highlights the behavioural/lifestyle changes associated with rapid urbanisation, and specifically the decrease in levels of physical activity[9,14,41] and changes in dietary intake.[26,42,43] Both of which have previously been shown to contribute to the significant progression and prevalence of obesity in South Africa, particularly among urban "Black (African)" SA women (2003: 33.8% vs. 2012: 40.9%).[44,34] Although, when comparing the prevalence of overweight and obesity according to BMI, 68.0% of all SA adult women are either overweight or obese compared to only 31.0% of SA adult men (Figure 1.6).[35]

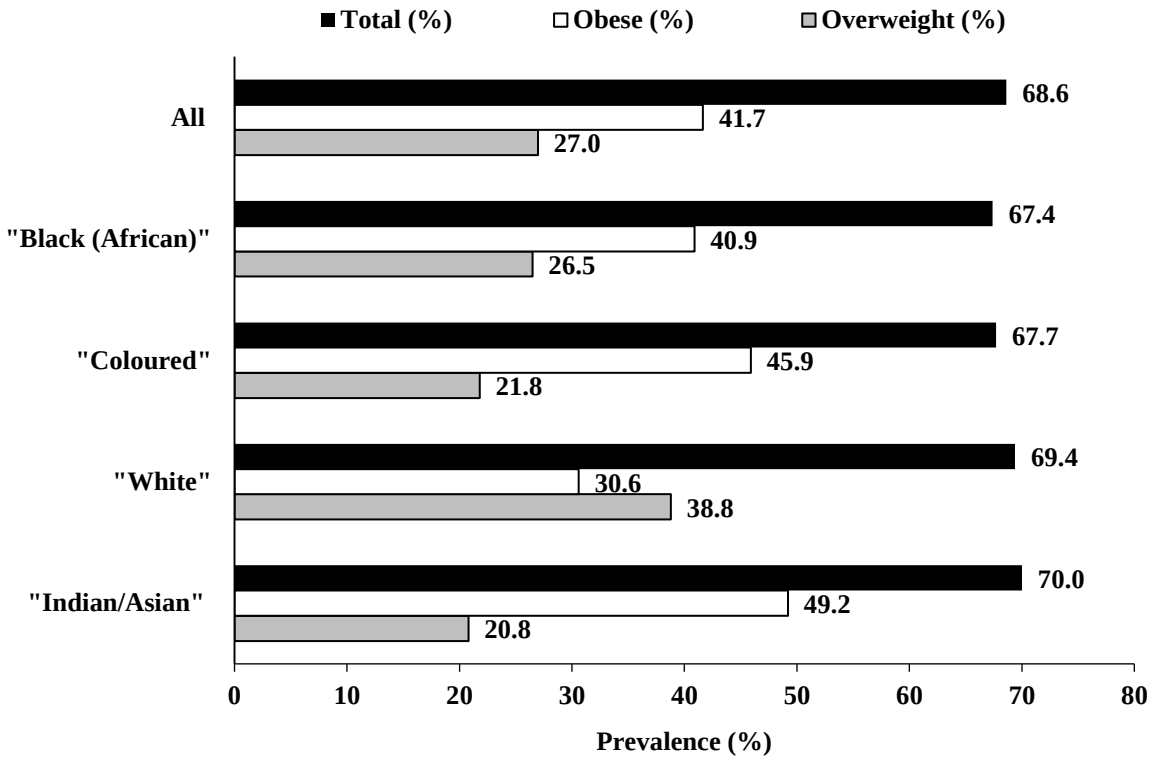

Figure 1.6 Prevalence (%) of overweight and obesity among SA women (n = 4 658, aged: ≥15 yrs).[35]

Of even greater concern is the increased prevalence of SA adult women who are severely obese (BMI: ≥ 35.0 kg/m^2), and thus at greater risk for CVD and T2DM.[35] In 2016 it was reported that one in five adult women were severely obese. Most notably, the highest and second highest ranked proportions were reported among "Coloured" and "Black (African)" women (26.0% and 20.0%, respectively) compared to the lower proportions among "Indian/Asian" and "White" women (18.0% and 15.0%, respectively). The prevalence of obesity among "Coloured" and "Black (African)" women increased

alarmingly between 2003 and 2012 (25.7% vs. 45.9% and 28.5% vs. 40.9%, respectively).[34,35] Some plausible reasons may include changes in socio-economic standing which influences both food security and selection, as well as the influence of the urban living environment. When financial resources are low, evidence suggests that eating healthy, whole foods are limited due to restrictions in choice and access, as opposed to a lack of awareness. Furthermore, the influence of strong aspirations to consume more fast foods is associated with higher socio-economic status and therefore more desirable.[164] The latest SA national survey (2016)[35] specifically highlighted the increasing number of severe obesity among women according to quintiles of wealth, namely, those in the highest quintile have the highest prevalence of severe obesity. These quintiles were derived from a "wealth index" which consisted of household assets, namely: ownership of a television, car, livestock, as well as housing characteristics (e.g. source of drinking water, toilet facilities and flooring materials) (Figure 1.7).[35]

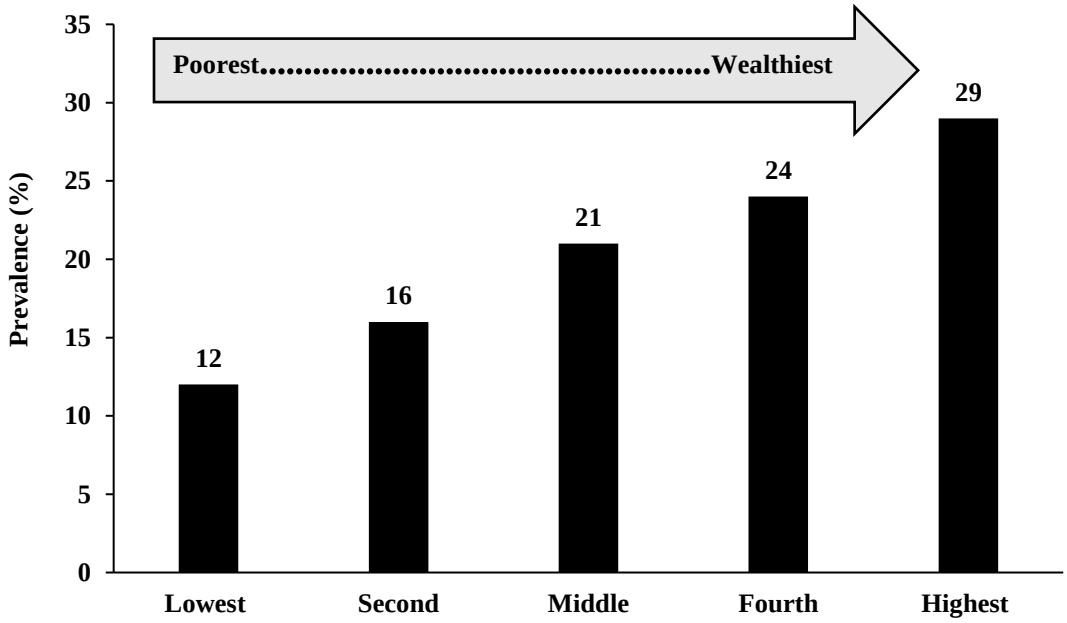

Figure 1.7 Prevalence (%) of severe obesity among SA women (aged: ≥15 yrs) which is shown to increase according to increases in wealth.[35]

The available SA statistics thus correlate with the previously described determinants of obesity, i.e. socio-cultural, behavioural/lifestyle and environmental factors, as well as their inter-relationships as proposed by Micklesfield et al.[45] (Figure 1.8).

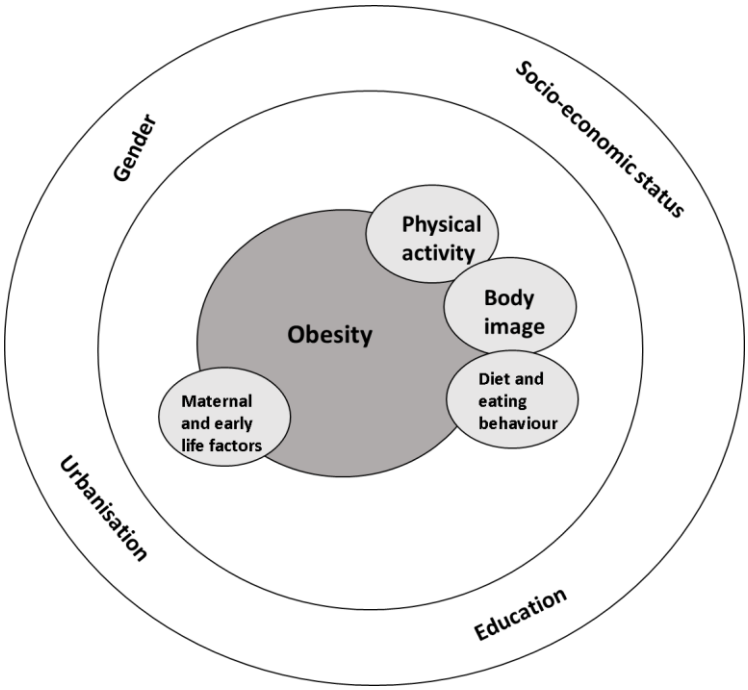

Figure 1.8 A schematic representation of the inter-relationships between socio-cultural, behavioural/lifestyle and environmental determinants of obesity among "Black" sub-Saharan African women.[45]

Although specific to only urban "Black (African)" SA adult women, the study by Micklesfield et al.[45] provides compelling evidence of the links between the increasing prevalence of obesity and urbanisation, economic development and the concomitant behavioural/lifestyle risk factors (e.g. physical inactivity,[46] inadequate dietary practices[23,24,25] and food insecurity,[47] body image linked to a greater body size tolerance[48] and maternal/early life factors).[49] Given these inferences, it is very likely that similar inter-relationships exist among "Coloured" women . However, descriptive studies are required to confirm this and contribute to our understanding of how to create public health interventions that addresses the contributing factors to the health status of "Black (African)" and "Coloured" women.

Peer et al.[50] suggested that the rapid rise in diabetes mellitus prevalence is strongly related to higher levels of adiposity. More than 80.0% of the diabetic urban "Black (African)" participants in their study were overweight or obese (BMI-defined) and had higher measures of central adiposity compared to their non-diabetic counterparts. Similar findings were reported by earlier SA studies,[51,52] namely an atypical presentation of CVD-risk factors among urban "Black (African)" women when compared to age-matched urban "White" women. In particular, the urban "Black (African)" women

had significantly lower levels of visceral adipose tissue area (i.e. a measure of central adiposity) and more favourable lipid profiles compared to the urban "White" women. However, the "Black (African)" women were more insulin resistant compared to the "White" women and thus were at higher risk for developing T2DM.[52]

South Africa's historic political background was characterised by marginalisation and inequalities among minority sub-groups of the population. In particular, during the Apartheid era (1948-1994) certain individuals were classified as "Coloured". In more recent times, De Witt et al.[53] attempted to contextualise this sub-group as those individuals whose ancestry represents "Khoisan" (32.0–43.0%), "Black (African)" (20.0–36.0%), "White" (21.0–28.0%), and "Asian" (9.0–11.0%), and with regards to adult individuals living in urban and rural settings. To my knowledge, descriptive data pertaining to the cardiometabolic disease risk profiles for CVD and T2DM among women, other than "Whites" and "Black (African)" are limited.

Almost a decade ago (2008 – 2009) the cardiometabolic disease risk profiles associated with obesity and T2DM among "Coloured" women (*n* = 454, median age [interquartile range]: 51 yrs [43 – 48])[54] from the Bellville-South urban community in Cape Town (Western Cape Province) were published. The study highlighted the prevalence of T2DM[55] and the MetS according to the three international definitions (i.e. National Cholesterol Education Program Adult Treatment Panel III [NCEP ATP III],[56] International Diabetes Federation [IDF],[57] and the Harmonised Guidelines [58]). Of most significance was the finding of the increasing trend in frequency of undiagnosed T2DM with increasing age (Figure 1.9).[54]

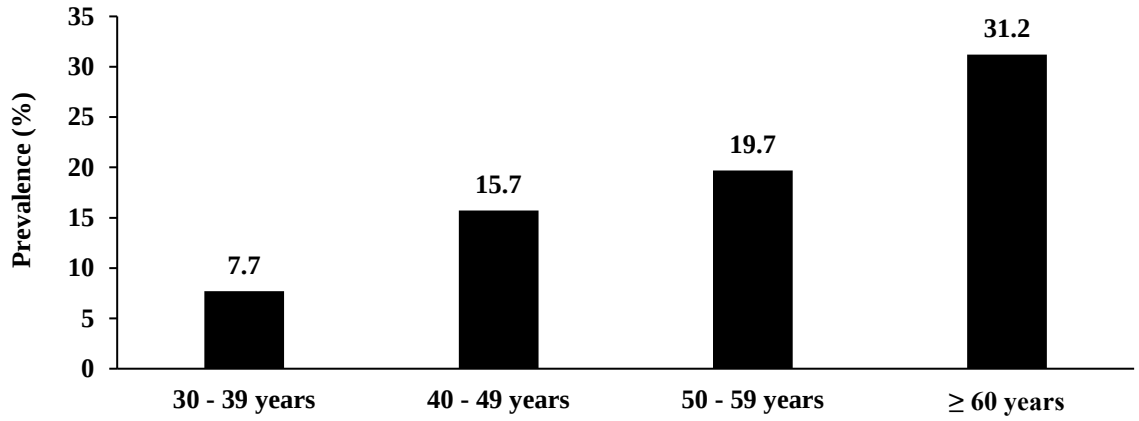

Figure 1.9 Prevalence (%) of undiagnosed T2DM according to age groups among urban "Coloured" women from the Bellville-South community cohort study.[54]

In contrast, those with prediabetes (impaired FPG: ≥ 5.6 – 7.7 mmol/L)[59] showed the opposite frequency trend with increasing age; in other words, a higher prevalence of prediabetes among the younger than the older age groups (Figure 1.10). However, the same frequency trend in prediabetes was not shown when IGT (i.e. 2-hour plasma glucose: 7.8 – 11.0 mmol/L)[59] was used (Figure 1.11).[54]

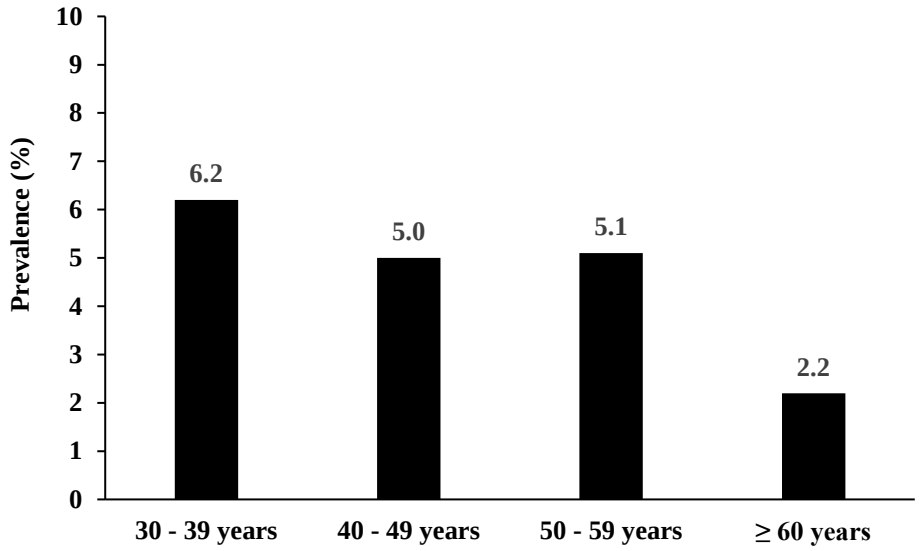

Figure 1.10 Prevalence (%) of impaired fasting plasma glucose (prediabetes) according to age groups among urban "Coloured" women from the Bellville-South community cohort study.[54]

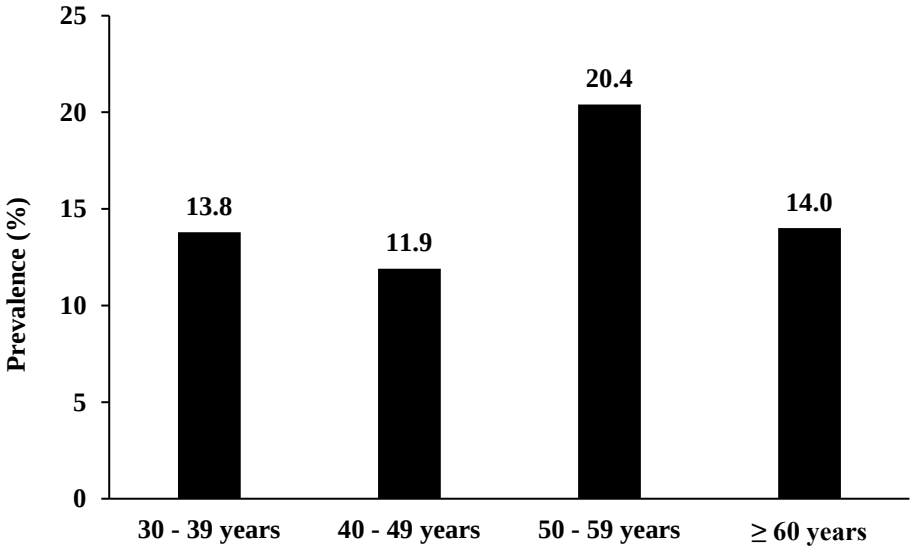

Figure 1.11 Prevalence (%) of impaired glucose tolerance (prediabetes) according to age groups among urban "Coloured" SA women from the Bellville-South community cohort study.[54]

The identification of the MetS according to each set of criteria varied (i.e. NCEP ATP III criteria: 62.2% [*n* = 280][56] vs. IDF criteria: 67.8% [*n* = 305][57] vs. Harmonised Guidelines: 68.4% [*n* = 308][58]).[54] Overall, these results highlight the progressive and age-related trends in undiagnosed T2DM among "Coloured" women living in a urban community setting, as well as the presence of prediabetes, especially among the younger age groups.

More recent cross-sectional findings from the same Bellville-South community cohort provide further insight into the prevalence of obesity (53.7%) and diabetes mellitus (28.6%).[60] The results reflect a combined sample of women and men (73.5% vs. 24.5%) (mean age: 54 yrs),[60] thus, sex-specific differences were neither investigated nor reported. However, in the presence of the MetS (i.e. hypertension, IFG and dyslipidaemia) an equal frequency of cardiometabolic disease risk was shown among normal weight (BMI: 18.5 – 24.9 kg/m^2), overweight, and obese BMI-categories. A total of 31.0% of the sample was characterised as "metabolically healthy obese" (MHO), compared to 29.0% who was "metabolically obese normal weight" [MONW]).[60] The distinct presence of these two different obese phenotypes is of particular interest, as it proposes that cardiometabolic-related abnormalities are not uniform among all obese individuals.

In contrast to the urban setting, age-standardised prevalence data for T2DM and prediabetes among rural "Coloured" communities seems considerably outdated. Results from Mamre, a small village near Cape Town (Western Cape) were reported as far back as 1999[61]. However, it still provides valuable insight into the prevalence of prediabetes (IGT) (10.2%) and T2DM (10.8%) in a non-urban setting and thus, also specific to "Coloured" adults (*n* = 974, age range: 30 – 65 yrs).

Of perhaps most concern are the recent survey results reported among middle-aged (~ 50 yrs), urban SA women already diagnosed with T2DM. The majority were "Coloured" and from a low-income group (i.e. family income: ≤ R4 167/month) and already using pharmacological treatment for T2DM and hypertension.[24] However, on routine follow-up examination at a primary health care district hospital (e.g. False Bay, Cape Town, Western Cape), the majority were shown to be hypertensive (83.4%) (SBP [mean ± SD]: 145.6 ± 21.0 mm Hg) (DBP: 84.5 ± 12.0 mm Hg) and presented with dyslipidaemia (69.5%) (TC: 5.4 ± 1.2 mmol/L).[24] Other intermediate risk factors associated with cardiometabolic disease for CVD and T2DM were also reported. Notably, obesity (BMI: 39.3 ± 7.3 kg/m^2), central obesity (WC: 117 ± 12 cm) and uncontrolled plasma glucose (HbA1c: 9.1 ± 2.0%) stood out.[24] Furthermore, only 14.0% were deemed physically active, while television viewing, reported as a proxy measure of sedentary behaviour, averaged > 2-hours/day. In addition, mean daily intake of fruit and vegetables was considered relatively low (mean: 2.2 portions/day), whereas the consumption of added sugar (mean: 5 teaspoons/day) and sugar-sweetened beverages (mean: 1.3 glasses/day) were relatively high.

Overall, these results demonstrate the high prevalence of T2DM and prediabetes among "Coloured" women from both urban and rural settings. Furthermore, there is an increasing frequency of undiagnosed T2DM and when diagnosed, is shown among women as young as 30 yrs of age. Distinct and different obesity phenotypes (MHO and MONW), specific to urban "Coloured" women were also noted. However, of most concern is the high prevalence of T2DM, as well as measurable cardiometabolic disease risk for CVD, among "Coloured" obese women who are already receiving pharmacological treatment and actively seeking medical advice from the public health sector. Thus, knowledge pertaining to behavioural/lifestyle factors (e.g. PA and sedentary behaviour) as well as physical health-related fitness, and each of their associations with obesity and cardiometabolic disease risk outcomes for CVD and T2DM, requires urgent investigation. This especially among urban "Coloured" women, who are already at risk for severe obesity.[35]

Prior to presenting a summary of evidence detailing the associations between PA (Table 1.1) and sedentary behaviour (Table 1.2), with cardiometabolic disease risk outcomes for CVD and T2DM among SA women, the definitions and methodologies used to measure both will be presented.

1.4 Behavioural/lifestyle factors

1.4.1 Definitions: physical activity and sedentary behaviour

According to Caspersen et al.[62] physical activity (PA) refers to any bodily movement produced by skeletal muscle contraction, resulting in a sizeable increase in energy requirements over resting energy expenditure. It is important to note that PA is not the same as "exercise". Simply stated, "exercise" is a sub-type of PA and described as planned, structured, and repetitive bodily movements executed to either improve or maintain various physical fitness components (Figure 1.12). [62]

Figure 1.12 The term "physical activity" represents the full continuum of bodily movement, with "exercise" being a sub-type representing the higher end of this continuum.[62]

Prominent organisations such as the American College of Sports Medicine (ACSM) in collaboration with the CDC,[63] as well as the USA Surgeon General,[64] and the National Institutes of Health (including the AHA) published seminal articles highlighting the health-associated benefits of PA. Findings had already been published as far back as the 1950's by Morris et al.[65] and the 1970's by Paffenbarger et al.[66] These publications were integral to the research that followed, with the primary objectives to: i) clarify how much PA was enough to derive health-associated benefits; and ii) determine what intensity was required to improve an individual's overall health status. Thus, the overall aim was to determine what PA recommendations must be made to the public which would result in lowering an individual's susceptibility of disease morbidity.

In unison with the ongoing development of the evidenced-based US PA recommendations, the 57th World Health Assembly (WHA) in 2004, under the auspices of the WHO, endorsed the "*Global Strategy on Diet, PA, and Health resolution (WHA57.17)*".[67] Thus, calling to action the need for all member states to develop a national PA action plan, along with supporting policies. For example: i) to introduce transport policies that promote active and safe methods of travelling to and from schools and workplaces, such as walking or cycling; and ii) to ensure that physical environments support safe active commuting, and create space for recreational activity. It was anticipated that these measures would increase the PA levels of member country citizens.[67] During the 61st WHA in 2008 the resolution (WHA61.14) entitled: "*Prevention and Control of NCDs: Implementation of the Global Strategy and the Action Plan for the Global Strategy for the Prevention and Control of NCDs*" was endorsed.

Although somewhat similar to the individual-specific PA recommendations advocated by the USA, the WHO released their own Global Recommendations on Physical Activity for Health in 2010.[17] Similar to the 2008 PA Guidelines for Americans, the dose-response relationship between PA and health-derived benefits was taken into consideration and included in the recommendations (e.g. frequency, duration, intensity, type and total amount of PA). The WHO Global PA Recommendations for Health advocate the following: recreational or leisure-time PA, transportation (e.g. walking or cycling), occupational (i.e. work), household chores, play, games, sports or planned exercise, in the context of daily, family, and community activities should be performed. In order to improve cardiorespiratory and muscular fitness, bone health and reduce the risk of NCDs and depression the following are recommended: i) adults aged 18 – 64 yrs should do ≥ 150 minutes of moderate-intensity aerobic PA, or activity throughout the week, or do ≥ 75 minutes of vigorous-intensity aerobic PA throughout the week, or an equivalent combination of MVPA; ii) aerobic activity should be performed in bouts of ≥ 10 minutes duration; iii) for additional health benefits, adults should increase their moderate intensity aerobic PA to 300 min/week, or engage in 150 min/week of vigorous intensity aerobic PA, or an equivalent combination of MVPA; and iv) muscle-strengthening activities should be done involving major muscle groups on ≥ 2 days per week.[17] Ongoing investigations of PA level using the Global PA Questionnaire (GPAQ), which forms part of the WHO Stepwise approach to chronic disease risk factor surveillance (STEPS), continues.[68] Its use allows for domain-specific PA data specified in the WHA57.17 (i.e. work, transport and leisure time).

Another form of PA and health-related recommendations includes the prescription of daily step counts (steps per day [steps/day]) using commercially available step counters (e.g. pedometers and accelerometers). The well-publicised ≥ 10 000 steps/day guideline, which seems to be globally accepted by various media and commercial entities, originates from several professional organisations and/or government agencies from various high-income groups (i.e. USA, Northern Ireland, United Kingdom, Japan, and Australia). As far back as 2004, Tudor-Locke and Bassett proposed preliminary pedometer-determined PA cut-points for healthy adults based on a large body of previously published literature. The following categories were created: i) sedentary (< 5 000 steps/day); ii) low active (5 000 – 7 499 steps/day); iii) somewhat active (7 500 – 9 999 steps/day); iv) active (≥ 10 000 – 12 499 steps/day); and v) highly active (≥ 12 500 steps/day).[69] Although it was only in 2011, with the use of sufficient and credible scientific evidence, that the same research group created a "steps/day" version of the MVPA guidelines.[18] Thus, the need to take more steps, over and above those taken in the course of habitual and incidental daily activities; and that these additional steps be taken in bouts of ≥ 10 minutes in duration, were specified.[18] At the same time other studies

emphasised the importance of intensity-based steps in line with the MVPA guidelines and thus recommended the number of steps per minute of ambulation (i.e. step rate or cadence).[70,71] As an example, 30-minutes of moderate to vigorous-intensity walking was shown to range between 3 100 and 4 000 steps even after differences in BMI and stride length were considered. In support of these preliminary findings, are more recent inferences made by Tudor-Locke et al.[72] following a larger meta-analysis examining the relationship between the rate of steps taken and intensity level. They reported that a step rate or ambulatory cadence value of ≥ 100 steps/min in adults is indicative of moderate-intensity PA.[72] Overall, the association between the volume of daily step counts and average step rate, needs to be examined especially among populations from lower to middle-income countries, where evidence suggests that the majority of daily PA is acquired for travel-related purposes (e.g. walking).[73,74]

Despite the numerous PA guidelines/recommendations that have evolved over the past few decades, those which currently exist, as well as the increased awareness and understanding of the health-associated benefits in leading a physically active lifestyle, "physical inactivity" continues to raise concern across the globe. This deduction follows the reported and published findings from the Lancet Physical Activity Series Working Group released in 2012. One article in particular highlighted "physical inactivity" to be one of the four leading four contributors to premature mortality.[75] Simply described, "physical inactivity" refers to individuals who perform insufficient amounts of MVPA,[76] or equally stated, those who do not meet the WHO Global Recommendations on Physical Activity for Health for adults (18 – 64 yrs).[17]

Sedentary behaviour refers to any waking behaviour while in a seated, reclined or lying posture and is characterised by an energy expenditure ≤ 1.5 metabolic equivalents (METs).[76,77] Thus, it is considered the lowest in energy expenditure when compared to PA and its continuum of increasing intensities (i.e. light intensity PA [> 1.5 – 2.9 METs], moderate-intensity [3.0 – 5.9 METs], and vigorous-intensity [≥ 6.0 METs]) (Figure 1.13).[17,77] Notably so, sedentary behaviour should not be confused, nor used reciprocally, with "physical inactivity".

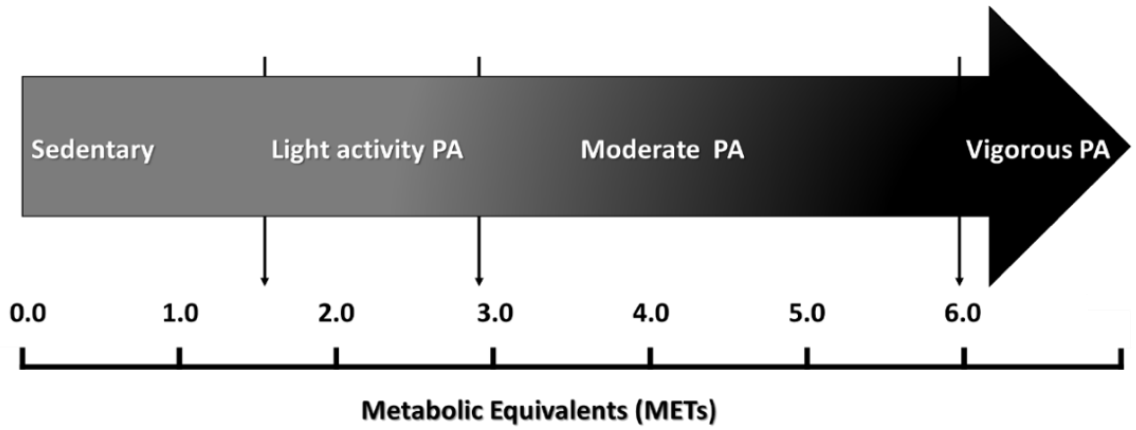

Figure 1.13 The "Energy Expenditure Continuum".[77]

1.4.2 Measurement methodologies: physical activity and sedentary behaviour

Given the complex and multi-dimensional nature of PA, it is considered a challenging entity to assess.[86] The same inference can be made when characterising and/or measuring sedentary behaviour. Thanks to numerous technological advancements a wide spectrum of measurement methodologies are used to quantify total energy expenditure. Some of these are illustrated by Ekelund (unpublished) (Figure 1.15). A clear inverse relationship exists between degrees of accuracy (precision), cost and ease of assessment.

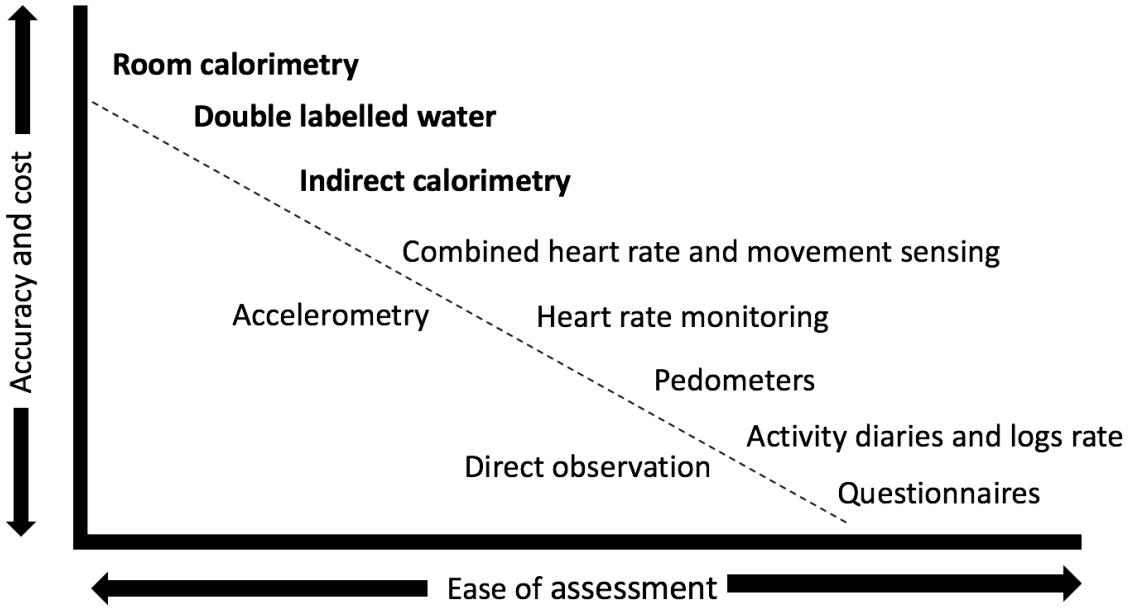

Figure 1.15 Measures of total energy expenditure (physical activity and sedentary behaviour) according to degrees of accuracy, cost and ease of assessment (Ekelund, unpublished).

In terms of PA, the criterion method used is that of whole-room direct calorimetry, which quantifies total energy expenditure (TEE) according to kilocalories per day (kCal/day). Conversely, indirect calorimetry (e.g. metabolic cart, or mobile calorimeter) allows for an estimation of TEE and physical activity-related energy expenditure (PAEE). The disadvantage of these highly sophisticated methods is that they are expensive and testing is time-consuming. Thus, objective monitoring devices (e.g. combined heart rate and movement sensing, accelerometers, and pedometers), as well as subjective/self-report instruments (e.g. questionnaires or PA diaries) offer easy alternatives. All of these methods can also be used to predict TEE and PAEE, although with varying degrees of validity and reliability.

Given the cost and time implications, opportunities to use both objective monitoring devices (e.g. accelerometers), as well as subjective questionnaires (e.g. GPAQ[87] or Sedentary Behaviour Questionnaire [SBQ][88]) are beneficial, especially when trying to capture PAEE in free-living conditions (i.e. non-laboratory settings). For example, hip-worn accelerometers (e.g. Triaxial ActiGraph GT3X) holds a motion sensor that is able to record the frequency and amplitude of accelerations of motion (i.e. counts per minute [counts/min]). Using predetermined cut-points,[89, 90, 91] one is able to quantify activity intensity levels. The cut-points derived by Freedson et al.[88] and used

in a previous SA study,[92] define and divide PA into 4 sub-categories, namely: light-intensity (100 - 1951 counts/min), moderate-intensity (1952 - 5724 counts/min), vigorous-intensity (5725 - 9498 counts/min) and very vigorous-intensity (≥ 9499 counts/min). An added benefit of using accelerometry includes the capturing of low motion counts (< 100 counts/min), i.e. sedentary behaviour. Although this definition by Freedson et al.[89] is consistent with that by Troiano et al.[91] the higher intensity cut-points are different (e.g. light-intensity Freedson[89]: 100 - 1952 counts/min vs. Troiano[91]: 100 - 2019 counts/min). Comparison of accelerometer-derived data across different studies should therefore be done with caution.

The GPAQ, which forms part of the WHO Stepwise approach to chronic disease risk factor surveillance (STEPS),[87] has been validated[68] in numerous countries and thus makes the data captured easily comparable. Another advantage includes the description of domain-specific PA time (e.g. work, travel and leisure time, respectively), which allows for PA behavioural patterns to be described. Similarly, the SBQ[88] can be used to assess time spent seated and involved in one of nine different sedentary behaviours (e.g. watching television, playing computer/video games, sitting while listening to music, sitting and talking on the phone, doing paperwork or office work, sitting and reading, playing a musical instrument, doing arts and crafts, sitting and driving/riding in a car, bus, or train). Thus, like the GPAQ, the use of the SBQ enables the capturing of behavioural time and help to determine patterns of "sedentarism" reported on a typical weekday and weekend day. The major disadvantage of these methods is that one relies on the honest and thorough self-report of individuals.

1.4.3 Physical activity among South African adult women: levels and patterns

National PA prevalence estimates, reported in 2003, indicate a relatively low proportion of adult women to have met the recommended PA level (14%).[44] The GPAQ data showed that leisure-time PA (54%) was highest among all women (15-65yrs), compared to work- (18%) and travel-domain (28%) PA time. On the other hand, PA prevalence revealed that only 12% urban women were sufficiently active, compared to 17% rural women. Furthermore, patterns of PA differed between the two groups with urban women having reported more leisure-domain PA time (57% vs. 50%) and less work- (17% vs. 20%) and travel-domain PA time (26% vs. 30%) compared to their rural counterparts.

When comparing PA level across the different population (racial) sub-groups, "Coloured" women were the least sufficiently active (8.4%), with 91.6% not meeting the minimum PA level associated with health-enhancing benefits (i.e. minimally active: 25.6% and physically inactive: 66.0%) compared to their other ethnic counterparts (Figure 1.16).

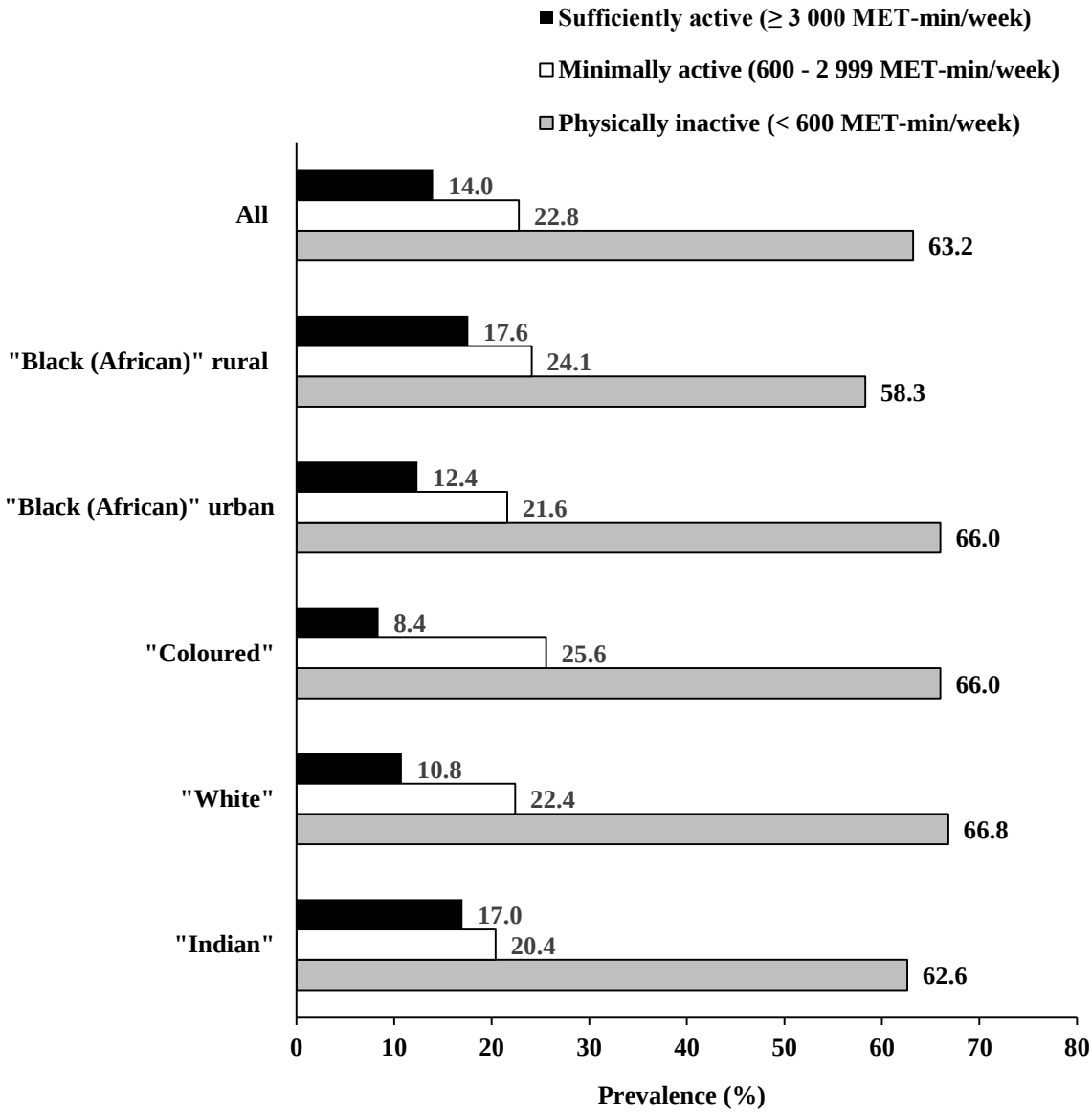

Figure 1.16 Prevalence (%) of physical activity in a representative sample of SA women according to population (racial) sub-group from the SADHS (2003).[44]

The majority of "Coloured" women reported more leisure-domain (46%) and less work- (27%) and travel-domain (27%) PA time, respectively. Thus, domain-specific PA patterns were reported by women from all population [racial] sub-groups (Figure 1.17).

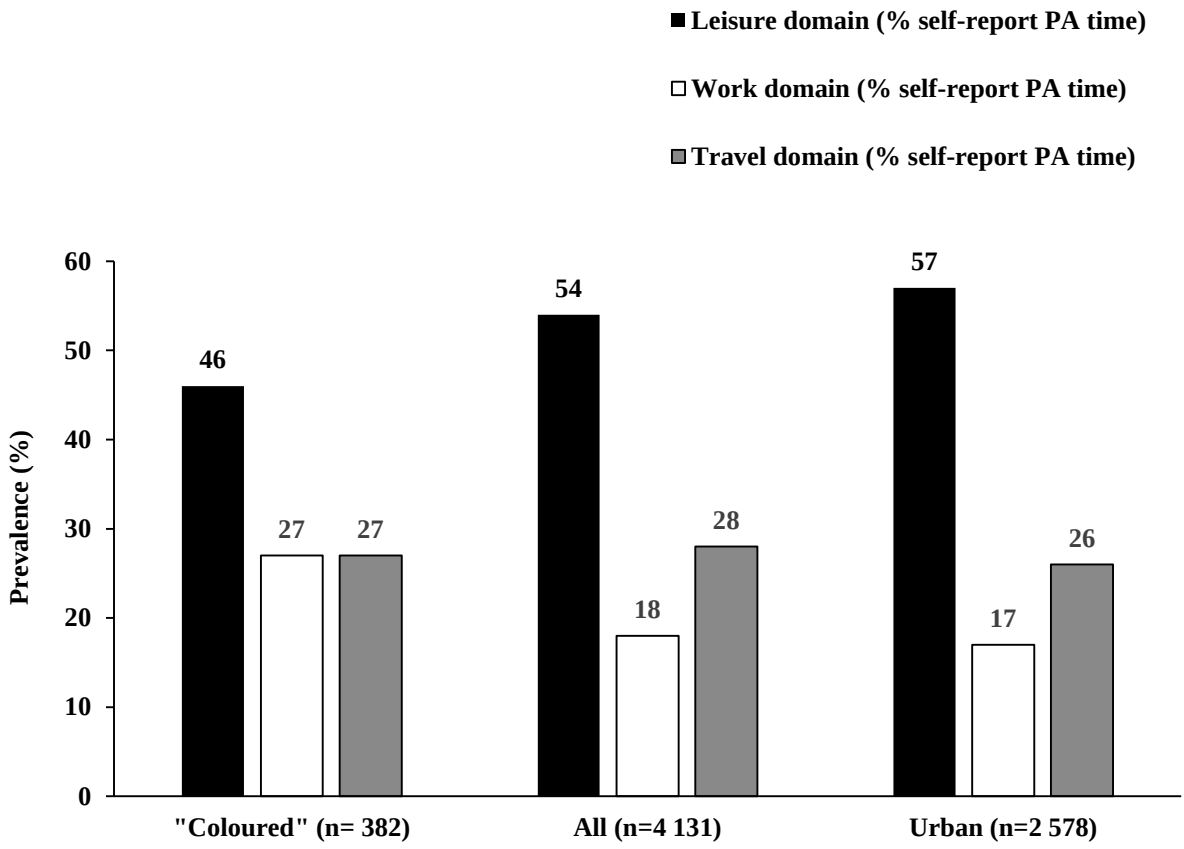

Figure 1.17 Prevalence (%) of domain-specific physical activity time among the "Coloured" women, all women and the urban women sub-group.[44]

It is important to highlight the relatively lower proportion of leisure-domain PA time among the "Coloured" women compared to the other two groups ("Coloured": 46% vs. all: 54% vs. urban: 57%), whereas the opposite exists for work-domain PA time ("Coloured": 27% vs. all: 18% vs. urban: 17%). Although not stated, speculative reasons for these differences may include occupation type and moreover, those which require physical labour (e.g. domestic cleaning). Also, the need for active (e.g. walking) vs. motorised transport and having to travel longer distances due to home and places of purpose (e.g. work, school and shopping centres) not being in close proximity to one another. Recently published data from two different provinces (Western Cape[9] and Gauteng[14]) highlighted that the majority of GPAQ self-report PA time among urban "Black" women (mean age: 26 ± 7 yrs) was for travel-related purposes (i.e. walking).[9] Gradidge et al.[14] also mentioned the negative influence of motor vehicle ownership on total walking PA time. Thus, there is scope for more local studies on the characterisation of PA pattern among women living in different urban settings.

Population-based results from the WHO commissioned World Health Survey inclusive of South Africa, indicate that more SA women were deemed sufficiently active in 2014[100] (58%) than in 2005[99] (37%). However, it is important to note that a different set of PA criteria were used, and in particular, included the 2010 WHO PA Global Health Recommendations for Health.[17] Therefore, these results are not entirely comparable with those reported in the 2003 SADHS.[44] To my knowledge, national PA prevalence estimates from the more recent SANHANES-1 (2012) are non-existent. Nevertheless, the collective findings of the large-scale national surveys[34,99,100] highlight that low levels of physical activity are very likely a contributing risk factor for CVD and T2DM among SA women, and even more so among sub-groups of urban-dwellers and "Coloured" women.

1.4.4 Physical activity among adult women from other countries: levels and patterns

Results from a 22 African country survey[73] (excluding South Africa), which formed part of the WHO Stepwise approach for Surveillance (STEPS), reported a wide range of physical inactivity prevalence estimates among women.[73] In particular, women from Mali were reported to be the most inactive (67%), while those from Mozambique were the least inactive (7%). The survey also showed that leisure time PA was consistently low (5%), compared to work- (49%) and travel-related PA (46%). These results were thus in contrast to the SADHS (2003)[44] findings among SA women. Possibly, the ongoing and rapid rate of epidemiological transition in South Africa, as compared to the other African countries, may explain the difference in findings. The likelihood of participants misunderstanding the description of the GPAQ PA-specific domains is also a plausible reason. Nonetheless, these descriptive domain-specific PA findings are in contrast to those from South Africa and thus raises the need to investigate PA using objective measurements. It is also conceivable that objectively derived PA may indicate different levels to those reported using subjective measures, hence the need for studies using more sophisticated and objective measures.

A previous 20 multi-country survey in 2004 underscored the differences in PA patterns between high- and low to middle-income countries.[74] Notably the majority of leisure PA time performed at high intensities (i.e. MVPA) were among high-income adult populations. In contrast, the majority of PA time among those from low to middle-income countries was for travel-related purposes (i.e. walking), and at relatively lower perceived level of intensity (i.e. moderate).

A more recent (2012) global surveillance report, inclusive of low to middle- and high-income countries, showed that as many as 31% of adults are physically inactive.[75] The Global Observatory for Physical Activity (GoPA), which is a joint initiative of the International Society of Physical Activity and Health and the Lancet Physical Activity Series Working Group, developed country cards on the global status of PA. The results among women from high-income countries (e.g. Australia, USA, Canada, Argentina and China), upper to middle-income countries (e.g. Colombia and South Africa) and lower to middle-income countries (e.g. India) found that as many as 31% of adults are inactive.[75] The results per country are depicted in Figure 1.18.

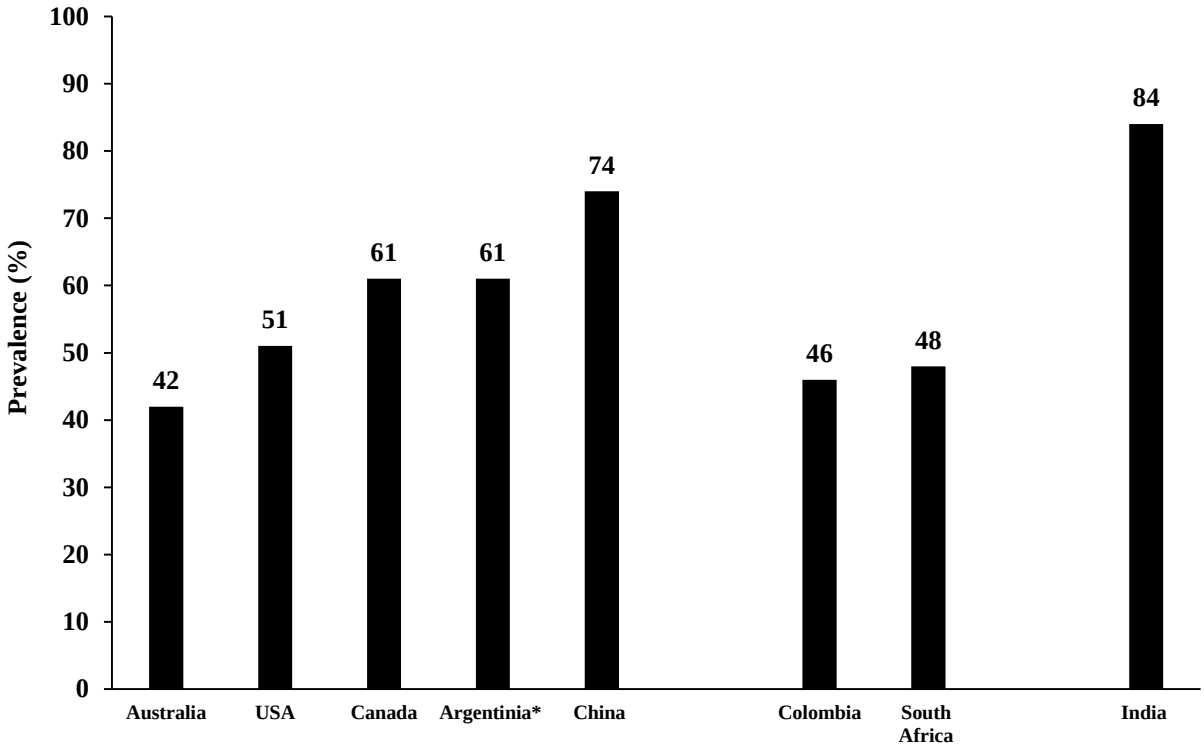

Figure 1.18 Prevalence (%) of physical activity among women from different high-, upper to middle- and lower to middle-income countries, respectively. * denotes 2018 classification

Evidently, levels of physical activity among women vary across the different WHO income-categorised countries. Although the GoPA continues its efforts to document global trends in PA, less than a third of the countries, including South Africa, currently engage in ongoing surveillance studies.

Overall, these population-based surveillance studies derived from self-report PA data indicate how widely PA levels and patterns vary among women from different countries. Notably, the prevalence

of low PA levels in South Africa, as compared to other African countries is worrisome.[4,5] The influence of technology (e.g. computer games and television), as well as time-based challenges (e.g. extended travel time to and from work and/or other purposeful places), the lack of an inclusive PA environment (e.g. limited access to exercise facilities and issues of safety), and the lack of social (community) networks to promote PA,[8] remain significant barriers. Thus, any proposed interventions to address the issue of physical inactivity will have to take these factors into consideration.

1.4.5 Sedentary behaviour among South African adult women

To my knowledge, there are data on sedentary behaviour which was gathered during the large national SADHS published in 2003,[44] however, it has never been reported. More recent GPAQ-derived data from the Birth to Twenty (Bt20) cohort study have been published and provide valuable insight on sitting time among a large sample of middle-aged urban black women (n = 977).[14] There are also numerous published findings from small-scale studies among urban[92,112,125] and rural "Black (African)" women[12,116,117] and where objective measurement instruments were used to quantify sedentary behaviour.

Comparing sedentary behaviour data from two separate cross-sectional analyses, both from the larger Bt20 cohort study (Soweto, Johannesburg, Gauteng Province), it transpired that the relatively older urban "Black (African)" women averaged 180 min/day of sitting time per day (mean age: 41 ± 8 yrs),[14] compared to the higher amount of accelerometer-derived sedentary time (median: 575 min/day [95% CI: 568 to 597 min/day]) reported among the younger women (aged: 19 to 20 yrs).[125] Having also used accelerometer-derived sedentary time, results from urban "Black (African)" women in Cape Town (Western Cape Province) showed similar amounts of time spent sedentary (± 510 min/day).[92] Whether the difference observed between the older and younger women is solely attributable to the method of data collection, is unclear.

Comparative findings between urban (n = 16) and rural (n = 263) "Black (African)" women, reported by Cook et al.[10] provide unique and valuable insight within the SA context. Irrespective of the visible difference in sample sizes between the groups (n =16 vs. n = 263), the use of accelerometer-derived sedentary time adds strength to the inferences drawn about sedentary behaviour among adult women in two different settings. Urban women were significantly younger (30 ± 7 yrs vs. 35 ± 11 yrs, p =

0.0168) and more sedentary (842 ± 40 min/day vs. 780 ± 10 min/day, $p = 0.0042$) compared to their older and less sedentary rural counterparts. Interestingly, no statistically significant differences were found between normal-weight, overweight and obese women across the two groups ($p > 0.05$).

In the interpretation of the above data, it should be remembered that the use of different objective devices and measurement units used to quantify sedentary behaviour also have their limitations. Not only are pedometer-measured step counts and accelerometer-derived motion counts incompatible, but so are the definitions used to characterise sedentary level (< 5 000 steps/day[18]) and time (< 100 counts/min[89,90,91]). Thus, the use of different measurement instruments and definitions to describe the term sedentary, make any attempts to draw definitive and collective inferences unconvincing.

1.4.6 Sedentary behaviour among adult women from other countries

A growing body of literature describe the adverse health effects of prolonged bouts of time spent sedentary.[127,128,129] Valuable results from a meta-analysis among adults indicate the significant and independent associations between sedentary time and i) CVD incidence (hazard ratio [HR]: 1.143 [95% CI: 1.002 to 1.729]); ii) T2DM incidence (HR: 1.910 [95% CI: 1.642 to 2.222]); and iii) all-cause mortality (HR: 1.179 [95% CI:1.106 to 1.257]).[130] Most interestingly, the meta-analysis also showed that when participants were matched for time spent sedentary, those with relatively higher PA levels had a 30% lower all-cause mortality risk compared to those who were less active. Given this, the ability to mitigate the adverse health effects of time spent sedentary with increasing PA time seems plausible.[130]

1.4.7 Associations between physical activity and cardiometabolic disease risk for cardiovascular disease and type 2 diabetes mellitus among adult women from other countries and South Africa

Recently published findings from a large multi-ethnic women study (The Objective Physical Activity and Cardiovascular Health [OPACH])[101] highlighted the favourable associations between PA and reduced cardiometabolic disease risk. Even after adjusting for differences in age, accelerometer wear time, ethnicity and BMI, higher volumes of PA were statistically significantly associated with reduced SBP, DBP, TC, HDL-C, TG and FPG levels ($p < 0.01$). More importantly, higher volumes of light-intensity PA were associated with reduced cardiometabolic disease risk and thus, corroborate

previous findings also from the USA. In particular, longitudinal results from the National Health and Nutrition Examination Survey (NHANES) among the adult population group (aged: 20 – 84 yrs) highlighted the health-related benefits of LPA, even after adjusting for differences in age and MVPA.[101]

Evidence from earlier women cohort studies,[103, 104, 105,106] all from high-income countries, also revealed the positive association between PA and reduced cardiometabolic disease risk for CVD[103,104] and T2DM.[105,106] In particular, results from the multi-ethnic Women's Health Initiative Observational Study (WHI-OS) indicate those who walked ≥ 5 hours per week were 33% less likely to develop T2DM compared to those who were non-regular walkers.[104,105] Bao et al.[106] reported a 9% risk reduction in developing T2DM with each 100 minute increment of moderate-intensity PA performed per week.[106] Most notably, these results were independent of differences in BMI. On the other hand, findings from the Australian Longitudinal Study on Women's Health indicate the equal importance of PA and the ability to maintain a healthy weight (i.e. BMI) in association with reduced CVD-risk.[103] Notably, an increase in BMI and decrease in PA were associated with increased risk of hypertension. In comparison with healthy weight "high-active" women, hypertensive-risk in the obese "high-active" women was 3.4 times greater (odds ratio [OR]: 3.43, 95% CI 2.68 to 4.39) and in obese "inactive" women 4.9 times greater (OR: 4.91, 95% CI 3.92 to 6.13).[103] Thus, PA was shown to reduce the risk of hypertension, however, could not remove the negative effect of obesity on risk for hypertension.

The debate as to whether high levels of PA counteracts the adverse effect of weight (i.e. BMI) on cardiometabolic disease risk for CVD and T2DM remains ongoing and requires further investigation. Similarly, whether an increase in total adiposity is the cause or consequence of insufficient PA levels.[107] The true relationship between body weight and PA levels is equivocal, mainly because of methodological issues. For example, the use of BMI, WC and WHR, as proxy measures of obesity and central obesity must also be taken into account when reviewing its strength of association with PA. Another matter is the tendency to use self-report instruments (e.g. questionnaires) which usually leads to over-report of PA level when compared to objectively derived PA measures (e.g. accelerometers).[108]

Conversely, studies reporting the use of higher precision radiological body composition scanning methods (e.g. DXA and computerised tomography [CT]), which include absolute and relative body fat measures, as well as its regional distribution measurements (e.g. CFM, AFM and VAT area), may help to validate the associations previously reported with BMI, WC and WHR. Furthermore, objective measurements will also provide a more accurate representation of body fat and its regional distribution among those from different ethnical backgrounds. For example, results from a multi-country study[109] drew attention to the differences in the relationships between DXA-derived %BF and BMI, and ethnicity (New Zealand sub-groups: "European", "Maori", "Pacific and Asian Indian" and South African sub-groups: "European" and "Black (African)").[109]

Data from sub-Saharan Africa investigating associations between PA and intermediate cardiometabolic disease risk factors for CVD and T2DM are lacking. However, some studies have published findings on PA and measures of adiposity (e.g. BMI, WC, WHR and %BF). The majority of which report the use of subjectively-derived PA data (i.e. self-report questionnaire)[24,50,51,52,110,111,112,113] and only two the use of objectively-derived PA measures.[112,114] Cross-sectional findings from a small-scale Cameroonian study[115] among adult women and men highlight an inverse association between PAEE and %BF. Although limited in the researcher's use of bioelectrical impedance to quantify %BF a major strength of the study was the use of the sophisticated double labelled water technique, to measure TEE and PAEE. In SA, there are data from small-scale cross-sectional studies[46,92,116,117] and one relatively larger study (Bt20)[14] on the associations between PA and various intermediate cardiometabolic disease risk factors in women from both urban[9,14,46,92] and rural[46,116,117] settings. These are summarised in Table 1.1. Some of the findings therein are adapted from Dickie (MSc dissertation, 2013)[118] among urban and rural "Black (African)" SA women (15 – 70 yrs).[118] The table also include earlier (1991 to 1995) and more recent (2013 – 2018) data reported among women older than 18 years, from urban and rural settings and inclusive of all racial sub-groupings.

Table 1.1 Summary of SA studies investigating physical activity and its association with intermediate cardiometabolic disease risk factors for CVD and T2DM in adult women from different settings and racial categories.

Reference	**Study design (name of study/survey) (*n*)**	**Age in yrs (range/mean)**	**Racial categories**	**SA Province (urban/rural)**	**Measures of physical activity (PA)**	**Measures of cardiometabolic disease risk**	**Findings**
Mollentze et al., 1995[110]	Cross-sectional survey *n* = 1042	25 to 65+	"Black (African)"	Free State (urban sample from Mangaung and rural sample from QwaQwa)	Subjective PA questionnaire	BMI, WC, WHR, SBP, DBP, TC, LDL-C, HDL-C, TG and FPG	Prevalence of obesity according to BMI (≥ 30 kg/m^2) among adult women: Urban vs. Rural: 43.5% vs. 38.4% Prevalence of hypertension*: Urban vs. Rural: 30.0% vs. 29.0% Prevalence of hypercholesterolemia*: Urban vs. Rural: 6.0% vs. 12.5% Prevalence of diabetes mellitus*: Urban vs. Rural: 6.0% vs. 4.8% (*) denotes age- and sex-adjusted prevalence **Did not report any data on PA level or domain-related patterns, and thus associations between PA and any of the measured cardiometabolic disease risk were not explored**
Steyn et al., 1999[38]	Cross-sectional survey *n* = 544	15 to 64	"Black (African)"	Western Cape (urban sample from Khayelitsha, Nyanga, Langa, Guguletu, and Crossroads [all of which are recognised as informal settlements])	Subjective risk factor, PA and dietary questionnaire (Only PA work-domain)	BMI, SBP, DBP, TC and HDL-C	27.3% of women who were employed were classified as inadequately active at work Prevalence of obesity according to BMI (≥ 30 kg/m^2) among urban adult women: 44.4% **Did not examine the association between PA at work and BMI, nor any of the other risk factors**

Reference	**Study design (name of study/survey) (*n*)**	**Age in yrs (range/mean)**	**Racial categories**	**SA Province (urban/rural)**	**Measures of physical activity (PA)**	**Measures of cardiometabolic disease risk**	**Findings**
Tshabangu et al., 2001[11]	Cross-sectional *n* = 226	18 to 29	"Black (African)"	Gauteng (urban sample from Mmasechaba informal settlement)	Subjective lifestyle questionnaire) (PA level)	BMI and WHR	According to BMI (≥ 25.0 – 29.9 kg/m^2) the majority of women were overweight: 61.0% Mean MVPA reported among the adult women: 180 min/day **Did not examine the association between PA and BMI, nor PA and WHR**
Kruger et al., 2002[46]	Cross-sectional (Transition and Health During Urbanisation of South Africa [THUSA]) *n* = 530	15 to 70	"Black (African)"	North West (rural and urban)	Subjective (*Baecke* short questionnaire)[165] (PA index score [PAI])	BMI, WC, WHR, and adiposity (sum of 4 skinfolds [SSF])	Fewer women in the highest PAI-tertile were obese compared to those in the lowest- and middle-PAI tertile, respectively **After adjusting for differences in age, smoking and total household income, inverse associations were reported between:** **PAI and BMI** **(r = -0.135, p < 0.001)** **PAI and WC** **(r = -0.147, p < 0.0001)** **PAI and adiposity** **(r = -0.104, p = 0.03)**

Reference	**Study design (name of study/survey) (*n*)**	**Age in yrs (range/mean)**	**Racial categories**	**SA Province (urban/rural)**	**Measures of physical activity (PA)**	**Measures of cardiometabolic disease risk**	**Findings**
Kruger et al., 2003[120]	Cross-sectional (THUSA) *n* = 530	39	"Black (African)"	North West (rural and urban)	Subjective (*Baecke* short questionnaire)[165] (PAI score)	BMI	According to BMI (≥ 25.0 – 29.9 kg/m^2) the majority of women were overweight: 53.8% **Did not examine the association between PAI and BMI**
Alberts et al., 2005[119]	Cross-sectional *n* = 1563	30 to 65	"Black (African)"	Limpopo (rural)	Subjective risk factor & lifestyle questionnaire (Only PA work-domain)	BMI, WHR, TC, HDL-C, LDL-C, TG, SBP and DBP	Age-standardised prevalence of obesity according to BMI (≥ 30 kg/m^2): 27.3% Only 14.4% of women who were employed were classified as inadequately active at work **Did not examine the association between PA work-domain and BMI, nor any of the other cardiometabolic risk factors**
Jennings et al., 2008[51]	Cross-sectional *n* = 223	18 to 45	"Black (African)"	Western Cape (urban)	Subjective (GPAQ) (PAEE, MET-min/week)	BMI, WC, DXA-derived %BF, CT-derived VAT and SAT, SBP, DBP, TC, LDL-C, HDL-C, TG, FPG and fasting serum insulin	**Did not report on PA level nor prevalence of women overweight/obese** **Did not examine the association between PAEE and any of the cardiometabolic disease risk factors measured**

Reference	**Study design (name of study/survey) (*n*)**	**Age in yrs (range/mean)**	**Racial categories**	**SA Province (urban/rural)**	**Measures of physical activity (PA)**	**Measures of cardiometabolic disease risk**	**Findings**
Cook et al., 2008[116]	Cross-sectional (Dikgale Health and Demographic and Surveillance System [DHDSS]) *n* = 151	15 to 55	"Black (African)"	Limpopo (rural)	Objective (Pedometry, steps/day)	BMI, WC and adiposity (SSF)	Majority of the women were overweight according to BMI (≥ 25.0 kg/m^2): Mean BMI: 26.6 kg/m^2 Mean WC: 79.4cm Mean steps/day: 9 085 **Inverse associations were reported between:** **Steps/day and BMI (*r* = -0.22, *p* < 0.02) (remained significant even after adjustment for age: *r* = -0.20, *p* = 0.032)** **Steps/day and WC (*r* = -0.23, *p* < 0.02)** Only BMI remained significant after adjusting for age (p = 0.036) For every additional 5000 steps/day increased, BMI was shown to decrease by 1.4 kg/m^2
Cook et al., 2008[12]	Cross-sectional (DHDSS) *n* = 160	34	"Black (African)"	Limpopo (rural)	Objective (Accelerometry) (PA, min/day)	BMI	Majority of the women were overweight however "highly" active Mean BMI: 26.6 kg/m^2 Mean MVPA: 224 min/day 86% of the women met the ACSM/CDC physical activity guidelines (i.e. ≥ 30 min/day of MVPA, at least 5 days per week and in ≥ 10-min bouts) **Did not examine the association between PA and BMI**

Reference	Study design (name of study/survey) (*n*)	Age in yrs (range/mean)	Racial categories	SA Province (urban/rural)	Measures of physical activity (PA)	Measures of cardiometabolic disease risk	Findings
Cook et al., 2009[10]	Part 1: Cross-sectional (DHDSS) *n* = 206 (1997)	30 to 55	"Black (African)"	Limpopo (rural)	Subjective (1997 and 2003/2004) (PA Index level)	BMI, WC adiposity (SSF), SBP, DBP, TC, LDL-C, HDL-C, TG and FPG	**Linear relationship was reported: Self-reported diagnosis with, or on medication for, hypertension and/or diabetes mellitus with PAI (p = 0.0180)** **Inverse associations reported between:** **PAI and BMI** **(r = -0.24, p = 0.0037)** **PAI and WC** **(r = -0.147, p < 0.0001)** **PAI and FPG** **(r = -0.47, p < 0.0001) and remained even after adjusting for difference in BMI** **(r = -0.20, p = 0.0034)**
	Part 2: Cross-sectional (DHDSS) *n* = 138 (2003/2004)	19 to 56			Objective (only 2003/2004) (Accelerometry: counts/day, steps/day and min/day in different intensity bands (*Matthews* MVPA cut-points used: ≥ 760 counts/min)[166]	BMI, WC, adiposity (SSF), SBP and DBP	**PAI level and adiposity (SSF) and remained significant after adjusting for age (p < 0.04)** Majority of the women were overweight according to BMI (≥ 25.0 kg/m^2) Mean BMI: 26.9 kg/m^2 Mean MVPA: 253 min/day 96.4% of women met the ACSM/CDC physical activity guidelines, whereas 69.6% met the Institute of Medicine (IOM) guidelines (i.e. 60 min/day of MVPA, at least 5 days a week and in ≥ 10-min bouts)

Reference	**Study design (name of study/survey) (*n*)**	**Age in yrs (range/mean)**	**Racial categories**	**SA Province (urban/rural)**	**Measures of physical activity (PA)**	**Measures of cardiometabolic disease risk**	**Findings**
Dugas et al., 2009[114]	Cross-sectional *n* = 44	30	"Black (African)" and "White"	Western Cape (urban)	Subjective (self-report questionnaire) (PAEE, kJ/day) Objective (Metabolic chamber) (PAEE, kJ/min)	BMI, WHR and DXA-derived %BF	Included lean (< 25.0 kg/m^2) vs. obese (≥ 30 kg/m^2) BMI sub-groups **Did not examine any association between PAEE and BMI, WHR and %BF** **Did not examine any associations between PAEE and BMI, nor PAEE and WHR or PAEE and %BF**
Dugas et al., 2009[121]	Cross-sectional *n* = 44	30	"Black (African)" and "White"	Western Cape (urban)	Objective (Double labelled water technique) (PAEE, kJ/min) Objective (Accelerometry [*n* = 13], PAEE, min/day and %awake time)	BMI, isotope dilution method %BF	**Associations between PAEE and BMI, and PAEE and %BF were non-significant ($p > 0.05$)** **Did not examine any associations between PAEE and BMI, nor PAEE and WHR or PAEE and %BF**
Goedecke et al., 2009[52]	Cross-sectional *n* = 29	26	"Black (African)" and "White"	Western Cape (urban)	Subjective (GPAQ) (PAEE, MET-min/day)	BMI, WC, DXA-derived %BF, CT-derived VAT and SAT, FPG and fasting serum insulin	**Did not examine the association between PAEE and any of the cardiometabolic disease risk factors measured**
Goedecke et al., 2009[122]	Cross-sectional *n* = 28	26	"Black (African)"	Western Cape (urban)	Subjective (GPAQ) (PAEE, MET-min/day)	FPG and fasting serum insulin	**Did not examine the association between PAEE and FPG, nor fasting serum insulin**
Cook et al., 2010[117]	Cross-sectional survey (DHDSS) *n* = 516	41	"Black (African)"	Limpopo (rural)	Objective (Pedometry, steps/day)	BMI and WC	**Inverse associations between steps/day and BMI, as well as steps/day and WC; both remained significant after adjusting for differences in age** **Steps/day and BMI ($r = -0.08$, $p < 0.03$)** **Steps/day and WC ($r = -0.12$, $p < 0.03$)**

Reference	**Study design (name of study/survey) (*n*)**	**Age in yrs (range/mean)**	**Racial categories**	**SA Province (urban/rural)**	**Measures of physical activity (PA)**	**Measures of cardiometabolic disease risk**	**Findings**
Goedecke et al., 2010[111]	Cross-sectional *n* = 110	28	"Black (African)" and "White"	Western Cape (urban)	Subjective (GPAQ) (PAEE, MET/day)	BMI, WC, DXA-derived %BF, CT-derived VAT and SAT, TC, HDL-C, TG, LDL-C, total LDL particle size as well as LDL subclass I-IV	Included lean vs. obese BMI sub-groups No association between PAEE and TG, TC, LDL-C, HDL-C, total LDL particle size as well as LDL subclass I-IV No statistically significant ethnic differences or BMI-derived sub-group differences in PAEE
Walter et al., 2011[112]	Cross-sectional study *n* = 180	18 to 45	"Black (African)"	Eastern Cape (urban)	Subjective (*n* = 146) (GPAQ) (PAEE, MET-min/week) Objective (*n* = 69) (Accelerometry) (PAEE [METs/day], MVPA [min/day] and steps/day)	BMI	Neither the younger age group (18 to 21 yrs), nor the older age group (35 to 45 yrs) were sufficiently active as they failed to meet the ACSM/CDC PA guidelines **Did not examine associations between any of the objective PA variables and BMI**
Peer et al., 2012[123]	Cross-sectional study *n* = 707	25 to 74	"Black (African)"	Western Cape (urban)	Subjective (GPAQ) (PA, min/week)	BMI, WC and WHR	Significantly higher proportion of physical inactivity amongst those who were diabetic (11.6%) compared to those who were non-diabetic (6.1%) (p = 0.035) **Did not examine the association between PA and BMI, nor PA and WC or PA and WHR**

Reference	**Study design (name of study/survey) (*n*)**	**Age in yrs (range/mean)**	**Racial categories**	**SA Province (urban/rural)**	**Measures of physical activity (PA)**	**Measures of cardiometabolic disease risk**	**Findings**
Cook et al., 2012[13]	Cross-sectional survey (DHDSS) *n* = 288	41	"Black (African)"	Limpopo (rural [*n* = 272] and urban [*n* = 16])	Objective (Accelerometry) (counts/day, light-intensity PA, MVPA) (*Matthews* MVPA cut-points used: ≥ 760 counts/min [166] and compared with *Freedson* MVPA cut-points used: ≥ 1952 counts/min) [89]	BMI	Higher proportion of rural women met the ACSM/CDC PA guidelines compared to their urban counterparts: 38.2% vs. 27.5%, although when using the higher *Freedson* MVPA cut-point the proportions decreased: 34.4% vs. 29.0% Mean BMI: Rural women: 26.8 ± 6.0 kg/m^2 Urban women: 28.5 ± 6.0 kg/m^2 **Did not examine the association between PA and BMI**
Gradidge et al., 2014[14]	Cross-sectional (Bt20 study) *n* = 977	41	"Black (African)"	Gauteng (urban, Soweto informal settlement)	Subjective (GPAQ) (PA, MET-min/week)	BMI, WC, WHR, %BF, FM, FFSTM (DXA), TC, LDL-C, HDL-C, TG, SBP, DBP, FPG, fasting serum insulin, and homeostasis model insulin resistance (HOMA-IR)	67% were classified as active according to GPAQ MVPA-criteria Prevalence of MetS was 40% Prevalence of overweight (29.2%) and obesity (48.0%) Women who owned a motor vehicle reported less travel-related PA time and more leisure-related PA time ($p < 0.01$) compared to those who did not own a motor vehicle Women who owned a television reported significantly lower total MVPA and walking for travel ($p < 0.01$) **An inverse association was observed between total MVPA and fasting serum insulin**

Reference	**Study design (name of study/survey) (*n*)**	**Age in yrs (range/mean)**	**Racial categories**	**SA Province (urban/rural)**	**Measures of physical activity (PA)**	**Measures of cardiometabolic disease risk**	**Findings**
Dickie et al., 2014[9]	Part 1: Cross-sectional *n* = 195 Part 2: Longitudinal observational follow-up (5.5-year) *n* = 76	32 Baseline: 25 (Active) 28 (Inactive) Follow-up: 31 (Active) 24 (Inactive)	"Black (African)"	Western Cape (urban)	Subjective (GPAQ) (PA, min/week)	BMI, WC, DXA-derived %BF, CT-derived VAT and SAT, TC, LDL-C, HDL-C, TG, FPG, fasting serum insulin and HOMA-IR	61% were classified as active according to GPAQ MVPA-criteria Active women had significantly lower body mass, BMI, FM, %BF, WC, CFM, and AFM ($p < 0.001$), measures of insulin resistance (fasting serum insulin and HOMA-IR [$p = 0.01$]) and higher HDL-C ($p = 0.041$), compared to women who were inactive After adjusting for differences in age, body fat measures were significantly increased in both groups ($p < 0.05$) DBP level was lower in women who were active at baseline, but did not change in those who were inactive Meeting WHO Global PA Guidelines was associated with decreased cardiometabolic risk, but did not prevent the increase in body fat over a follow-up period of 5.5-yrs **No associations were examined between PA and any of the cardiometabolic risk factors**

Reference	**Study design (name of study/survey) (*n*)**	**Age in yrs (range/mean)**	**Racial categories**	**SA Province (urban/rural)**	**Measures of physical activity (PA)**	**Measures of cardiometabolic disease risk**	**Findings**
Dickie et al., 2016[92]	Cross-sectional *n* = 76	18 to 45	"Black (African)"	Western Cape (urban)	Objective (Accelerometry, PA, min/day) (light-intensity PA, MVPA) (*Freedson* cut-points[88]: light-intensity PA 100 - 1951 counts/min and MVPA: ≥ 1952 counts/min)	BMI, WC, %BF (DXA), VAT and SAT (CT), TC, LDL-C, HDL-C, TG, FPG, fasting serum insulin and HOMA-IR	53.1% were classified as active according to GPAQ MVPA-criteria, whereas 55.3% reported an average of ≥ 10 000 steps/day **Inverse association between light-intensity PA and trunk FM ($p < 0.05$)** **Associations between MVPA and cardiometabolic risk outcomes were not statistically significant**
Manning et al., 2016[24]	Part 1: Cross-sectional survey *n* = 193 Part 2: Intervention-study with two different groups	50.4	"Coloured" [49.2%], "Black (African)" [29.2%], "Asian" or "White" [25.4%])	Western Cape (urban)	Subjective (PA, min/week)	BMI, WC, HbA1c, SBP, DBP, TC,	Only 14% were physically active Proportion of women: 77.7% Prevalence of T2DM: 41.5% Prevalence of hypertension: 83.4% Prevalence of hypercholesterolemia: 69.5% Other cardiometabolic risk markers (mean ± SD): HbA1c: 9.1 ± 2.0% SBP: 146 ± 21 mm Hg DBP: 85 ± 12 mm Hg TC: 5.4 ± 1.2 mmol/L **Did not examine associations between PA and cardiometabolic disease risk outcomes**

Reference	**Study design (name of study/survey) (*n*)**	**Age in yrs (range/mean)**	**Racial categories**	**SA Province (urban/rural)**	**Measures of physical activity (PA)**	**Measures of cardiometabolic disease risk**	**Findings**
Oyeyemi et al., 2016[124]	Cross-sectional survey *n* = 843 (Prospective Urban and Rural Epidemiological [PURE] study)	35 to 70	"Black (African)"	North West (rural and urban)	Subjective (*Baecke* short questionnaire [PAI score] [166] and the International Physical Activity Questionnaire [IPAQ], PA min/week)	BMI	BMI of the rural women: 27.6±7.4 kg/m^2 (overweight) BMI of the urban women: 28.9±8.1 kg/m^2 (overweight) **Did not examine associations between PAI and BMI, or PA and BMI**
Prioreschi et al., 2017[125]	Cross-sectional observational *n* = 191	19 to 20	"Black (African)"	Gauteng (urban, Soweto informal settlement, Johannesburg)	Objective (Accelerometry, counts/day, intensity levels i.e. Light-intensity PA, MVPA) (*Troiano* cut-points: light-intensity PA 100 – 2091 counts/min and MVPA: ≥ 2020 counts/min)	BMI	83% of the young urban women met the ACSM/CDC physical activity guidelines (i.e. ≥ 30 min/day of MVPA, at least 5 days per week and in ≥ 10-min bouts) The proportion was lower when using the WHO Global PA Recommendation (i.e. ≥ 75 min/week of vigorous-intensity PA; or ≥ 150 min/week of moderate-intensity PA; or a combination) 1952 counts/min): 20.0% **Did not examine association between PA and BMI**
Motadi et al., 2018[113]	Cross-sectional *n* = 65	18 to 45	"Black (African)"	Limpopo (rural, Mopani municipal district, Giyani town)	Subjective (Questionnaire) (PA status)	BMI, WC and BF% (sum of four skinfolds), SBP, DBP, TC and FPG	64.6% were categorised as physically inactive; whereas 36.9% were obese according to BMI (≥ 30.0kg/m^2) and 95.4% overweight according to %BF (≥31.0%) **Did not explore examine associations between PA and cardiometabolic disease risk outcomes**

1.4.7.1 Summarised findings of Table 1.1 and concluding remarks

Associations between PA and cardiometabolic disease risk outcomes among SA adult women aged 18 to 65+ yrs were only reported in six of the twenty-six studies summarised in Table 1.1 Results from the Transition and Health During Urbanisation of South Africa (THUSA) study[46] showed significant inverse associations between PA index (PAI) and BMI (r = -0.135, $p < 0.001$), PAI and WC (r = -0.147, $p < 0.0001$) and PAI and adiposity (r = -0.104, $p = 0.03$), even after adjustments for differences in age, smoking status and household income were taken in account.[46] Women in the highest PAI tertile were less likely to be obese compared to those in the lowest PAI tertile (OR: 0.38; 95% CI: 0.22 to 0.26). However, those at greatest risk for obesity were from the higher income categories and lowest PA tertile.[46]

Although using a different PAI, similar results from the DHDSS site reported by Cook et al.[10] also showed significant inverse associations between PAI and BMI (r = -0.24, $p = 0.0037$), PAI and WC (r = -0.147, $p < 0.0001$) and, most notably, PAI and FPG (r = -0.47, $p < 0.0001$). These relationships remained statistically significant after adjustment was made for differences in BMI (r = -0.20, p = 0.0034). A significant linear relationship was also found between PAI and self-report diagnosis of hypertension and/or diabetes mellitus ($p = 0.0180$).

Additional survey findings from the DHDSS site reported by Cook et al.[116,117] indicate similar associations between objectively-measured PA (i.e. pedometry) and cardiometabolic disease risk. Statistically significant inverse associations were shown between steps/day and WC and steps/day and BMI ($p < 0.05$).[116,117] Similar to the findings from the THUSA study,[46] the inverse association between steps/day and BMI remained statistically significant after adjusting for differences in age ($p < 0.004$).[116,117] Of greatest importance, however, was the notable reduction in BMI-defined obesity risk ($\geq$ 30 kg/m^2) with increasing levels of steps/day.[116] A measurable decrease in BMI of 1.4 kg/m^2 was observed with every 5 000 steps achieved ($p = 0.035$). Thus, women who achieved $\geq$ 12 500 steps/day, $\geq$ 10 000 steps/day and $\geq$ 7 500 steps/day were 62%, 52% and 35%, respectively, less likely to be obese compared to women who managed < 5000 steps/day.

Study results reported by Gradidge et al.[14] include those from the Bt20 cohort and represent the largest sample of women (n = 977) included in Table 1.1. They found a significant inverse association

between PA and fasting serum insulin ($p < 0.05$). Unlike the results from the THUSA study[46] and DHDSS surveys,[116,117] none of the obesity (BMI, total FM and %BF) and central obesity measures (WC and WHR) were statistically significantly related to PA ($p > 0.05$). On the contrary, age was positively associated with obesity measures (total FM and WC) and other cardiometabolic disease risk outcomes (SBP, DBP, FPG, TC, LDL-C, TG, SBP and DBP) ($p < 0.05$). The credibility of these results is quite substantial as the researchers included a large sample size, used DXA-derived adiposity measures and descriptive PA data (domains) from the GPAQ. Concerns in their use of subjective PA time was acknowledged by Gradidge et al.[14] as the authors noted a tendency of PA time to be overestimated.

The associations reported by Dickie et al.[92] using objective PA time (i.e. accelerometry) and DXA-derived adiposity measures also among urban women prove useful in eliminating subjective bias, albeit in a much smaller study than that of Gradidge et al.[14] It also enabled the researchers to examine the associations between different PA intensities and cardiometabolic disease risk outcomes (BMI, WC, WHR, BP, serum lipid concentrations, FPG, fasting insulin serum and HOMA-IR). The only statistically significant inverse association was between LPA and trunk FM ($r = -0.25$, $p < 0.05$), whereas all the associations between MVPA and the cardiometabolic risk outcomes were not statistically significant ($p > 0.05$). Although PA was objectively measured, the study is limited by a small sample and the use of pre-determined accelerometer cut-points.[89] The latter prohibits comparisons with other SA studies[10,13,125] included in Table 1.1 which used different cut-points.[90,91]

Overall, the summarised findings of these studies and surveys confirm the association between PA and obesity as a recognised intermediate risk factor for CVD and T2DM in rural and urban "Black (African)" SA adult women[10,14,46,92,116,117] To my knowledge, there are no studies that have determined whether the same associations exist among urban "Coloured" women. Given the national survey data[34,35] that pointed to "Coloured" women as the most inactive and severely obese of all women (racial) sub-groups in SA, it is important to investigate their cardiometabolic risk profiles in relation to their engagement in PA. It also remains to be seen whether those who meet PA public health recommendations (i.e. sufficiently active) are indeed less likely to be overweight or obese, and present with a more favourable cardiometabolic disease risk profile compared to those who are insufficiently active.

Given this background, it is in my view important to profile the PA levels and cardiometabolic disease risk factors for CVD and T2DM in a sub-population group in South Africa which are clearly understudied, as it cannot be assumed that "Coloured" women present with the same characteristics as reported among other SA subgroups.

1.4.8 Associations between sedentary behaviour and cardiometabolic disease risk for cardiovascular disease and type 2 diabetes mellitus among adult women from other countries and South Africa

Results from both high-income[131,132] and low to middle-income[133,134] countries consistently report inverse associations between self-report sedentary behaviour and cardiometabolic disease risk factors. Particularly, it was found that BMI is significantly higher among individuals who report higher levels of sitting time.[131,132,133,134] However, studies with equally sized samples using objectively measured sedentary time, as opposed to subjective data, do not necessarily report the same inverse associations.[135,136] The equivocal findings could be attributed to the use of different accelerometer devices, different cut-points and thus, the greater likelihood of the misclassification of sedentary vs. PA time. Furthermore, the additional limitations in using proxy measures of obesity and central obesity, as opposed to absolute %BF and regional body fat distribution measures (e.g. CFM and VAT), must also be taken into account.

Using both subjective and objective sedentary behaviour data captured from the ProActive cohort study among adults aged between 30 to 50 yrs and over a 6-year follow-up period showed that sedentary time were significantly inversely associated with cardiometabolic disease risk.[137] Most notably, more sedentary time (min/day) was associated with larger increases in clustered cardiometabolic risk score (CCMRS: $\beta = 0.08$ [95% CI: 0.01, 0.15]); with CCMRS when WC was removed (i.e. CCMRS no central adiposity: $\beta = 0.08$ [95% CI: 0.01, 0.16]) and with; TG ($\beta = 0.15$ [95% CI: 0.01, 0.29]). These associations were independent of baseline sedentary and MVPA times, change in MVPA time and other confounding variables. On the other hand, greater increases in objectively measured MVPA time (min/day) were associated with larger decreases in WC ($\beta = -3.86$ [95% CI: -7.58, -0.14]) and independent of baseline MVPA and sedentary times, change in sedentary time and other confounders.

Published SA evidence investigating the association between sedentary behaviour, whether self-report sitting time, pedometry or accelerometer-derived time are sparse. Results [10,14,92,116,117,125] are summarised in Table 1.2.

Table 1.2 Summary of SA studies investigating sedentary behaviour and its association with intermediate cardiometabolic disease risk factors for CVD and T2DM in women from different settings and racial categories.

Reference	**Study design (name of study/survey) (*n*)**	**Age in yrs (range/mean)**	**Race categories**	**SA Province (urban/rural)**	**Measures of sedentary behaviour**	**Measures of cardiometabolic disease risk**	**Findings**
Cook et al., 2008[116]	Cross-sectional (Dikgale Health and Demographic and Surveillance System [DHDSS]) *n* = 151	15 to 55	"Black (African)"	Limpopo (rural)	Objective (Pedometry, steps/day) (sedentarism defined: < 5 000 steps/day)	BMI, WC and adiposity (SSF)	13.2% (*n* = 151) of the women were classified as sedentary **Did not examine any associations but did show ambulation decreased the risk of obesity, while motor vehicle access was associated with increased adiposity levels**
Cook et al., 2009[10]	Part 2: Cross-sectional (DHDSS) *n* = 138 (2003/2004)	19 to 56	"Black (African)"	Limpopo (rural)	Objective (Accelerometry: min/day in different intensity bands. *Swartz* cut-points used: 0 counts/min)	BMI, WC, adiposity (SSF), SBP and DBP	Mean (95% CI): 797 min/day (780; 814) or 13.8 hr/day **Did not examine the association between sedentary time and any of the cardiometabolic disease risk factors**
Cook et al., 2010[117]	Cross-sectional survey (DHDSS) *n* = 516	41	"Black (African)"	Limpopo (rural)	Objective (Pedometry, steps/day) (Public health pedometry thresholds: Sedentary defined: < 5 000 steps/day)	BMI and WC	10.9% (*n* = 56) of the women were classified as sedentary **After adjusting for differences in age, sex, pedometry output, village and season, the risk of obesity was more than twofold higher for those in the sedentary to low activity zones (5 000 – 7 499 steps/day) compared with those in the active (7 500 – 9 999 steps/day) and the very active (≥ 10 000 steps/day) zones**

Reference	**Study design (name of study/survey) (*n*)**	**Age in yrs (range/mean)**	**Race categories**	**SA Province (urban/rural)**	**Measures of sedentary behaviour**	**Measures of cardiometabolic disease risk**	**Findings**
Gradidge et al., 2014[14]	Cross-sectional (Bt20 Study) *n* = 977	41	"Black (African)"	Gauteng (urban, Soweto informal settlement)	Subjective (GPAQ) (Sitting time, min/week) Subjective: Household ownership of a motor vehicle and/or television ("stimulators of sedentary behaviour")	BMI, WC, WHR, %BF, FM, FFSTM (DXA), TC, LDL-C, HDL-C, TG, SBP, DBP, FPG, fasting serum insulin, and homeostasis model insulin resistance (HOMA-IR)	67% were classified as active according to GPAQ MVPA-criteria; median (IQR) sitting time of the urban women: 1260 min/week (840-2100) or equivalent to ±21 hrs/week or ±3 hrs/day 33% were classified as inactive according to GPAQ MVPA-criteria; median (IQR) sitting time of the urban women: 1260 min/week (630-1680) or equivalent to ±21 hrs/week or ±3 hrs/day No significant difference in time spent sedentary between active vs. inactive groups ($p > 0.05$) **Positive associations reported between:** **Sitting time and TG (age adjusted)** **($\beta = 0.12$, $p < 0.001$)** **Sitting time and DBP (age & WC adjusted)** **($\beta = 0.08$, $p = 0.01$)**

Reference	**Study design (name of study/survey) (*n*)**	**Age in yrs (range/mean)**	**Race categories**	**SA Province (urban/rural)**	**Measures of sedentary behaviour**	**Measures of cardiometabolic disease risk**	**Findings**
Dickie et al., 2016[92]	Cross-sectional *n* = 76	18 to 45	"Black (African)"	Western Cape (urban)	Objective (Accelerometry, counts/min i.e. Sedentary time) (*Freedson* cut-point: < 100 counts/min)[89]	BMI, WC, %BF (DXA), VAT and SAT (CT), TC, LDL-C, HDL-C, TG, FPG, fasting serum insulin and HOMA-IR	Majority of awake-time (59.4%) was spent in sedentary behaviour (~8.5 hr/day) **Positive associations between:** **Sedentary time and TG (*r* = 0.36, *p* = 0.01);** **Sedentary time and TG:HDL-C (*r* = 0.34, *p* = 0.04).** **Both correlations were independent of fat mass (kg)**
Prioreschi et al., 2017[125]	Cross-sectional observational *n* = 191	19 to 20	"Black (African)"	Gauteng (urban, Soweto informal settlement, Johannesburg)	Objective (accelerometry, counts/min, i.e. sedentary time) (*Troiano* cut-point: < 100 counts/min)[91]	BMI	Median (CI) sedentary time of the young urban women: 575 min/day (568; 597) or equivalent of ~9.5hr/day **Did not examine association between sedentary behaviour (time) and BMI**

1.4.8.1 Summarised findings of Table 1.2 and concluding remarks

Overall, the summarised findings of these SA cross-sectional studies indicate the beneficial and statistically significant associations between sedentary time (subjective and objective) and recognised cardiometabolic disease risk factors for CVD and T2DM.[14,92,117] For example, rural "Black (African)" women who accumulated < 7 499 steps/day had twice the risk for obesity compared to their more active rural counterparts (≥ 7 500 steps/day). [117] Among two separate samples of urban "Black (African)" women[14,92] high levels of sitting time were associated with raised TG serum concentrations[14,92] and SBP.[14] These associations remained after adjusting for covariates related to age and WC,[14] and total fat mass.[92]

Despite the steady increase and availability of sedentary behaviour data in South Africa, the lack of a standardised measurement instrument or approach proves to be the current research challenge. Gradidge[126] proposes that future studies use standardised instruments to investigate the different domains of sedentary behaviour. The reported difference in PA level among urban and rural groups, which suggest the possibility of differences in time spent sedentary, also requires thorough investigation. Thus, there is scope for studies on women from different residential settings beyond the larger metropolitan areas and from all population (racial) sub-groups. Such results will not only contribute to the larger picture of sedentary behaviour in South Africa, but also provide valuable information on how and where our efforts to combat sedentary behaviour must be concentrated.

1.5 Physical health-related fitness

The section below introduces the definitions pertaining to physical fitness, and in particular health-related fitness and its components of interest (e.g. body composition, muscular strength and CRF). Evidence in support of the health-related benefits among women with higher CRF level and muscular strength are presented, as well as those independent of obesity according to the "fat-but-fit" paradox.[144] Following which methods used to measure each of these components are presented; concluding with a summarised table of SA studies (Table 1.3) in which physical health-related fitness components were measured among adult women. Notably, only one study reported the association between CRF with cardiometabolic disease risk outcomes for CVD and T2DM.

1.5.1 Physical health-related fitness: definitions

As described by Pate et al.[78] physical fitness relates to a set of attributes that individuals either have, or look to achieve, to be categorised as "physically fit", i.e. *"the ability to carry out daily tasks with vigour and alertness, without undue fatigue and with ample energy to enjoy leisure-time pursuits and to meet unforeseen emergencies"*.[78] However, as stated by Pate et al.[78] the subjective and emotional constructs which form part of the overarching physical fitness definition are not easily measurable (e.g. vigour and fatigue). In comparison: i) health-related fitness components and ii) skill-related fitness components (Figure 1.14) can be objectively measured.

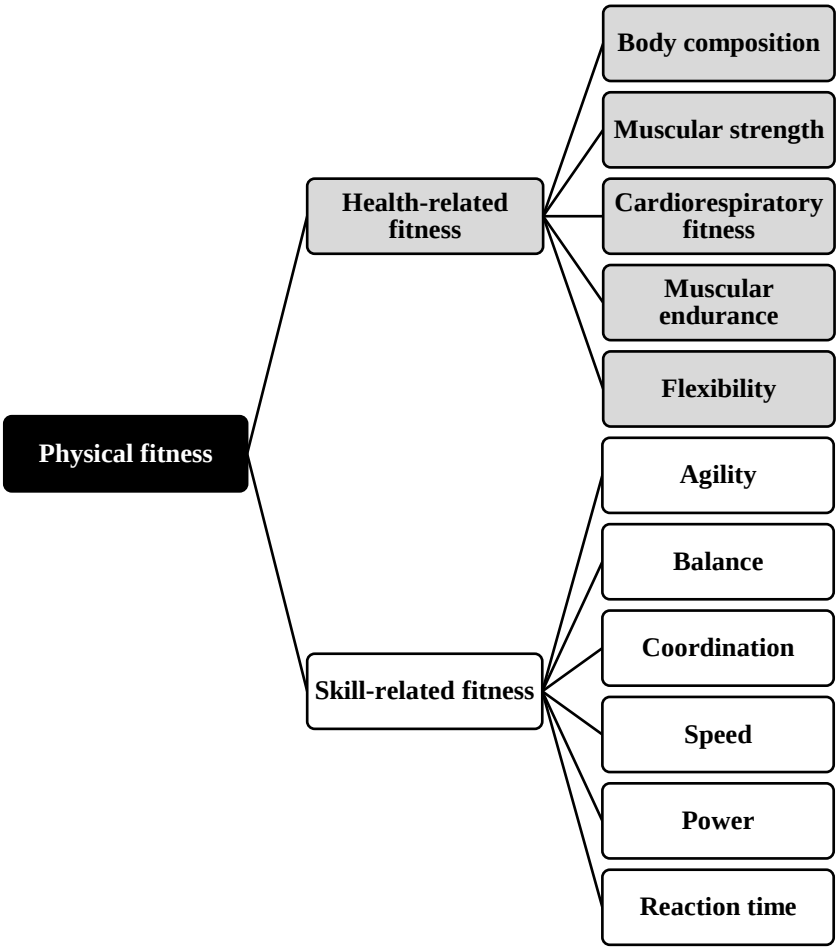

Figure 1.14 The main components of physical fitness, namely health-related and skill-related fitness. [62]

This dissertation focusses on three measurable components of physical health-related fitness, namely: body composition, muscular strength and CRF. The motivation to select these three includes the need

to describe health risk conditions, such as obesity and sarcopnia. Whereas those related to the selection for CRF and muscular strength stem from evidence in support of the numerous health-related benefits associated with regular participation in PA; and specifically common activities within the SA context. Such as occupations associated with manual labour, as well as walking for transport, while carrying items, on a daily basis. All of which underpin the components of both CRF and muscular strength. In addition, knowledge of muscular strength would also prove advantageous, as maintenance or improvement thereof has been shown to counter the adverse effects associated with sarcopenia. It too has an effect on energy expenditure, given the positive relationship between higher skeletal muscle mass and a higher resting metabolic rate. Thus, attaining novel baseline data relative to the wide range in age of women tested would aid in identifying possible physical health-related components where intervention may impact positive changes in their overall health status.

1.5.1.1 Body composition

Using the basic two-compartment model of body composition, body mass (kg) can be divided into: fat-free mass (FFM) and fat mass (FM).[79] Fat-free soft tissue mass (FFSTM) forms part of FFM, while adipose tissue (or body fat [BF]) is part of FM. All of which can also be expressed relative to total body mass (i.e. %FFM, %FFSTM and %BF).

As a component of health-related fitness, recognition of changes associated with each of these compartments are vitally important. Thus, obesity, and in particular central adiposity, as previously discussed, is recognised as an intermediate cardiometabolic risk factor for CVD and T2DM. Sarcopenia, which refers to the generalised loss of skeletal muscle mass,[80] is a sub-compartment of FFSTM and is associated with an increased risk for disability and mortality.[81] However, an added adverse effect of a reduction in FFSTM relates in part to the lowering of daily resting metabolic rate (RMR) and total energy expenditure (TEE).[82] These, in turn, have been shown to affect body weight management, and most notably, weight gain.[82]

1.5.1.2 Muscular strength

Muscular strength refers to the external force that is either generated by a specific muscle or group of muscles.[83] It is usually expressed in kg, however, correctly quantified in newton of force. Specific

focus drawn to maintaining or improving muscular strength can potentially counter the adverse effects associated with sarcopenia and the maintenance of, or increase in RMR.[84]

1.5.1.3 Cardiorespiratory fitness

"*The ability to perform large muscle, dynamic, as well as moderate to vigorous-intensity exercise for prolonged periods of time*," provides a broad description of CRF.[83] Furthermore, it describes the ability to perform exercise at higher levels of physical exertion and the integration of numerous physiological systems working in unison (i.e. cardiovascular, respiratory, neurological and musculoskeletal system, respectively). Thus, CRF is considered a reflection of total body health[85] and/or physical wellness.

1.5.2 Physical health-related fitness benefits among adult women

Based on an already extensive and still growing body of scientific evidence it is clear that adult women with higher levels of CRF have significantly lower all-cause mortality risk, especially CVD.[140,141] Noticeably, higher CRF levels are also associated with higher habitual PA.[83] It is important to highlight that PA differs to CRF, as described by Carthenon et al.[168] Physical activity is described as a behaviour (lifestyle choice), whereas CRF is a physiological measure that reflects a combination of PA behaviours, genetic potential and functional health of several organ systems. [168] Researchers estimate that 40–50% of the variance in CRF is genetically determined (i.e. heritable factors),[142] whereas improvements in CRF level in response to PA or exercise (i.e. trainability) accounts for the remaining proportion (i.e. 45–50%).[143] Given this, improvement of CRF level as a component of physical health-related fitness maybe considered a beneficial and significant influencing factor which attenuates the adverse effects of obesity on cardiometabolic disease risk for CVD and T2DM. To this end, the "fat-but-fit" paradox[144] and subsequent evidence [21,145] suggest that a moderate-high CRF level may in part, counteract the negative consequences associated with obesity. In other words, individuals who are obese according to BMI ($\geq$ 30kg/m^2) and/or %BF ($\geq$ 30%), but have a relatively good CRF level are better off than those who are obese and aerobically unfit. [169]

1.5.3 Physical health-related fitness: measurement methodologies

1.5.3.1 Body composition

Although the use of BMI, WC and Waist:Hip are cost- and time-effective measurements, they have limitations.[93,94] The use of scanning equipment, such as dual energy x-ray absorptiometry (DXA), allows for whole body composition measurement and includes the use of the basic two-compartment model, to determine FFSTM and FM (kg). FFSTM is defined as total body mass minus FM. Furthermore, the sophisticated and technical measurement allows for regional body fat distribution to be measured, e.g. central fat mass (CFM), appendicular fat mass (AFM) and trunk fat mass (TFM) (defined as CFM minus the head).[95] However, as with other techniques used to quantify body composition, its use is limited in lieu of exposure to low-dose radiation, cost, scanning area, and the requirement of a highly trained professional (e.g. radiologist). Nevertheless, advances have been made to adjust for those whose body proportions exceed the DXA scanning area,[96] as well as the measurement of total VAT area[97] as an indicator of central adiposity.

1.5.3.2 Muscular strength

A hand grip dynamometer is commonly used to determine dominant hand grip strength as a proxy measure of upper body strength.[83] A one repetition maximum (1-RM) supine bench press exercise test can also be used,[83] however, the risk of incurring a musculoskeletal-related injury is significantly higher and requires technical assistance from a trained exercise specialist. Thus, the hand grip test remains a convenient field test when testing large groups of individuals who are not familiar with 1-RM testing. The use of hand grip strength testing using a dynamometer among adult community-dwellers has been shown to have adequate test-retest reliability (r = 0.981) and reasonable validity (r = 0.798).[170] Furthermore, results from numerous studies [171, 172] recommend its clinical usage as a means to stratify an individual's risk of all-cause mortality,[171] as well as cardiometabolic disease specific causes (e.g. CVD[171] and T2DM[172]).

1.5.3.3 Cardiorespiratory fitness

Maximal volume of oxygen (O_2) uptake per unit of time (VO_{2max}) or maximal aerobic capacity, is accepted as the criterion measure of CRF.[83] This physiological variable is generally expressed in relative ($mL \cdot kg^{-1} \cdot min^{-1}$) rather than absolute (mL/min) terms, thus allowing comparisons between

individuals with differing body masses. Use of indirect calorimetry such as a metabolic cart system (e.g. COSMED Quark CPET®), allows for various metabolic variables (i.e. cardiopulmonary response) to be measured continuously while exercising to volitional exhaustion. Although the equipment and need of a highly-trained exercise physiologist associated with the use of the criterion measure is costly, its use eliminates the limitations associated with indirect measurement techniques (e.g. graded sub-maximal step-test).[98]

Data by Hall-López et al.[173] indicate an acceptable test-retest reliability (r = 0.907) among apparently healthy adults tested on two separate occasions (i.e. exercising to exhaustion on a treadmill). Furthermore, results from a large meta-analysis[173] confirm the inverse and strong relationships between high CRF levels and all-cause mortality among apparently healthy adult women. More importantly, the results also indicate that an increase in CRF (i.e. VO_{2max}) to the value of 1 MET, which equates to 3.5 mL of O_2 per kilogram per minute, is associated with an approximate 10-20% reduction in all-cause mortality.

1.5.4 Physical health-related fitness measurements among SA women

Evidence suggest that body composition vary not only with age and sex, but also with race.[138] As previously described, the prevalence of severe obesity among "Coloured" and "Black (African)" women is of greatest concern (Figure 1.6 and 1.7).[35] Of equal concern is the emerging evidence of the prevalence of sarcopenia and its associated risk with low levels of PAEE as recently reported by Kruger et al.[139] among urban and rural "Black (African)" women from the North West Province in South Africa. On examination, the DXA-derived body composition data indicated high levels of adiposity (%BF) (mean ± SD: 39.6 ± 8.7%) even among those who were diagnosed with sarcopenia (%BF: 30.4 ± 5.5%) and among women with low levels of lean body mass (mean age: 57 yrs) (n = 220).

There is a scarcity of SA data on muscular strength and CRF levels among adult women. The studies summarised in Table 1.3 indicate both the measurements and methods used. To my knowledge, only one small-scale study[92] reported significant associations between high CRF level and reduced central adiposity (TFM and VAT) and insulin resistance (i.e. HOMA-IR) among urban "Black" obese women.

Table 1.3 Summary of SA studies investigating components of physical health-related fitness with intermediate cardiometabolic disease risk factors for CVD and T2DM in women from different settings and racial categories.

Reference	**Study design (name of study/survey) (*n*)**	**Age in yrs (range/mean)**	**Racial categories**	**SA Province (urban/rural)**	**Measures of physical health-related fitness (cardiorespiratory fitness and muscular strength)**	**Measures of cardiometabolic disease risk**	**Findings**
Terblanche et al., 2005[146]	Intervention study (*n* = 26) (Training group, *n* = 13) (Untrained control group, *n* = 13)	18 to 23	Unknown	Western Cape	Estimated VO_{2max} measured using a 20-metre shuttle test protocol (before and after 6-weeks training intervention)	BMI and %BF (SSF: 7 skinfolds)	After 6-weeks of backward walk/run training, the trained group showed significant decreases in %BF (2.4%), skinfold thickness (19.7%) ($p < 0.01$) and a significant increase in VO_{2max} (5.2%) **Did not examine associations between estimated VO_{2max} and BMI, WC or SSF**
Cook et al., 2009[10]	Part 2: Cross-sectional (DHDSS) *n* = 138 (2003/2004)	19 to 56	"Black (African)"	Limpopo (rural)	Estimated VO_{2max} (Submaximal *Siconolfi* step-test[147]	BMI, WC, adiposity (SSF), SBP and DBP	Mean predicted VO_{2max}: 26.7 $mL \cdot kg^{-1} \cdot min^{-1}$ (95% CI: 25.6 to 27.7) **Did not examine associations between estimated VO_{2max} and BMI, WC or SSF**

Reference	**Study design (name of study/survey) (*n*)**	**Age in yrs (range/mean)**	**Racial categories**	**SA Province (urban/rural)**	**Measures of physical health-related fitness (cardiorespiratory fitness and muscular strength)**	**Measures of cardiometabolic disease risk**	**Findings**
Shisana et al., 2013[34]	National survey (SANHANES-1 [2012]) *n* = 1 524	18 to 40	"Black (African)", "Coloured", "White"*, "Asian/Indian"* (* – too few observations to record reliability)	All SA provinces except the Northern Cape* (* – too few observations to record reliability)	Estimated VO_{2max} (submaximal 3-minute step-test based on the Canadian Public Health Association Project[148]	BMI, WC, WHR, SBP, DBP, TC, LDL-C, HDL-C, TG and HbA1c	<u>Total group:</u> 42% fit, 13% average, 45% unfit 18 to 24 yrs: 38% fit, 12% average, 50% unfit 25 to 29 yrs: 46% fit, 11% average, 43% unfit 30 to 40 yrs: 45% fit, 15% average, 40% unfit <u>Race sub-groups:</u> "Black (African)" women – 43% fit, 14% average, 43 unfit "Coloured" women – 30% fit, 8% average, 62% unfit **Did not examine associations between estimated VO_{2max} and cardiometabolic risk factors**

Reference	**Study design (name of study/survey) (*n*)**	**Age in yrs (range/mean)**	**Racial categories**	**SA Province (urban/rural)**	**Measures of physical health-related fitness (cardiorespiratory fitness and muscular strength)**	**Measures of cardiometabolic disease risk**	**Findings**
Dickie et al., 2016[92]	Cross-sectional *n* = 46 (Sub-sample)	34	"Black (African)"	Western Cape (urban)	Estimated VO_{2max} (submaximal MRC step-test, Cambridge, United Kingdom[149]:	BMI, WC, DXA-derived %BF, CT-derived VAT and SAT, TC, LDL-C, HDL-C, TG, FPG, fasting serum insulin and HOMA-IR	Median predicted VO_{2max}: 25.1 $mL \cdot kg^{-1} \cdot min^{-1}$ (IQR: 22.8 to 28.4) **Inverse associations between:** **Estimated VO_{2max} and DXA-derived %BF (*r* = -0.34, *p* = 0.02)** **VO_{2max} and trunk FM (*r* = -0.31, *p* = 0.03)** **VO_{2max} and VAT (*r* = -0.47, *p* < 0.01)** **VO_{2max} and HOMA-IR (*r* = -0.41, *p* = 0.01) (remained significant after adjusting for differences in body fat [kg], but not with VAT.**
Kruger et al., 2016[150]	Cross-sectional (Prospective Urban and Rural Epidemiological [PURE] study) *n* = 247	57	"Black (African)"	North West (urban and rural, Tlokwe municipal area)	Hand grip strength (kg)	BMI and DXA-derived %BF	Mean ± SD: 20.4 ± 6.7 kg **Did not examine associations between hand grip strength and any of the cardiometabolic risk factors**

Reference	**Study design (name of study/survey) (*n*)**	**Age in yrs (range/mean)**	**Racial categories**	**SA Province (urban/rural)**	**Measures of physical health-related fitness (cardiorespiratory fitness and muscular strength)**	**Measures of cardiometabolic disease risk**	**Findings**
Prioreschi et al., 2017[125]	Cross-sectional observational *n* = 191	19 to 20	"Black (African)"	Gauteng (urban) (Soweto informal settlement)	Estimated VO_{2max} (submaximal MRC step-test, Cambridge, United Kingdom[149]:	BMI	BMI: 23.9 kg/m^2 According to BMI category: 12% = underweight; 53% = normal weight; 12% = overweight; 9% = obese Mean predicted VO_{2max}: 32.6 mL·kg^{-1}·min^{-1} (95% CI: 31.9 to 33.2) Estimated VO_{2max} was higher in underweight compared to overweight and obese women ($p < 0.0001$) **Did not examine any associations between estimated VO_{2max} and BMI**
Goedecke et al., 2018[151]	Intervention study (*n* = 45) (Exercise group, *n* = 23) (Control group, *n* = 22)	20 to 35	"Black (African)"	Western Cape (urban)	Estimated VO_{2peak} measured using a graded exercise treadmill test and modified Bruce protocol (before training intervention and after 12-weeks)	BMI, WC, WHR, DXA-derived %BF, VAT and SAT, serum lipid and inflammatory profile, fasting glucose	Baseline VO_{2peak} : Exercise group: 24.9 ± 2.9 mL·kg^{-1}·min^{-1} vs. Control group: 23.9 ± 3.0 mL·kg^{-1}·min^{-1} **Did not examine any associations between estimated VO_{2peak} and any of the cardiometabolic risk factors**

1.5.4.1 Summarised findings of Table 1.3

In summary, the data extracted from the SANHANES-1 (2012)[34] indicates the higher prevalence of unfit adult women (45%) compared to those deemed to be fit (42%). Although the use of the submaximal step test to estimate CRF level may be seen as a limitation, the survey provides valuable data on CRF ratings (i.e. fit vs. unfit) across the four age categories, and indicates the need for interventions aimed at increasing CRF level among women aged 20 – 40 yrs. In support of this, are the statistically significant inverse associations between CRF level and DXA-derived adiposity measures (%BF, trunk FM and VAT) as reported by Dickie et al.[92] Such findings highlight the potential health benefits associated with higher CRF levels.

Only one study[150] reported muscular strength obtained from hand grip strength testing. In comparison to the American College of Sport Medicine's age-specific muscular strength categories for women, the group mean of 20.4 ± 6.7 kg falls between the 25th and 30th percentiles for women aged 50 – 57 yrs, and thus is rated as "poor".

Given the paucity of physical health-related fitness data on SA women, there is a need for future studies and national surveys to include such measures. The results of which may assist in the design of context-specific lifestyle interventions aimed specifically at women who are obese, sarcopenic, or both, as well as unfit and with low levels of muscular strength.

1.6 Conclusion

In conclusion, it is in my view worthwhile to further explore the prevalence and risk for obesity, sarcopenia, and moreover, sarcopenic obesity among SA women. If, at the same time, one can objectively measure whole body and central adiposity, muscular strength and CRF levels, time spent physically active and sedentary, it would provide valuable information on numerous known cardiometabolic disease risk factors and the inter-relationships between these factors. Furthermore, it is imperative that we obtain a comprehensive view of the health states of women in SA, as they are the backbone of all communities.

1.7 Doctoral dissertation overview

1.7.1 Research gap and location of interest

Evaluation of the SA National Demographic and Health survey and examination statistics captured since 1998 indicate a significant and steady rise in the prevalence of cardiometabolic disease risk associated with CVD and diabetes mellitus among adults.[35,44,152] Of major concern is the higher prevalence of BMI-defined obesity (≥ 30.0 – 34.9 kg/m^2) and moreover, the increasing prevalence of severe BMI-defined obesity (≥ 35.0 kg/m^2) among women 15 years and older. In accordance with more recent national health data, one in every five women are severely obese. Thus, a considerable difference exists between women and their male counterparts (20.0% vs. 3.0%, respectively). Overall, these statistics underscore women's potentially higher-risk for CVD and T2DM.

Given the review of SA literature, existing cardiometabolic disease risk data only reflects that of urban women living in Cape Town (Western Cape Province). The latter is currently considered the second highest population dense metropolitan urban area to that of Johannesburg (Gauteng Province) in South Africa (Figure 1.19).

Figure 1.19 A map of the nine SA provinces.[153]

An important factor is the higher number of public and private health service facillities in these larger metropolitan urban areas, compared to those in surrounding non-metropolitan urban areas. Thus, the town of Stellenbosch, and in particular one of its neighbouring residential suburbs, namely Cloetesville have fewer health care facilities compared to the metropolis (Figure 1.20).

Figure 1.20 Location of interest: Cloetesville - considered an urban residential suburb neighbouring the town of Stellenbosch (Western Cape, South Africa).[154]

Cloetesville is largely considered a traditional "Coloured" residential area or "township", which under the Apartheid system was used to describe an under-developed urban residential area reserved for those who were considered racially non-white.[155] To date, Cloetesville's population approximates 15 390, of which 81.8% (*n* = 12 589) are categorised as "Coloured" (women vs. men: 52.6% vs. 47.4%).[156] With only one district public health community clinic and a few privately registered health-care practitioners, the suburb provides a suitable urban setting for this cross-sectional descriptive study.

1.7.2 Problem statement

In response to the SA National Department of Health's call to action, there is a need to investigate key determinants of obesity in specific communities, over and above those already outlined in the Strategy for the Prevention and Management of Obesity (2015 – 2020) national policy document.[8] Rapid urbanisation, the lack of quality education and a safe and accessible environment, have been identified as contributing factors to the overwhelming prevalence of obesity. Given South Africa's diverse settings (i.e. urban vs. rural), as well as the large body of evidence showing different obesity-

related risk profiles for CVD and T2DM among urban SA women,[52,157,158,159] studies investigating those from other low socio-economic and under-resourced residential settings, using accurate and reliable methods, are required. Additionally, it is important to investigate to what extent behavioural/lifestyle risk factors, such as physical inactivity and sedentarism, as well as poor health-related fitness levels, predict cardiometabolic disease risk outcomes associated with CVD and T2DM in the said community.

1.7.3 Potential benefits of the study

A comprehensive and detailed investigation will allow the characterisation of cardiometabolic disease risk profiles for CVD and T2DM, including the prevalence of obesity and central adiposity of the selected study population. The strength of this study is the use of sophisticated and high-precision measurements, including objectively-derived PA variables, sedentary time and physical health-related fitness measures. This broad examination also allows for the exploration of the association between behavioural/lifestyle entities and components of physical health-related fitness, with cardiometabolic disease risk in urban-dwelling SA women. All of which is critically important, in order to develop context-specific community-based lifestyle interventions, especially in under-resourced residential areas, aimed at managing and reducing the burden of NCDs.

1.7.4 Primary and secondary aims of the study

The primary aim of this study is to characterise behavioural/lifestyle entities, namely PA levels (time and intensities), sedentary behaviour (time) and physical health-related fitness (CRF level and muscular strength), using objective methodologies. Furthermore, to characterise cardiometabolic disease risk profiles, including the prevalence of obesity and central adiposity, among a sample of apparently healthy women (aged: 18 – 64 yrs) living in Cloetesville, a low socio-economic and under-resourced urban residential area near Stellenbosch (Western Cape, South Africa).

Secondary aims of the study include: i) the use of subjective measurement tools to characterise patterns of PA and types of sedentary behaviour; and ii) the investigation of the associations between PA time, sedentary time, and health-related fitness components (e.g. CRF level and muscular strength) with cardiometabolic disease risk for CVD and T2DM.

1.7.5 Research study hypotheses

1.7.5.1 Article 1

Using objectively-derived MVPA time, it is hypothesised that urban women from a low-socioeconomic community who are insufficiently active (< 30 min/day)[17] are at higher risk for CVD and T2DM compared to those who are sufficiently active (i.e. meet the WHO 2010 Global Recommendations on PA for Health).[17]

1.7.5.2 Article 2

Using objectively-derived PA data, it is hypothesised that, similar to other SA women,[92] high PA (irrespective of intensity) and CRF levels are independently associated with reduced adiposity and cardiometabolic disease risk outcomes for CVD and T2DM in urban-dwelling women.

1.7.5.3 Article 3

We hypothesise that objectively measured high sedentary time (ST), low MVPA and low measures of physical health-related fitness (e.g. CRF level and muscular strength), are independently associated with an unfavourable cardiometabolic disease risk profile in urban women.

CHAPTER 2

ARTICLE ONE:

PHYSICAL ACTIVITY AND CARDIOMETABOLIC DISEASE RISK PROFILES OF SOUTH AFRICAN WOMEN FROM A LOW SOCIO-ECONOMIC URBAN COMMUNITY

Article to be submitted to BMC Public Health and presented in accordance with the author guidelines (Appendix D)

Kasha Dickie, Carla Coetsee, Sharné Nieuwoudt, Louise Engelbrecht, Elmarie Terblanche

Department of Sport Science, Faculty of Medicine and Health Sciences, Stellenbosch University, Private Bag X1, Matieland, 7601, South Africa

Short Title: Cardiometabolic disease risk in urban South African women

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Contributions to the research article

Ms Kasha Dickie was involved in the conception and design of the research study, data cleaning and analysis, the drafting and writing of the manuscript, as well as the general management of the research group. Prof Elmarie Terblanche was involved in the conception and design of the research study, assisted and guided the statistical analysis, and the writing and editing of the manuscript. Dr Carla Coetsee assisted with data collection, and editing of the manuscript. Ms Sharné Nieuwoudt and Ms Louise Engelbrecht assisted with data collection, data cleaning and analysis.

2.1 Abstract

Background: Physical inactivity is associated with an increased risk for cardiometabolic diseases such as cardiovascular disease (CVD) and type 2 diabetes mellitus (T2DM). Few studies to date have described the levels and patterns of physical activity (PA) of urban South African (SA) women from an under-resourced and low socio-economic residential area. **Aims:** To characterise PA levels and patterns in urban-dwelling women and to determine if women who are sufficiently active have a more favourable cardiometabolic disease risk profile compared to those who are insufficiently active. **Methods:** Fifty-one apparently healthy women (42 ± 13 yrs) underwent the following measurements: PA (GPAQ and accelerometry), body composition and regional fat distribution (DXA), resting BP, HbA1c, fasting plasma glucose and lipid levels. **Results:** Less than a third of the women (27.4%, n = 14) met the World Health Organisation Global Health Recommendations for moderate to vigorous-intensity PA (MVPA). Although overweight, the sufficiently active sub-group had a significantly lower BMI (p = 0.01), FM (p = 0.02), AFM (p = 0.01) and hip circumference (p = 0.001), compared to their obese and insufficiently active counterparts. Although no statistically significant group differences were found for any of the cardiometabolic disease risk outcomes (p > 0.05), clinically significant differences were observed for DBP, LDL-C, Lp (a) and FPG. **Conclusion:** Although overweight, women who accumulated ≥ 30-min of MVPA per day presented with more favourable body composition and regional body fat measures, compared to those who did not. The cardiometabolic disease risk among the sufficiently active women was meaningfully lower than those deemed insufficiently active. In an attempt to combat cardiometabolic disease risk for CVD and T2DM among urban and low socio-economic community dwelling women, public health interventions should target domains in which women are already physically active, such as walking briskly for travel- and/or occupational-related activities. Furthermore, public awareness of the health-enhancing benefits associated with meeting MVPA recommendations must be intensified.

Keywords: Physical activity, accelerometry, cardiometabolic disease risk

2.2 Background

Evidence from longitudinal cohort studies conducted in high-income countries [1, 2] highlight the positive association between physical activity (PA) and reduced risk for non-communicable disease (NCD). Consequently, the World Health Organisation (WHO), the Centers for Disease Control and Prevention (CDC), the American College of Sports Medicine (ACSM) and the American Heart Association (AHA) established and advocate PA guidelines in an attempt to reduce overall NCD risk [3–5]. According to the most recent document, the WHO 2010 Global Recommendations on Physical Activity for Health [5], adults between 18 – 64 yrs are required to accumulate ≥ 75 min/week of vigorous-intensity PA; or ≥ 150 min/week of moderate-intensity PA; or an equivalent weekly combination of moderate to vigorous-intensity physical activity (MVPA) to be considered sufficiently active. Thus, the quantification and accuracy of PA data is crucially important in studies investigating its association with cardiometabolic disease risk outcomes for cardiovascular disease (CVD) and/or type 2 diabetes mellitus (T2DM).

Presently, a multitude of PA methodologies exist and while the use of subjective instruments (e.g. questionnaires and activity logs) are cheaper and easier to administer, the data lacks consistency when compared with data obtained from objective instruments (e.g. accelerometers and pedometers). Given the variability in methodological effectiveness [6], opportunities to examine both PA levels and patterns (i.e. time, intensity, and domain) using both instrumentation types, allow for an in-depth understanding of population sub-groups (e.g. obese individuals) [7]. The Global PA Questionnaire (GPAQ), which forms part of the WHO Stepwise approach to chronic disease risk factor surveillance (STEPS), includes work-, travel- and leisure-specified PA domains. Given its validity in a South African (SA) setting [8], results from the last comprehensive national demographic survey (2003) revealed that 86% of adult women (88% urban vs. 83% rural) are insufficiently active (< 3000 MET-min/week) [9]. Even though total PA time among the urban sub-group was insufficient for health-enhancing benefits, leisure-domain PA time (54%) was proportionally higher compared to work- (18%) and travel-domain PA time (28%) [9].

The predominance of insufficient PA levels among SA adult women is concerning, however, the steady increase in the prevalence of obesity (27 to 44% in 2003 and 2016, respectively) [9,10] and

cardiometabolic disease over the same period of time among adult women (CVD: 5–30% and diabetes mellitus: 4–8%) is even more alarming [9,10]. One in five SA adult women are categorised as severely obese, with higher proportions among urban vs. rural adult women (22.3% vs. 17.0%, respectively) [10].

Evidence from large women cohort studies consistently show an inverse relationship between PA and cardiometabolic disease risk [1, 2, 11]. Notably, the Objective Physical Activity and Cardiovascular Health study (OPACH) report that accelerometer-derived PA time is positively associated with reduced cardiometabolic disease risk among a diverse ethnic group of adult women (i.e. "White", "Black" and "Hispanic") [11]. In line with this finding are those from a small-scale SA cross-sectional study in which higher levels of accelerometer-derived PA time was shown to associate with reduced cardiometabolic disease risk, although limited to only urban "Black (African)" women [12]. Moreover, the national survey results highlighted that "Coloured" women (92%) are the most insufficiently active among all racial sub-categories ("White" 89%, urban "Black (African)" 88%, "Indian" 83% and rural "Black (African)" 82%) [9]. Thus, the need to profile PA and cardiometabolic disease risk, especially among women from other low socio-economic urban settings who are already obese and prediabetic, is warranted [13].

Therefore, the aim of this study was two-fold: (i) to characterise PA levels and patterns in women from an under-developed urban residential setting; and (ii) to determine whether those who are sufficiently active have a more favourable cardiometabolic disease risk profile compared to those who are insufficiently active. We hypothesised that urban and low socio-economic dwelling women who are insufficiently active are at higher risk for CVD and T2DM compared to those who meet the WHO Global Health Recommendations for MVPA [5].

2.3 Materials and methods

2.3.1 Location of interest

Located on the outskirts of Cape Town is the town of Stellenbosch, which neighbours the urban suburb of Cloetesville. According to the Bureau for Economic Research [14], Cloetesville is classified as a low socio-economic community as determined by the average monthly income of residents employed, their

highest level of education and access to basic services. Furthermore, its population approximates 15 390 of which 31% are women (≥ 20 yrs) [15].

2.3.2 Study participants

A convenience sample of 73 apparently healthy women volunteered to participate in this cross-sectional study. Women were recruited from local church groups, the public health clinic and community centre, and via "word of mouth" (Figure 2.1).

An Afrikaans-speaking health champion, living in Cloetesville, assisted with the participant recruitment. Participants were included if they were: i) 18–64 yrs old; ii) had no known diseases and were not taking medications for T2DM, human immunodeficiency virus (HIV) or acquired immune deficiency syndrome, or any other metabolic diseases; iii) not pregnant or lactating; and iv) had any known musculoskeletal problems that prevented them from being physically active. Rapid HIV screening tests were not performed, however, women were asked if they were receiving treatment for HIV. Study procedures and potential risks were explained to each participant in their preferred language (Afrikaans or English) following which written informed consent was received. Approval of the study was granted by the Human Research (Humanities) Ethics Committee (SU-HSD-004704).

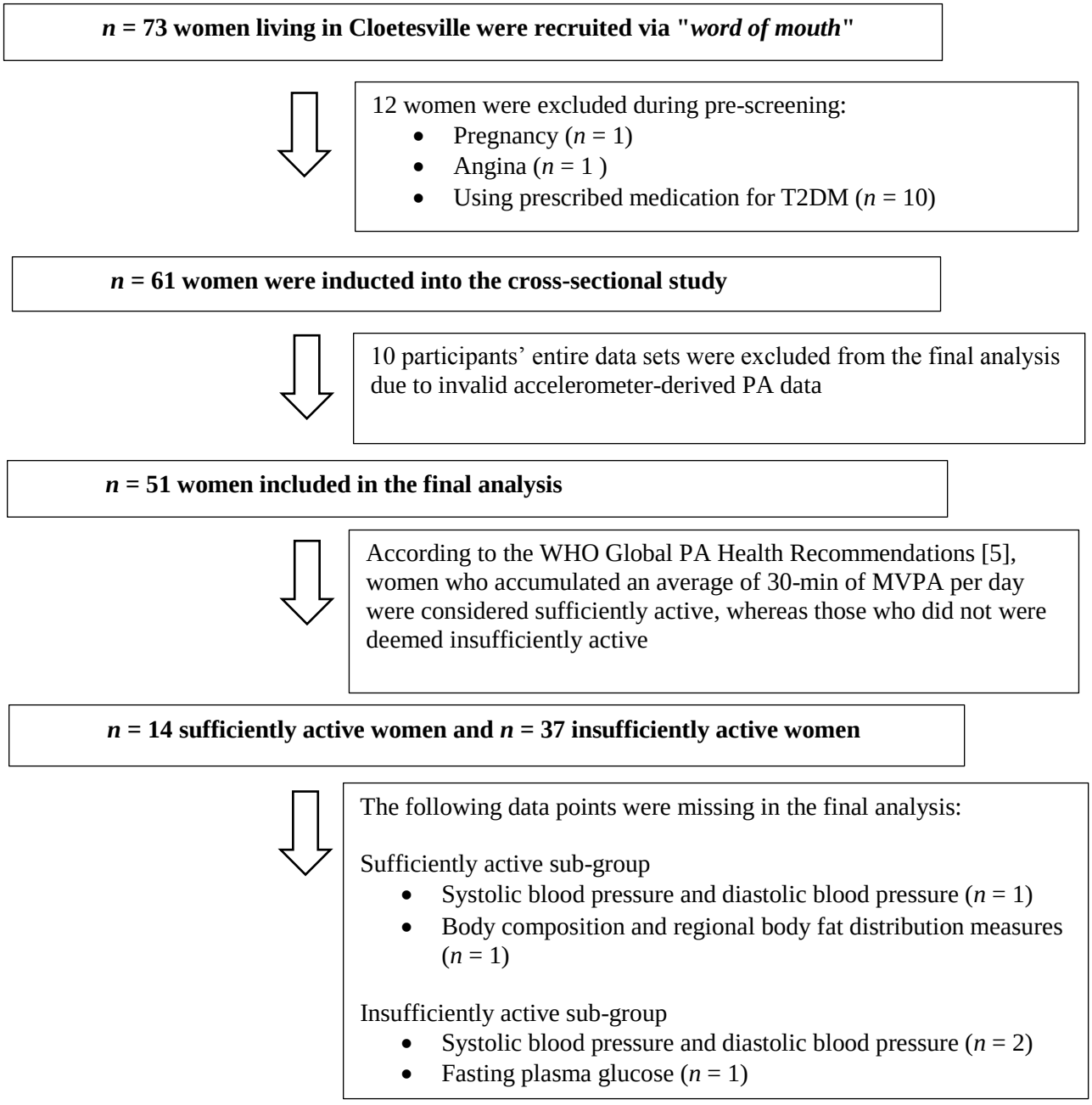

Figure 2.1 A flow diagram showing the participants included in the whole and sub-groups data analysis.

2.3.3 Physical activity

PA was measured for 7 consecutive days using the triaxial ActiGraph GT3X accelerometer (ActiGraph LLC, Pensacola, Florida). Recording began on the first day of testing, 2-hours after the monitor was received, and was completed when returned 8-days later. Participants were instructed to wear the accelerometer on their right hip, attached by an elastic belt during waking hours. As the monitors were not waterproof, the women were asked to remove the belt while bathing, showering or swimming. The time sampling interval was set at 60-sec epochs. The original ActiGraph data files (*.agd) were downloaded onto a personalised computer and processed using Microsoft® Excel using a custom-written program ('ACTILIFE', http://actigraphcorp.com/products-showcase/software/actilife/). Data from participants were included if they met the minimum requirement of ≥ 600-min of monitor wear time on ≥ 3-days of the week) [16]. Wear time was determined by subtracting non-wear time from 24-hours, where non-wear time was defined as an interval of ≥ 60 consecutive min with zero activity counts allowing for intervals of 1 to 2-min of relatively low activity counts per minute (counts/min) (i.e. < 100) [16]. Ten participants were excluded from the whole group analysis due to invalid accelerometer data. Sedentary time was defined as < 100 counts/min, whereas total PA time (≥ 100 counts/min) was divided into light-intensity PA (LPA) (100–1,951 counts/min) and MVPA (≥ 1,952 counts/min) [17]. In accordance with the WHO 2010 Global Recommendations on Physical Activity for Health [5], women who accumulated an average of 30-min of MVPA per day were considered sufficiently active, whereas those who did not were grouped as insufficiently active. The GPAQ provided descriptive PA data (min/week) according to the work-, travel- and leisure-domains [18]. One participant was excluded from this data set due to invalid data.

2.3.4 Socio-economic status and behavioural/lifestyle factors

Measures of socio-economic status (SES), including level of education (completion of grade 12) and employment status, were recorded using the WHO STEPS instrument [19]. Participants were categorised as employed or unemployed, while students, homemakers and retirees were grouped together in a separate category. Women were categorised as either smokers or non-smokers, whereas those who reported alcohol consumption (≥ 4 drinks per month) were categorised as consumers of alcohol.

An additional proxy measure of SES, an asset index score, was calculated and based on the 14-items used by Jennings et al. [20] and other researchers among urban SA women [21,22]. Ownership of items which are said to reflect individual and household wealth, as well as access to resources were determined. These included electricity in the home, ownership of a television, radio, motor vehicle, fridge, stove and oven, washing machine, telephone, DVD player, microwave, computer/laptop, cellular telephone and paid television channels.

2.3.5 Body composition assessment

Standing height and body mass, in lightweight clothing and without shoes, were measured using a sliding steel anthropometer (Seca® 711, Hamburg, Germany) and calibrated digital scale (Seca® 813, Hamburg, Germany), respectively. Hip circumference at the greatest protuberance of the buttocks and waist circumference (WC) at the level of the umbilicus, were both measured.

Whole body composition, including fat-free soft tissue mass (FFSTM) and fat mass (FM), were measured by dual-energy x-ray absorptiometry (DXA) (Discovery-W®, software version 13.4.1, Hologic, Bedford, MA) according to standard procedures. The DXA scan region was 195 × 65 cm and the DXA system weight limit was 310 kg. Those participants whose body proportions exceeded the DXA scanning area (n = 11) were analysed using the arm-replacement method which replaces the data obtained for the left arm with the data obtained for the right arm [23]. FFSTM was defined as total body mass minus FM. Regional body fat distribution was characterised as central fat mass (CFM) and appendicular fat mass (AFM) [24]. Visceral adipose tissue (VAT) area was determined using the DXA-VAT derived methodology [25]. Due to a technical computer software error, one participant's body composition data was reported missing.

2.3.6 Cardiometabolic disease risk outcomes

Blood pressure (BP) was measured after at least 5 min of seated rest, and three times in succession at 1 min intervals, using an appropriate-sized cuff and an automated BP monitor (Omron® HBP-1100, Omron

Healthcare, Mannheim, Germany). An average of the last two readings were used for the analysis. Three data sets were incomplete due to participants' refusal to have their BP measured more than once.

Participants were asked to fast overnight for a minimum period of 8 hours. On arrival at the testing site, blood samples were drawn by a trained nurse. The samples were analysed by a local commercial pathology laboratory (PathCare, Stellenbosch, South Africa). Using enzymatic colorimetric assays, serum total cholesterol (TC) (intra-assay CV: 0.72%), low-density lipoprotein cholesterol (LDL-C) (intra-assay CV: 1.3%), high-density lipoprotein cholesterol (HDL-C) (intra-assay CV: 0.62%), triglyceride (TG) (intra-assay CV: 0.72%) concentrations, and fasting plasma glucose (FPG) level (intra-assay CV: 0.54%) were measured using the Beckman AU5800 instrument (Beckman Coulter Inc., Fullerton, California, USA). Plasma lipoprotein (a) [Lp (a)] was measured using an IMMAGE 800 Immunochemistry System (Beckman Coulter Inc., Fullerton, California, USA). glycated haemoglobin (HbA1c) was performed on a Biorad Variant™ II Turbo (Bio-Rad Laboratories, Inc., Hercules, California, USA) (intra-assay CV: 1.2%). Only one participant's FPG level was missing due to an inadequate plasma concentration.

2.3.7 Statistical analysis

Data were analysed using STATISTICA version 13.3 (StatSoft Inc. Tulsa, OK, USA). Descriptive data are presented as means ± standard deviation (SD) or percentages. Non-gaussian distributed data (accelerometry, GPAQ, FPG and HbA1c) are presented as medians and interquartile range (IQR) and were normalised by log transformation for parametric statistical analyses. Chi-squared tests for independent groups were used to examine differences in categorical data (i.e. SES, behavioural/lifestyle factors and cardiometabolic disease risk factors and sub-categories). One-way analysis of variance (ANOVA) was used to compare age, asset index, body composition and regional body fat distribution measures between sub-groups. A two-way analysis of covariance (ANCOVA) adjusting for: i) body mass; and ii) fat mass (kg), was used to compare cardiometabolic disease risk measures between sub-groups. Statistical significance was set at $\alpha = 0.05$.

Additionally, Cohen's *d* effect size (ES) and 90% confidence intervals (CI) were calculated to assess the magnitude of the differences between the sub-groups [26, 27]. A published spreadsheet was used to make qualitative probabilistic inferences about the "true" differences which were classified as either small, moderate or large clinically significant differences between sub-groups [28]. Quantitative likelihoods of the true differences between sub-groups were assessed as follows: 0–0.5% (most unlikely); > 0.5–5% (very unlikely); > 5–25% (unlikely); > 25–75%, (possibly); > 75–95% (likely); > 95–99.5% (very likely); > 99.5–100% (most likely) [28]. Threshold values for Cohen's *d* ES were: < 0.2 (trivial), ≥ 0.2 (small), ≥ 0.6 (moderate) and ≥ 1.2 (large) [26, 27].

2.4 Results

2.4.1 Physical activity levels and patterns

Total PA time (min/week) for the whole group and sub-groups according to intensity bands (LPA and MVPA) are presented in Table 2.1.

Table 2.1 Physical activity time measured using accelerometry for the whole group and comparison between sub-groups.

Accelerometry	**All (*n* = 51)**	**Sufficiently active (*n* = 14)**	**Insufficiently active (*n* = 37)**	***P*-value**	**ES (90% CI) for the difference in log transformed mean values**	**Magnitude-based inferences**
Number of activity days measured	5 (5 - 6)	6 (5 - 6)	6 (5 - 6)	0.547	-0.02 (-0.5; 0.4)	trivial difference
Non-wear time (min/day)	611 (542 - 636)	573 (542 - 612)	622 (546 - 667)	0.053	-0.63 (-1.1; -0.1)	78% (likely) moderate difference
Wear time (min/day)	829 (801 - 898)	866 (827 - 898)	817 (772 - 893)	**0.040**	0.68 (0.1; 1.2)	34% (possibly) moderate difference
Sedentary time (min/day)	475 (442 - 514)	485 (438 - 527)	470 (443 - 510)	0.813	0.08 (-0.4; 0.5)	trivial difference
Total PA time (min/day)	365 (308 - 404)	386 (364 - 429)	345 (301 - 381)	0.171	0.44 (-0.1; 0.9)	76% (likely) moderate difference
LPA time (min/day)	340 (282 - 374)	351 (286 - 382)	338 (279 - 370)	0.983	-0.01 (-0.5; 0.5)	trivial difference
MVPA time (min/day)	22 (12 - 30)	42 (34 - 59)	18 (8 - 23)	**< 0.001***	2.07 (1.4; 2.6)	96% (very likely) large difference
Steps per day	8 232 (6 032 - 9 871)	11 686 (9 788 - 13 245)	6 296 (5 375 - 8 556)	**< 0.001***	1.65 (1.0; 2.2)	88% (likely) large difference

Values are medians with interquartile ranges in parenthesis (*n*). All values were normalised by log transformation for parametric analyses (ANOVA). *P*-values highlighted in bold indicate statistically significant differences ($p < 0.05$) between sub-groups (*). Sufficiently active women accumulated an average of 30-min/day of accelerometer-derived moderate to vigorous-intensity physical activity (MVPA). min/day, minutes per day; PA, physical activity; LPA, light-intensity physical activity; ES, effect size; CI, confidence interval.

Using the accelerometer-derived PA data, 27.4% (n = 14) of the women were classified as sufficiently active [5]. The sufficiently active sub-group recorded significantly greater MVPA (median: 42 min/day vs. 18 min/day; ES = 2.07; $p < 0.001$) and accumulated more steps/day (median: 11,686 steps/day vs. 6,296 steps/day; ES = 1.65; $p < 0.001$) compared to women who were insufficiently active. Moderate practical worthwhile differences were observed for all other accelerometer-derived variables, except sedentary and LPA time (trivial differences). The proportion of awake time spent sedentary and at the different PA intensities among the whole group and sub-groups are presented in Figure 2.2.

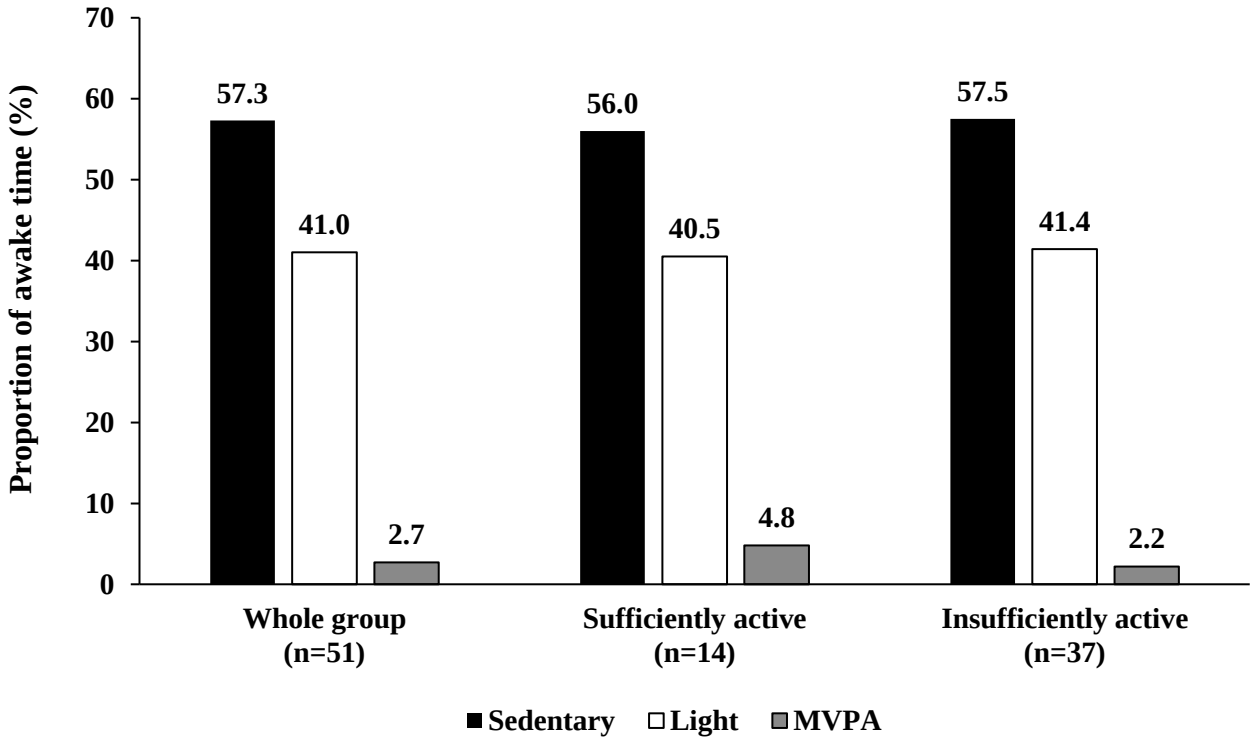

Figure 2.2 The proportion of awake time spent sedentary and at different physical activity intensities among the whole group and sub-groups.

According to the GPAQ analysis, the majority of PA time reported by the women was work-related (74.2%) and performed at moderate-intensity (median: 150 min/week; IQR: 0–360 min/week) (Table 2.2), whereas travel (20.0%) and leisure PA time (5.8%) were proportionally less. The sufficiently active sub-group reported significantly higher leisure PA time (median: 52 min/day vs. 0 min/day; ES = 0.73; p = 0.042) compared to women who were insufficiently active. Small practical worthwhile differences

in total work (ES = 0.25; p = 0.429) and total travel (ES = 0.20; p = 0.538) PA time were observed between sub-groups.

Table 2.2 Domain-specific subjective physical activity time (GPAQ) for the whole group and comparison between sub-groups.

Physical activity time	**All (*n* = 50)**	**Sufficiently active (*n* = 14)**	**Insufficiently active (*n* = 36)**	***P*-value**	**ES (90% CI) for differences in log transformed mean values**	**Magnitude-based inference**
Total vigorous (min/week)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	-	-	-
Total moderate (min/week)	352 (190 - 840)	427 (345 - 1400)	285 (165 - 470)	0.164	0.44 (-0.1; 0.9)	78% (likely) small difference
Total MVPA (min/week)	352 (190 - 900)	465 (345 - 1400)	285 (165 - 470)	0.162	0.45 (-0.1; 0.9)	78% (likely) small difference
Work domain						
Total work (min/week)	150 (0 - 360)	165 (0 - 1200)	142 (0 - 300)	0.429	0.25 (-0.2; 0.7)	56% (possibly) small difference
Travel domain						
Total travel (min/week)	90 (0 - 150)	82 (50 - 225)	90 (0 - 150)	0.538	0.20 (-0.3; 0.7)	50% (possibly) small difference
Leisure domain						
Total leisure (min/week)	0 (0 - 80)	52 (0 - 90)	0 (0 - 35)	**0.042***	0.73 (0.1; 1.2)	65% (possibly) moderate difference

Values are medians with interquartile ranges in parenthesis. All values were normalised by log transformation for parametric analyses (ANOVA). *P*-values highlighted in bold indicate statistically significant differences ($p < 0.05$) between sub-groups (*). Sufficiently active women accumulated an average of 30-min/day of accelerometer-derived moderate to vigorous-intensity physical activity (MVPA). min/week, minutes per week; ES, effect size; CI, confidence interval.

2.4.2 Socio-economic and behavioural/lifestyle characteristics

Of the 51 participants who were interviewed, 17 reported their completion of grade 12 (33.3%) and there was no difference in the level of education between sub-groups (sufficiently active vs. insufficiently active: 35.7% vs. 32.2%; $p = 0.824$). After excluding homemakers and retirees ($n = 5$), as well as those still attending secondary school ($n = 3$), the majority of women were employed (60.8%), with no statistically significant difference in employment status between the sufficiently active and insufficiently active sub-groups (78.5% vs. 54.0%; $p = 0.228$).

Women who were smokers (21.6%) were in the minority, as were those who consumed alcohol (25.5%). No sub-group differences were found for smoking (sufficiently active: 35.7% vs. insufficiently active: 16.2%; $p = 0.130$) or alcohol consumption (sufficiently active: 28.5% vs. insufficiently active: 24.2%; $p = 0.110$).

The majority of women reported ownership of 12 of the 14 items (12 ± 2 items) used to characterise individual and household wealth, with the insufficiently active group significantly better off than the sufficiently active group (12 ± 2 vs. 10 ± 2 items; $p = 0.036$). A significantly higher proportion of insufficiently active women (62.1%) compared to their sufficiently active counterparts (28.5%), had access to a motor vehicle ($p = 0.050$).

2.4.3 Age, body composition and body fat distribution characteristics

Table 2.3 depicts the age, body composition and regional body fat results of the participants. The mean age of the whole group was 42 ± 13 yrs, with no significant difference between the sub-groups ($p = 0.825$). Although the sufficiently active sub-group was overweight (BMI: 27.3 ± 4.0 kg/m^2), they had statistically significantly lower body mass (ES = -0.78; $p = 0.017$) and total FM (ES = -0.72; $p = 0.029$) compared to their insufficiently active and obese counterparts (BMI: 32.8 ± 7.6 kg/m^2; ES = -0.80; $p = 0.015$). Although FFSTM (kg) was not significantly lower in the sufficiently active versus insufficiently active sub-group, a moderate practical worthwhile group difference was found (ES = -0.63; $p = 0.063$). Both hip circumference (ES = -0.83; $p = 0.001$) and AFM (kg) (ES = -0.77; $p = 0.019$) were significantly

lower in the sufficiently active versus insufficiently active sub-group, whereas small to moderate practical worthwhile group differences were shown for body composition (%BF) and regional body fat distribution measures (WC, CFM, relative AFM and VAT area).

Table 2.3 Age, body composition and body fat distribution measurements of the whole group and comparison between sub-groups.

	All (Range)	*n*	Sufficiently active	*n*	Insufficiently active	*P*-value	ES (90% CI)	Magnitude-based inference
***Age (yrs)* (*n* = 51)**	42 ± 13 (18 - 64)	*14*	41 ± 14	*37*	42 ± 13	0.825	-0.07 (-0.5; 0.4)	trivial difference
Body composition								
Height (m) (*n* = 51)	1.56 ± 0.1 (1.37 - 1.69)	*14*	1.55 ± 0.1	*37*	1.56 ± 0.1	0.691	-0.08 (-0.5; 0.4)	trivial difference
Body mass (kg) (*n* = 51)	76.2 ± 18.8 (37.7 - 127.0)	*14*	66.2 ± 11.5	*37*	80.1 ± 19.7	**0.017***	-0.78 (-1.3; -0.2)	72% (possibly) moderate difference
BMI (kg/m^2) (*n* = 51)	31.3 ± 7.2 (15.1 - 53.1)	*14*	27.3 ± 4.0	*37*	32.8 ± 7.6	**0.015***	-0.80 (-1.3; -0.2)	74% (possibly) moderate difference
FFSTM (kg) (*n* = 50)	33.8 ± 6.5 (21.8 - 57.9)	*13*	30.9 ± 4.3	*37*	34.9 ± 6.9	0.063	-0.63 (-1.1; -0.1)	54% (possibly) moderate difference
FFSTM (%) (*n* = 50)	45.8 ± 6.0 (33.4 - 64.3)	*13*	47.6 ± 4.4	*37*	45.2 ± 6.4	0.204	0.40 (-0.1; 0.9)	74% (likely) small difference
Fat mass (kg) (*n* = 50)	35.6 ± 12.9 (8.2 - 67.3)	*13*	29.9 ± 8.1	*37*	39.0 ± 13.6	**0.029***	-0.72 (-1.2; -0.1)	65% (possibly) moderate difference
Body fat (%) (*n* = 50)	47.2 ± 7.0 (24.3 - 61.1)	*13*	44.9 ± 5.1	*37*	48.0 ± 7.4	0.175	-0.45 (-0.9; 0.1)	78% (possibly) small difference
Regional fat distribution								
Waist (cm) (*n* = 51)	88.7 ± 16.2 (57.4 - 138.3)	*14*	82.3 ± 11.1	*37*	91.1 ± 17.3	0.082	-0.55 (-1.0; -0.0)	87% (likely) small difference
Hip (cm) (*n* = 51)	110.5 ± 15.1 (78.5 - 153.5)	*14*	104.1 ± 15.2	*35*	113.5 ± 14.3	**0.001***	-0.83 (-1.3; -0.2)	77% (likely) moderate difference
Waist:Hip (*n* = 51)	0.80 ± 0.1 (0.64 - 0.97)	*14*	0.80 ± 0.1	*37*	0.80 ± 0.1	0.681	0.00 (0.0; 0.0)	trivial difference
CFM (kg) (*n* = 50)	18.9 ± 7.0 (4.2 - 39.3)	*13*	15.8 ± 4.8	*37*	20.0 ± 7.3	0.063	-0.62 (-1.1; -0.1)	53% (possibly) moderate difference
CFM (% FM) (*n* = 50)	53.1 ± 4.8 (41.2 - 63.0)	*13*	54.2 ± 3.9	*37*	52.6 ± 5.0	0.314	0.36 (-0.1; 0.8)	67% (possibly) small difference
AFM (kg) (*n* = 50)	17.7 ± 6.5 (4.8 - 36.2)	*13*	14.1 ± 3.5	*37*	18.9 ± 6.9	**0.019***	-0.77 (-1.3; -0.2)	70% (possibly) moderate difference
AFM (% FM) (*n* = 50)	50.0 ± 5.1 (39.4 - 60.5)	*13*	49.0 ± 4.3	*37*	50.4 ± 5.4	0.429	-0.19 (-0.7; 0.3)	trivial difference
VAT area (cm^2) (*n* = 50)	152.7 ± 66.4 (19.2 - 418.0)	*13*	128.7 ± 38.5	*37*	161.1 ± 72.3	0.131	-0.49 (-1.0; 0.0)	75% (possibly) small difference

Values are means ± standard deviations. *P*-values highlighted in bold indicate statistically significant differences ($p < 0.05$) between sub-groups (*). Sufficiently active women accumulated an average of 30-min/day of accelerometer-derived moderate to vigorous-intensity physical activity (MVPA). ES, effect size; CI, confidence interval; yrs, years; m, metres; kg, kilograms; BMI, body mass index; kg/m^2, kilograms per metre squared; %, FFSTM, fat-free soft tissue mass; percentage; cm, centimetres; Waist:Hip; waist to hip ratio; CFM, central fat mass; AFM, appendicular fat mass; VAT, visceral adipose tissue; cm^2, centimetres squared.

2.4.4 Cardiometabolic disease risk outcomes

Cardiometabolic disease risk outcomes of the whole group, as well as the sub-groups are presented in Table 2.4. In accordance with the 2017 American College of Cardiology/American Heart Association (ACC/AHA) Task Force on Clinical Practice Guidelines for the Prevention, Detection, Evaluation, and Management of High Blood Pressure (BP) [29], only 3 of the 13 women (23.0%) who were previously diagnosed with hypertension and reported use of anti-hypertensive medication, presented with normal BP levels on the day of investigation.

On average, the whole group presented with unfavourable BP levels. The sufficiently active sub-group had elevated systolic BP (SBP) levels (≥ 120 mm Hg), of which six women were hypertensive (i.e. stage 1 [n = 2] and stage 2 [n = 4]). In comparison, 23 women in the insufficiently active sub-group were hypertensive (i.e. stage 1 [n = 6] and stage 2 [n = 17]). For both SBP and diastolic (DBP) levels, body mass and fat mass adjusted differences between sub-groups were not statistically significant, although a small clinically significant difference was observed for DBP levels (ES = -0.25; p = 0.147).

No statistically significant group differences were observed for any of the serum lipid concentrations, even after adjusting for: i) body mass and ii) fat mass (kg). On average, TC, LDL-C and TG concentrations for the whole group were categorised as "desirable" (TC: < 5.0 mmol/L, LDL-C: < 3.0 mmol/L and TG: < 1.7 mmol/L) according to the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) criteria [30]. Notably, a small clinically significant difference between the sufficiently active and insufficiently active sub-groups was observed for LDL-C (ES = -0.22; p = 0.979). Mean HDL-C concentration fell below the "desirable" value (< 1.3 mmol/L) for both the whole group and insufficiently active sub-group. The difference between the sub-groups for HDL-C was trivial (ES = 0.21; p = 0.263). Lipoprotein (a) was higher than the "desirable" cut-off value for the whole group and both sub-groups (Lp (a) > 50 mg/dL) according to the European Consensus Statement of the European Atherosclerosis Society [31]. Although not statistically significantly, a small clinically significant difference was observed for Lp (a) between the sub-groups (ES = -0.29; p = 0.347).

Table 2.4 Cardiometabolic disease risk outcomes of the whole group and a comparison between sub-groups.

	Ideal value	All (Range)	*n*	Sufficiently active	*n*	Insufficiently active	Body mass adjusted *P*-value	ES (90% CI)	Magnitude-based inference
Blood pressure									
SBP (mm Hg) (*n* = 48)	< 120[ǂ]	128.0 ± 20.0 (93.3 - 183.0)	*14*	127.0 ± 19.6	*34*	128.7 ± 20.5	0.255	-0.08 (-0.6; 0.4)	trivial difference
DBP (mm Hg) (*n* = 48)	< 80[ǂ]	84.4 ± 14.8 (54.6 - 133.0)	*14*	81.8 ± 11.6	*34*	85.5 ± 15.9	0.147	-0.25 (-0.7; 0.2)	56% (possibly) small difference
Serum lipid concentrations									
Total cholesterol (mmol/L) (*n* = 51)	< 5.0[^]	4.9 ± 1.1 (2.2 - 8.1)	*14*	4.9 ± 1.3	*37*	4.9 ± 1.1	0.809	0.00 (-0.5; 0.5)	trivial difference
LDL-C (mmol/L) (*n* = 51)	< 3.0[^]	2.9 ± 0.9 (0.8 - 5.5)	*14*	2.8 ± 1.0	*37*	3.0 ± 0.9	0.592	-0.22 (-0.7; 0.3)	50% (possibly) small difference
HDL-C (mmol/L) (*n* = 51)	≥ 1.3[^]	1.2 ± 0.3 (0.7 - 1.9)	*14*	1.3 ± 0.3	*37*	1.2 ± 0.3	0.091	0.21 (-0.3; 0.7)	trivial difference
Triglycerides (mmol/L) (*n* = 51)	< 1.7[^]	1.3 ± 0.7 (0.3 - 3.6)	*14*	1.2 ± 0.5	*37*	1.3 ± 0.8	0.141	0.00 (-0.5; 0.5)	trivial difference
Lipoprotein (a) (mg/dL) (*n* = 51)	< 50.0[¥]	54.5 ± 49.4 (2.0 - 232.0)	*14*	54.3 ± 41.1	*37*	68.4 ± 52.0	0.874	-0.29 (-0.8; 0.2)	61% (possibly) small difference
	Ideal value	**All (Range)**	***n***	**Active**	***n***	**Inactive**	**Body mass adjusted *P*-value**	**ES (90% CI) for differences in log transformed mean values**	**Magnitude-based inference**
Prediabetes indicators									
FPG (mmol/L) (*n* = 50)	< 5.6[α]	4.9 (4.5 - 5.6)	*14*	4.6 (4.3 - 5.1)	*36*	5.0 (4.6 - 5.7)	0.421	-0.44 (-0.9; 0.0)	78% (likely) moderate difference
HbA1c (%) (*n* = 51)	< 5.7[Δ]	5.7 (5.4 -5.9)	*14*	5.7 (5.5 - 5.8)	*37*	5.8 (5.3 - 5.9)	0.460	-0.05 (-0.5; 0.4)	trivial difference

Values are unadjusted means ± standard deviations (range), except FPG (fasting plasma glucose) and HbA1c (glycated haemoglobin) which are medians with interquartile range in parenthesis. Body mass adjusted *P*-values highlighted in bold indicate statistically significant differences ($p < 0.05$) between sub-groups (*). Sufficiently active women accumulated an average of 30-min/day of accelerometer-derived moderate to vigorous-intensity physical activity (MVPA). ES, effect size; CI, confidence interval; SBP, systolic blood pressure; mm Hg, millilitre of mercury; DBP, diastolic blood pressure; mmol/L, millimoles per litre; LDL-C, low-density lipoprotein; HDL-C, high-density lipoprotein cholesterol; mg/dL, milligrams per decilitre; %, percentage. Ideal range values highlighted according to the ACC/AHA Guideline for the Prevention, Detection, Evaluation, and Management of High Blood Pressure in Adults (ǂ) [29], the NCEP ATP III criteria (^) [30], the European Atherosclerosis Society Consensus Panel (¥) [31], the International Diabetes Federation (α) [32] and Harmonised Expert Committee for use of A1c assay to diagnose T2DM (Δ) [34, 35].

As a prediabetes indicator, the median FPG value for the whole group and sub-groups fell below the impaired FPG cut-off value of ≥ 5.6 mmol/L set by the International Diabetes Federation (IDF) [32] and the Harmonised Guidelines [33]. Even after adjusting for differences in body mass and fat mass (kg) no statistically significant group differences were observed. A statistically significantly higher proportion of women in the insufficiently active sub-group presented with impaired FPG levels (insufficiently active: 27.0% vs. sufficiently active: 21.4%; $p = 0.044$) (Table 2.5), however, the proportion of women with impaired HbA1c levels [34, 35] were similar (insufficiently active: 51.3% vs. sufficiently active: 50.0%; $p = 0.711$). Fifteen women (40.5%) in the insufficiently active sub-group could be considered prediabetic and another four (10.8%) as having undiagnosed T2DM (≥ 6.5%), while five women (35.7%) in the sufficiently active sub-group were prediabetic and two presented with undiagnosed T2DM (14.2%). Although no statistically significant differences in impaired FPG and HbA1c were shown between the sub-groups, a moderate clinically significant difference was observed for FPG level (ES = -0.44; $p = 0.176$).

Table 2.5 Frequency of cardiometabolic disease risk factors among sub-groups.

Cardiometabolic disease risk factor	International authority	Cut-off value	Sufficiently active	Insufficiently active	*P*-value
Smoker (%) (*n*)	WHO	Smoking of tobacco cigarettes	35 (5/14)	16 (6/37)	0.130
Consumer of alcohol (%) (*n*)	WHO	≥ 4 drinks consumed per month	28 (4/14)	24 (9/37)	0.756
Obesity (%) (*n*)	WHO	BMI ≥ 30 kg/m^2	35 (5/14)	64 (24/37)	0.060
Central obesity (%) (*n*)	IDF and Harmonised Guidelines	WC ≥ 80 cm	57 (8/14)	81 (30/37)	0.080
Elevated SBP (%) (*n*)	IDF and Harmonised Guidelines	SBP ≥ 130 mm Hg and/or diagnosed hypertension	57 (8/14)	54 (20/34ǂ)	0.369
Elevated DBP (%) (*n*)	IDF and Harmonised Guidelines	DBP ≥ 85 mm Hg or diagnosed hypertension	57 (8/14)	51 (19/34ǂ)	0.936
Elevated LDL-C (%) (*n*)	NCEP ATP III	≥ 3.0 mmol/L	42 (6/14)	54 (20/37)	0.475
Low HDL-C (%) (*n*)	IDF and Harmonised Guideline	< 1.3 mmol/L	28 (4/14)	54 (20/37)	0.123
Elevated TG (%) (*n*)	ID F and Harmonised Guideline	≥ 1.7 mmol/L	14 (2/14)	27 (10/37)	0.338
Elevated lipoprotein (a) (%) (*n*)	NCEP ATP III	≥ 50.0 mg/dL	85 (12/14)	70 (26/37)	0.258
Impaired FPG (%) (*n*)	IDF and Harmonised Guidelines	≥ 5.6 mmol/L	21 (3/14)	27 (10/36ǂ)	**0.044***
HbA1c (%) (*n*)	WHO	≥ 5.7%	50 (7/14)	51 (19/37)	0.711

(ǂ) indicates missing data points. Sufficiently active women accumulated an average of 30-min/day of accelerometer-derived moderate to vigorous-intensity physical activity (MVPA). %, percentage; WHO, World Health Organisation; BMI, body mass index; kg/m^2, kilograms per metre squared; IDF, International Diabetes Federation; WC, waist circumference; cm, centimetre; SBP, systolic blood pressure; mm Hg, millilitre of mercury; DBP, diastolic blood pressure; LDL-C, low-density lipoprotein; NCEP ATP III, National Cholesterol Education Program Adult Treatment Panel III; mmol/L, millimoles per decilitre; HDL-C, high-density lipoprotein; TG, triglycerides; FPG, fasting plasma glucose; mg/dL, milligrams per decilitre; HbA1c, glycated haemoglobin. *P*-values highlighted in bold indicate statistically significant differences ($P < 0.05$) between sub-groups (*).

Table 2.6 compares the proportions of women from the sub-groups according to four cardiometabolic disease risk factor sub-categories (0–2; 3–5; 6–8 and ≥ 9). The distribution of women in these categories were not statistically significantly different between the sub-groups ($p > 0.05$).

Table 2.6 A comparison of the proportions of women in each activity sub-group with increasing numbers of cardiometabolic disease risk factors.

Number of cardiometabolic disease risk factors	% of sufficiently active women (*n*)	% of insufficiently active women (*n*)	*P*-value
0 - 2	29 (4/14)	16 (6/37)	0.321
3 - 5	36 (5/14)	27 (10/37)	0.543
6 - 8	35 (5/14)	51 (19/37)	0.318
≥ 9	0 (0/14)	5 (2/37)	0.374

Maximum possible number of cardiometabolic disease risk factors is 12. Sufficiently active women accumulated an average of 30-min/day of accelerometer-derived moderate to vigorous-intensity physical activity (MVPA).

2.5 Discussion

Using objectively-derived MVPA time, this small-scale cross-sectional study showed that less than a third of the urban dwelling women were sufficiently active, and although overweight according to BMI, presented with more favourable body composition and regional body fat measures compared to their insufficiently active counterparts. Sufficiently active women also presented with lower DBP and FPG levels, and reduced serum lipid concentrations (LDL-C and Lp (a)). Although not statistically significant, the proportion of women who presented with ≤ 2 cardiometabolic disease risk factors was higher among the sufficiently vs. insufficiently active sub-group (29% vs. 16%, respectively). The opposite was true when comparing women with ≥ 6 risk factors (insufficiently active: 51% vs. sufficiently active: 35%). The majority of self-reported PA time was work-related, however, the sufficiently active sub-group reported significantly more leisure-time PA compared to the insufficiently active sub-group.

Although only a minority of women (27.4%) who took part in this study met the WHO 2010 Global Recommendations on Physical Activity for Health [5], observable differences in BMI and total adiposity in comparison to those who failed to meet the guideline, were shown. These results are consistent with data from the USA National Health and Nutrition Examination Survey (NHANES), indicating the health-

associated benefit of reduced adiposity with higher daily volumes of total activity counts including all intensities, and reduced cardiometabolic disease risk measures [36]. Given the positive and strong relationship between activity counts and steps measured per day (adjusted $R^2 = 0.87$) [37], the sufficiently active sub-group accumulated a significantly greater amount of MVPA (min/day) and steps/day compared to their insufficiently active counterparts. This finding is in agreement with another SA study where a dose-dependent relationship between the number of steps/day and obesity-risk reduction among rural women was observed [38]. Following adjustment for age and other potential confounders (i.e. motor vehicle access, education level and smoking), BMI was 1.4 kg/m^2 lower per 5,000 steps/day. It is thus plausible to suggest that the higher volume of PA (i.e. steps/day) recorded by the sufficiently active sub-group may also, in part, explain their significantly lower levels of total and central adiposity, and in particular, their lower VAT area, which is a recognised pathogenic fat depot. In the Modeling the Epidemiologic Transition Study (METS) among a community-based sample of "African-American" adult women (n = 161), statistically significant inverse correlations were shown between DXA-derived VAT volume and accelerometer-derived MVPA (r = -0.25; p = 0.001) and, VAT volume and activity counts (r = -0.24; p = 0.002) [39]. Both measures remained significant after adjusting for differences in age and smoking status. Therefore, our results reinforces the beneficial effects of higher MVPA and daily PA volume (i.e. steps/day) on central obesity measures and cardiometabolic disease risk.

Although none of the body- and fat-mass adjusted group differences for the other cardiometabolic disease risk factors were statistically significant, clinically significant differences were observed for DBP and FPG levels, and serum lipid concentrations (LDL-C and Lp (a)) between the sub-groups. Inferences from the Framingham Heart Study [40] indicate that high DBP is a main determinant of hypertension-associated CVD risk [40]. The Australian Longitudinal Women's Health Study [41] also reported that ≥ 150 min/week of moderate-intensity PA is associated with a reduction in hypertension-risk. Thus, consistent with these findings, women in our study who met the WHO MVPA guideline presented with a more favourable cardiometabolic disease risk profile [5]. Conversely, moderate-intensity PA does not appear to lower elevated Lp (a) concentrations [42], which is known to raise CVD-risk due to its pro-thrombotic and anti-fibrinolytic effects, or acceleration in atherosclerosis [31]. Diet-induced changes, specifically carbohydrate restriction and multivitamin supplementation, have been associated with a 12% decrease in absolute Lp (a) concentrations and it also correlated with reductions in LDL-C (r = 0.436; p < 0.05) and total adiposity (FM: r = 0.385; p < 0.05) [43]. Thus, it seems plausible that the high prevalence of elevated Lp (a) concentrations among women in the present study (sufficiently active: 75%

and insufficiently active: 74%) are largely driven by their dietary intake. Similarly, the prevalence of prediabetes (HbA1c: ≥ 5.7%) among the sub-groups (50% vs. 51%, respectively), may also partially be attributed to their dietary intake. A 24-week diet-intervention trial in which 93 T2DM patients were randomly assigned to either a very low-carbohydrate (LC) group or high-unrefined carbohydrate (HC) group resulted in a greater reduction in HbA1c among the LC group (-2.6 ± 1.0% vs. -1.9 ± 1.2%; p = 0.002) [44]. Thus, the assessment of habitual dietary intake of low socio-economic urban dwelling SA women, independent of total activity level, is required. This information will help to inform future lifestyle intervention studies aimed at reducing cardiometabolic disease risk for CVD and T2DM.

Domain-specific PA time (%) reported among the whole group in our study differed greatly from those previously reported among women at national level [9]. Most notably, the group in this study only reported 6% of leisure time PA, compared to 54% among the national representative sample. Travel-domain PA time was comparably lower (20% vs. 28%, respectively), whereas work-domain PA time considerably higher (74% vs. 18%) compared to the national sample. A plausible explanation for these differences may relate, in part, to the ongoing and rapid epidemiological transition in SA [45, 46], which negatively affects daily activity level. For example, a significantly higher proportion of insufficiently active women (62% vs. 31%) had access to a motor vehicle compared to women who were sufficiently active. These results are in support of those by Gradidge et al. [47] from a different SA location and in which the GPAQ was used to characterise PA level among urban adult women. Thus, the current study results re-emphasise the collective importance of work- and travel-related PA time, and most likely performed at light- and moderate-intensities given our additional use of objectively measured PA time. Given the combination of these inferences, future SA studies are needed to examine the association between varying intensity levels of objectively measured PA and cardiometabolic disease risk. In addition, descriptive studies identifying factors influencing changes in PA patterns are also required. All of which, will help to inform future intervention studies aimed at increasing PA level or the intensity of time already spent physically active, especially among low socio-economic urban dwelling SA adult women who are already obese and either prediabetic or diagnosed with T2DM [13].

Our results emphasise the clinical health benefits associated with being sufficiently active and thus the importance of meeting global MVPA recommendations [5]. Even though the majority of PA time was work- and travel-related, as opposed to “deliberate exercise” (i.e. leisure-domain PA time) performed at

vigorous intensity, time spent moderately active was sufficient to reduce overall cardiometabolic disease risk. However, despite their current PA status, the sufficiently active sub-group's future health cannot be predicted. Nevertheless, it does not deter from the fact that the entire sample, on average, spent the majority of awake time sedentary. According to Ploeg et al. [48], sedentary behaviour is more deleterious to one's health than physical inactivity and it minimises the "benefits" associated with ≥30 min/day of MVPA [5]. Given the challenge to reduce time spent sedentary, while increasing time spent physically active, it is important to understand the context in which the women from the current study reside. Notably, the lack of an inclusive PA environment (e.g. limited access to exercise facilities and issues of safety) and the lack of social/community networks to promote PA, as well as time-based challenges, such as the extended travel time to and from work and/or other purposeful places. Notably, any proposed interventions to address issues of physical inactivity and sedentarism will have to take these factors into consideration.

The strengths of the present study include the use of sophisticated measurement equipment, namely the DXA-scanner and accelerometry, to characterise body composition and regional fat distribution, as well as PA level. This especially among a sample of urban women which, to our knowledge, little is currently known about. Potential limitations include the cross-sectional study design, sample of convenience, as well as the small sample size, especially when categorised into the two activity sub-groups. In addition, the loss of data due to non-compliance in wearing the activity monitors should also be considered. Thus, the findings should be considered exploratory, with limited generalisability to the entire urban adult women population in SA. Another limiting factor is the omission of measuring fasting serum insulin level, and thus our inability to assess beta cell function and insulin resistance using the Homeostatic Model Assessment of Insulin Resistance [49]. Future studies should include its measurement, as it may help to explain the underlying reason for the high number of prediabetic women among this sample of apparently healthy individuals.

2.6 Conclusion

Unique to this study was the presentation of both accelerometer and subjective PA data. Thus, allowing for PA time to be objectively quantified and the domains described. Notably, the majority of women did not meet the MVPA Global Recommendations [5], although those who did, presented with more

favourable body composition and regional body fat measures, as well as reduced cardiometabolic disease risk. In an attempt to combat cardiometabolic disease risk for CVD and T2DM among urban and low socio-economic community dwelling women, public health interventions should target domains in which time is already spent physically active. For example, walking briskly for travel- and/or occupational-related activities, while also aiming to increase awareness of the health-enhancing benefits associated with meeting MVPA recommendations. Nonetheless, the success of interventions are dependent on our understanding of the community's specific barriers to PA and dietary habits.

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CHAPTER 3

ARTICLE TWO:

DOES PHYSICAL ACTIVITY INTENSITY AND VOLUME ASSOCIATE WITH CARDIORESPIRATORY FITNESS AND CARDIOMETABOLIC DISEASE RISK IN URBAN SOUTH AFRICAN WOMEN FROM A LOW SOCIO-ECONOMIC COMMUNITY?

Article to be submitted to the International Journal for Behavioural Nutrition and Physical Activity and presented in accordance with the author guidelines (Appendix E)

Kasha Dickie, Carla Coetsee, Sharné Nieuwoudt, Louise Engelbrecht, Elmarie Terblanche

Department of Sport Science, Faculty of Medicine and Health Sciences, Stellenbosch University, Private Bag X1, Matieland, 7601, South Africa

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Contributions to the research article

Ms Kasha Dickie was involved in the conception and design of the research study, data cleaning and analysis, the drafting and writing of the manuscript, as well as the general management of the research group. Prof Elmarie Terblanche was involved in the conception and design of the research study, assisted and guided the statistical analysis, and the writing and editing of the manuscript. Dr Carla Coetsee assisted with data collection, and editing of the manuscript. Ms Sharné Nieuwoudt and Ms Louise Engelbrecht assisted with data collection, data cleaning and analysis.

3.1 Abstract

Background: Few South African (SA) studies have examined the association between objectively-derived physical activity (PA) time in different intensities and daily volume, with cardiorespiratory fitness (CRF) level. The aim of this study was to investigate these associations among women living in an under-resourced urban setting, and to examine each in relation to i) body composition, ii) regional body fat measures and, iii) cardiometabolic disease risk outcomes. **Methods:** Sixty-one apparently healthy women (42 ± 13 yrs) completed a socio-demographic questionnaire followed by the measurement of resting blood pressure, fasting plasma glucose level and serum lipid concentrations. Dual-energy x-ray absorptiometry was used to measure body composition and accelerometry to measure PA time (intensities) and volume (steps/day), respectively. A graded exercise test to exhaustion was performed to determine CRF level. **Results:** Although the associations between PA (intensities and volume) and CRF level were not statistically significant, all were clinically important and positive associations. Independent of steps/day, higher CRF level was associated with women who were younger and with reduced measures of total and central adiposity (BMI, fat mass, waist circumference and visceral adipose tissue area) ($p < .001$). Independent of steps/day, higher CRF level was associated with women who were younger and with reduced measures of total and central adiposity (BMI, fat mass, waist circumference and visceral adipose tissue area) ($p < .001$). Both steps/day and CRF level were also inversely associated with fat-free soft tissue mass and skeletal mass index ($p < .050$). Even though the associations between PA intensities with each cardiometabolic risk outcome were statistically non-significant, small clinically important associations were observed. **Conclusion:** The study highlights the health-related benefits of higher daily PA volume and CRF level, with reduced total adiposity and central obesity among both young and older women residing in an under-resourced urban setting. The challenge to design healthy lifestyle-based interventions for women of all ages and fitness levels requires immediate action. In the interim, content from a focus group of self-nominated community leaders with a vested interest in personal and public health can provide the foundation for such interventions. Most notably, those aimed at behavioural/lifestyle modification to reduce cardiometabolic disease risk.

Keywords: Physical activity, intensity, steps, fitness, cardiometabolic risk

3.2 Background

The World Health Organization (WHO) expects the burden of non-communicable disease (NCD) morbidity and mortality to increase further, from already high levels, among women residing in low- and middle-income countries, such as South Africa [7]. A well-established body of evidence highlights the unequivocal health-related benefits of high cardiorespiratory fitness (CRF) levels which, independent of total adiposity [1], associate with reduced all-cause mortality risk [2-4]. Notably, CRF is described as a physiological measure that reflects a combination of physical activity (PA) behaviour and innate genetic potential [1]. Thus, the WHO 2010 Global Recommendations on PA for Health [8] aligns itself to increasing PA in an attempt to decrease NCD, however, these guidelines draw explicit reference to moderate to vigorous-intensity physical activity (MVPA) and not light-intensity physical activity (LPA). Even when using the steps·day^{-1} version of these guidelines [9], the intensity determined by duration and step frequency (i.e. cadence) includes only MVPA. Tudor-Locke et al. [9] stated: "*An appropriate translation, specifically allowing for minimal amounts of time in MVPA, implied that steps should be taken over and above those taken in the course of habitual and incidental daily activities; and also should be taken in bouts of at least 10-minutes in duration*." Although, they too purport the notion that any PA is better than none, and that increased levels of PA should be progressively approached. Interestingly, some research propose that LPA also hold significant health benefits [5,6]. Therefore the investigation of LPA as a separate entity to MVPA and total daily volume (i.e. steps·day^{-1}), in relation to risk factors associated with NCD, namely cardiovascular disease (CVD) and type 2 diabetes mellitus (T2DM), is warranted.

Results from a large cross-sectional analysis, the Objective Physical Activity and Cardiovascular Health study (OPACH), inclusive of three diverse ethnic groups ("White", "Black" and "Hispanic"), show objectively-derived LPA is associated with lower CVD risk [10]. After adjusting for differences in age and monitor wear time, favourable associations were shown between low- and high-LPA and cardiometabolic disease risk factors (body mass index [BMI], waist circumference [WC], resting systolic blood pressure [SBP] and diastolic blood pressure [DBP], triglyceride [TG] and fasting plasma glucose [FPG]) ($p < .01$). Of practical importance is the ≥ 5 hrs per person per day of LPA reported in the OPACH study, and thus in support of other studies reporting the health-related associations with: i) higher daily LPA levels [5,6] and ii) increasing total daily PA volume [9].

Few South African (SA) studies examined the associations of PA and CRF with body composition measures and cardiometabolic disease risk outcomes. Results from a number of small-scale cross-sectional studies have shown favourable associations between PA measured subjectively (questionnaire-based PA level index scores) [11,12] and objectively (pedometers [13,14] and accelerometers [12]), with lower measures of adiposity (BMI, WC and, % body fat [%BF]). However, to our knowledge, only one SA study has explored relationships between LPA and body composition [15]. Similar to the objectively-derived PA results indicative of MVPA [12] and steps·day^{-1} [13,14], Dickie et al. [15] showed an inverse association between LPA and trunk fat mass (TFM) (r = -0.25, p = .03), measured using high-precision dual-energy x-ray absorptiometry (DXA) among 76 apparently healthy urban SA women. Although none of the other cardiometabolic risk factors (i.e. SBP, DBP, serum lipid concentrations, FPG and fasting serum insulin) were associated with LPA, higher CRF levels (indirect assessment) were inversely associated with %BF (r = -0.34, p = .02), central fat mass (CFM) (kg) (r = -0.31, p = .03), visceral adipose tissue (VAT) area (cm^2) (r = -0.47, p < .01) and insulin resistance (r = -0.41, p = .03). When adjusting for differences in fat mass (FM), the association between CRF and insulin resistance remained, however, not when VAT area was adjusted for (p > .05).

These findings are important, as PA and CRF play a significant role in influencing health outcomes, especially among SA communities undergoing epidemiological transition [16], and moreover, among child-bearing women. What's more are the noticeable differences in the prevalence of severe obesity (BMI: ≥ 35 kg·m^2) among "Coloured" and "Black (African)" SA adult women (26% and 20%, respectively) compared to "Asian/Indian" and "White" SA adult women (18% and 15%, respectively) [17]. Given South Africa's historical past these differences, as well as the prevalence of NCD among these groups [18], may in part, be attributed to social inequalities (e.g. education level, access to healthcare and earning capacity) [16]. Findings from the Bellville-South community cohort study (Cape Town, South Africa) provide further insight into the presence of obesity (53.7%) and diabetes mellitus (28.6%) among urban-dwelling and previously disadvantaged adults (mean age: 54 yrs) [19]. Although sex-specific results were not reported, the sample comprised mostly of women (73.5%) and showed an equal frequency of cardiometabolic disease risk among normal weight, overweight and obese BMI-categories [19]. A further outcome of this study was the description and prevalence of two distinct obese phenotypes, i) metabolically healthy and obese (31%) and; ii) metabolically unhealthy and normal weight (29%) [20]. These findings corroborate with the results from the extensively published HERITAGE family study which suggest that as much as 50% of obesity, and CRF, may be due to heritability [21].

Previous studies have mostly used subjective and indirect methods to characterise PA [11, 12] and CRF [15], which may over- or underestimate their relative role in cardiometabolic disease risk for CVD and T2DM. Thus, there is a compelling need to characterise modifiable behavioural/lifestyle factors such as PA, as well as CRF, while also exploring its associations with obesity and cardiometabolic disease risk outcomes among low socio-economic urban-dwelling women using objectively-derived methodologies and high precision measurement techniques.

Therefore, the aims of this cross-sectional study were two-fold: i) to investigate the association between PA (LPA, MVPA and steps·day^{-1}) and CRF; and ii) to examine both PA and CRF in relation to body composition, regional body fat measures, and cardiometabolic disease risk outcomes. We hypothesise that similar to other SA women [15] both high PA (irrespective of intensity) and CRF levels are independently associated with reduced adiposity and cardiometabolic disease risk outcomes for CVD and T2DM in urban-dwelling SA adult women.

3.3 Materials and methods

3.3.1 Cloetesville (Stellenbosch, Western Cape, South Africa)

Cloetesville is considered a low socio-economic residential urban suburb neighbouring the university town of Stellenbosch in the Western Cape Province of South Africa [22]. Its population approximates 15 390, of which 31% are adult women [23].

3.3.2 Study participants

Women were recruited from local church groups, the public health clinic, community centre, and via "word of mouth" (i.e. snowball sampling). An Afrikaans-speaking health champion, living in Cloetesville, assisted with the participant recruitment. All the procedures and potential risks were explained to each participant in her preferred language (Afrikaans or English) and everyone provided written informed consent prior to participation.

Participants were included in the study if they were: i) 18 – 64 yrs old; ii) had no known diseases and were not taking medications for T2DM, human immunodeficiency virus (HIV) or acquired immune deficiency syndrome, or any other metabolic diseases; iii) not pregnant or lactating; and iv) free of any known musculoskeletal problems that prevented them from being physically active. Rapid HIV screening tests were not performed, although women were asked if they were receiving anti-retroviral treatment for HIV. Twelve women, who underwent pre-screening, were excluded from the study. One woman tested positive to the compulsory urine pregnancy test, another presented with angina, whilst 10 were excluded as they reported the use of prescribed T2DM medication. Thus, a convenience sample of 61 apparently healthy women underwent testing on two separate days, approximately seven days apart. On completion of testing, 10 participants were excluded from the final group analysis due to invalid accelerometer data (Figure 3.1). The study proposal was approved by the Human Research (Humanities) Ethics Committee of Stellenbosch University (Ref. No.: SU-HSD-004704).

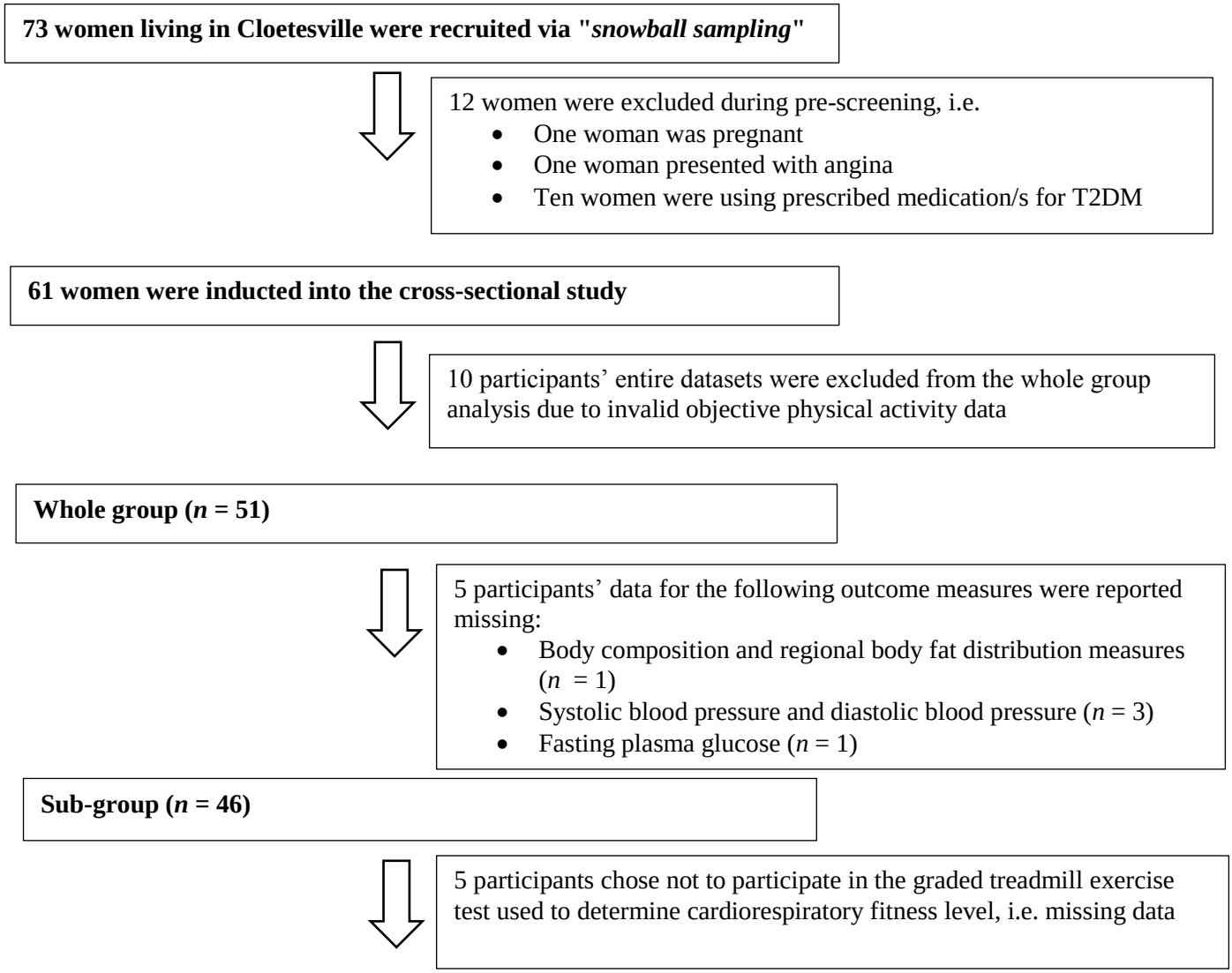

Figure 3.1 Flow chart of participant recruitment and testing of the whole group (*n* = 51) and sub-group (*n* = 46) of apparently healthy urban women.

3.3.3 Socio-economic status and behavioural/lifestyle factors

Using the WHO STEPwise approach to chronic disease risk factor surveillance (STEPS) instrument [24], each participant underwent an individualised interview. Questions pertaining to proxy measures of socio-economic status (SES) were asked including: i) the highest level of education completed and; ii) employment status over the previous 12-month period. Behavioural/lifestyle factors included current tobacco smoking status and alcohol consumption. Women were categorised as either smokers or non-smokers; whereas those who reported alcohol consumption based on an average monthly intake ($\geq$ 4 drinks per month) were categorised as consumers of alcohol.

An asset index score was also used as a proxy measure of SES and based on the 14-item asset list used by Jennings et al. [25], and since reported by other research groups among urban adult SA women [26,27]. The items included reflect measures of individual and/or household wealth plus accessibility to basic resources, namely, electricity in the home, ownership of a television, radio, motor vehicle, fridge, stove and oven, washing machine, telephone, DVD player, microwave, computer/laptop, cellular telephone and paid television channels (e.g., DSTV®).

3.3.4 Body composition and regional fat distribution assessment

Standard anthropometric measures (standing height, body mass, waist and hip circumferences) were determined according to the International Society for the Advancement of Kinanthropometry (ISAK) guidelines [28]. DXA (Discovery-W®, software version 13.4.1; Hologic, Bedford, MA) was used to determine whole body composition and regional body fat distribution. The latter included CFM, appendicular fat mass (AFM) and TFM defined as CFM minus the head [29].

In accordance with the guidelines set by the European Working Group on Sarcopenia in Older People (EWGSOP) [30] skeletal muscle index (SMI) was calculated using appendicular skeletal muscle (ASM) mass (i.e. the sum of the muscle masses of all four limbs) divided by height measured in metres squared. Using the DXA, visceral adipose tissue (VAT) area (cm^2) was derived using the methodology described by Kaul et al. [31].

3.3.5 Cardiometabolic disease risk outcomes

Three successive blood pressure (BP) measurements were taken after at least 5-min of seated rest, using an appropriate-sized cuff and an automated BP monitor (Omron® HBP-1100, Omron Healthcare, Mannheim, Germany). The average of the last two readings were noted for analysis. Three participants were excluded from the group BP data set as only one measure was recorded.

Participants were asked to fast overnight for a minimum of 8-hours. On arrival at the testing venue, venous blood samples were drawn by a trained nurse. The samples were analysed by a local commercial pathology laboratory (PathCare, Stellenbosch, South Africa). Due to an inadequate serum concentration one participant's FPG was reported missing.

3.3.6 Physical activity (time, intensities and steps·day^{-1})

Physical activity time was measured during waking hours for 7 consecutive days using the triaxial ActiGraph™ GT3X accelerometer (ActiGraph™ LLC, Pensacola, Florida). Time sampling intervals were set at 60-sec epochs. Each original ActiGraph™ data file (*.agd) was downloaded onto a personalised computer and processed on a Microsoft Excel spreadsheet using a custom-written program ('ACTILIFE', http://actigraphcorp.com/products-showcase/software/actilife/). Data from each participant was included if they met the minimum requirement of ≥ 600-min of monitor wear time on ≥ 3-days of the week [32]. Wear time was determined by subtracting non-wear time from 24-hours, where non-wear time was defined as an interval of ≥ 60 consecutive minutes with zero activity counts allowing for intervals of 1 to 2-min of relatively low activity counts per minute (< 100) [32]. Freedson cut-points were used to convert the accelerometer counts measured per minute (counts·min^{-1}) into intensity bands [33]. Sedentary time was defined as < 100 counts·min^{-1}. Physical activity (≥ 100 counts·min^{-1}) was divided into two sub-categories according to intensity level namely: light (100 – 951 counts·min^{-1}) and moderate to vigorous (≥ 1952 counts·min^{-1}) [33]. Average daily time in minutes per day (min·day^{-1}) was used to summarise both sedentary and physical activity time according to LPA and MVPA. Steps·day^{-1} were also recorded by the accelerometer and used as a measure of total daily PA volume.

3.3.7 Cardiorespiratory fitness

A graded exercise test to exhaustion was performed on the h/p/Cosmos Saturn® treadmill (Nussdorf-Traunstein, Germany) to determine maximal aerobic capacity (VO_{2max}). The COSMED Quark CPET metabolic system (Rome, Italy) was used to monitor metabolic variables continuously throughout the exercise test. The gas analysers were calibrated prior to each test with atmospheric gas and known concentrations of O_2 (16%), CO_2 (5%) and balance N_2. The turbine flow meter was calibrated using a 3-L calibration syringe. Each participant was fitted with a heart rate monitor, as well as a treadmill safety harness. To ensure that each participant achieved maximal exertion, at least two of the following five criteria needed to be met: i) oxygen consumption ($\dot{V}O_2$) did not increase by > 150 mL per successive workload; ii) a respiratory quotient (RQ) value of ≥ 1.15 was reached; iii) heart rate (HR) reached > 90% of age-predicted maximal HR, calculated as 220 - age (yrs); iv) rating of perceived exertion (RPE) was reported as > 19 on the 6 to 20 Borg scale [34] and; v) the participant indicated she was exhausted. Five women did not do the test, thus a sub-group of 46 women were included in the final group analysis (Figure 1). Relative VO_{2max} ($mL \cdot kg^{-1} \cdot min^{-1}$) was used as the criterion measure of CRF level.

3.3.8 Statistical analysis

Based on a power (1 - β) of 80% and α = 0.05 and assuming a medium to large effect size for four independent variables in a multiple regression analysis, the required sample size was between 38 and 68 participants [36] and the variance inflation factor (< 3) was assessed for multicollinearity. Statistica version 13.3 (StatSoft Inc. Tulsa, OK, USA) was used to perform the descriptive data analysis and null-hypothesis testing [35]. The level of statistical significance was set at $p < .05$.

The distribution of each variable was examined with the Shapiro-Wilk normality test. Parametric data are presented as means ± standard deviations (SD) or percentages. Non-Gaussian distributed variables (PA data, sedentary time, FPG and HbA1c) were normalised by log transformation for parametric analyses and presented as medians and interquartile range (IQR). One-way analysis of variance (ANOVA) was used to determine if PA and CRF differed according to categorical variables used to describe SES and behaviour/lifestyle. Chi-squared tests for independent groups and Student *t*-tests (PA,

body composition, regional fat distribution measures, and cardiometabolic outcome measures) were used to determine if there were differences between the whole group (n = 51) and the CRF sub-group (n = 46).

To evaluate the univariate associations between PA and CRF level, Pearson's product-moment correlation coefficients (r) were calculated. The same was done for associations between PA, body composition, CRF level and cardiometabolic disease risk outcome measurements (unadjusted and adjusted for confounding variables: i) FM [kg], and ii) VAT area [cm^2]). These were then used to determine which variables to include in the forward stepwise multiple regression analyses, which were calculated to investigate the independent associations between PA and CRF level, and all body composition, regional body fat distribution, and cardiometabolic risk outcome measurements.

The Pearson's r (± 90% CI) were interpreted using the magnitude-based inference methodology [37]. Qualitative probabilistic inferences about the true or clinically important correlation were determined according to the following thresholds: < 0.1, trivial; > 0.1 – 0.3, small; > 0.3 – 0.5, moderate; > 0.5 – 0.7, large; > 0.7 – 0.9, very large [38]. If the 90% CI overlapped small positive and negative values, the magnitude was deemed unclear; otherwise the magnitude was deemed to be the observed magnitude [37].

3.4 Results

3.4.1 Socio-economic and behavioural/lifestyle characteristics

The majority women (66.7%, n = 34) had completed primary school (grade 7). Of those who had completed high/secondary school (grade 12) (33.3%, n = 17), only two (3.9%) reported completion of a tertiary/college undergraduate degree. Women were classified as either: employed (58.8%, n = 30), unemployed (25.4%, n = 13), retired/homemaker (9.8%, n = 5) or grade 12 students (5.8%, n = 3).

Eleven women reported cigarette smoking (21.5%) and thirteen women reported consumption of alcohol (25.4%). The majority of women reported ownership of 12 of the 14-items (mean ± SD: 12 ± 2) used to describe individual and household wealth.

3.4.2 Age, body composition and body fat distribution characteristics

The mean age of the whole group was 42 ± 13 yrs (Table 3.1). The majority were obese (56.9%, *n* = 29) and overweight (25.5%, *n* = 13), whereas only seven (13.7%) were normal weight and two underweight (3.9%). When compared to the age-specific percentiles of the American College of Sports Medicine (ACSM) [39] the women's %BF (mean ± SD: 47.2 ± 7.0%) fell below the 1st percentile for ages 40 – 49 yrs and thus rated as "very poor".

According to the EWGSOP international SMI cut-off of ≤ 5.76 kg·m^2 [30], 13 of the women (26.0%) were diagnosed with sarcopenia. None of these women were obese, but were relatively younger compared to the whole group (mean ± SD [range]: 37 ± 14 [18 – 47 yrs] vs. 42 ± 13 yrs [18 – 64 yrs]). When using the more recently published SA-specific SMI cut-off (≤ 4.94 kg·m^2) [40], the proportion of women with sarcopenia decreased to 22.0% (*n* = 11) (mean age [range]: 34 ± 13 [18 – 52 yrs]).

Table 3.1. Age, body composition and regional body fat distribution measurements.

	n	Mean ± SD	Range
Age (yrs)	*51*	42 ± 13	(18 - 64)
Body composition			
Height (m)	*51*	1.56 ± 0.1	(1.37 - 1.69)
Body mass (kg)	*51*	76.2 ± 18.8	(37.7 - 127.0)
BMI (kg·m^2)	*51*	31.3 ± 7.2	(15.1 - 53.1)
Fat-free soft tissue mass (kg)	*50*	33.8 ± 6.5	(21.8 - 57.9)
Fat-free soft tissue mass (%)	*50*	45.8 ± 6.0	(33.4 - 64.3)
SMI (kg·m^2)	*50*	6.5 ± 1.0	(4.4 - 9.4)
Fat mass (kg)	*50*	35.6 ± 12.9	(8.2 - 67.3)
Body fat (%)	*50*	47.2 ± 7.0	(24.3 - 61.1)
Regional body fat distribution			
Waist (cm)	*51*	88.7 ± 16.2	(57.4 - 138.3)
Hip (cm)	*51*	110.5 ± 15.1	(78.5 - 153.5)
Waist:Hip	*51*	0.80 ± 0.1	(0.64 - 0.97)
CFM (kg)	*50*	18.9 ± 7.0	(4.2 - 39.3)
CFM (% FM)	*50*	53.1 ± 4.8	(41.2 - 63.0)
AFM (kg)	*50*	17.7 ± 6.5	(4.8 - 36.2)
AFM (% FM)	*50*	50.0 ± 5.1	(39.4 - 60.5)
TFM (kg)	*50*	17.9 ± 6.8	(34.1 - 37.2)
TFM (% FM)	*50*	47.4 ± 8.0	(20.0 - 63.7)
VAT area (cm^2)	*50*	152.7 ± 66.4	(19.2 - 418.0)

Values are unadjusted mean ± standard deviation (*n*). yrs, years; m, metres; kg, kilograms; BMI, body mass index; kg·m^2, kilogram per metre squared; %, percentage; SMI, skeletal mass index; cm, centimetre; Waist:Hip; waist to hip ratio; CFM, central fat mass; AFM, appendicular fat mass; TFM, trunk fat mass; VAT, visceral adipose tissue; cm^2, centimetre squared.

3.4.3 Characteristics of cardiometabolic disease risk outcomes

Cardiometabolic disease risk outcomes are presented in Table 3.2. Thirteen women reported their use of anti-hypertensive medication, with only three being normotensive when assessed. Mean DBP level of the whole group was > 80 mm Hg (mean ± SD: 84.4 ± 14.8 mm Hg) and thus categorised as stage 1 hypertension according to international guidelines [41].

In line with the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) [42], mean lipid serum concentrations fell below the upper limit value (TC: < 5.0 mmol·L^{-1}; LDL-C: < 3.0 mmol·L^{-1} and TG < 1.7 mmol·L^{-1}). Mean HDL-C fell below the desired value (≥ 1.3 mmol·L^{-1}) and, in accordance with the European Consensus Statement of the European Atherosclerosis Society [43] lipoprotein (a) (Lp (a) > 50 mg·dL^{-1}) exceeded the desired mean cut-off value of < 30 mg·dL^{-1}.

According to both the International Diabetes Federation (IDF) [44] and the Harmonised Guidelines [45], most of the women (74.0%, *n* = 37/50) were normoglycemic (FPG: < 5.6 mmol·L^{-1}), whereas the minority presented either with prediabetes (*n* = 11) or T2DM (*n* = 2) (26.0%, *n* = 13/50). Using the American Diabetes Association (ADA) Hb1Ac cut-off value of ≥ 5.7% [46,47] as another indicator of prediabetes, 51.0% (*n* = 26/51) of the women presented with prediabetes and 6 with undiagnosed T2DM (HbA1c: ≥ 6.1%).

Table 3.2. Cardiometabolic disease risk outcomes.

Blood pressure	***n***	**Mean ± SD**	**Range**
SBP (mm Hg)	*48*	128.0 ± 20.0	(93.3 - 183.0)
DBP (mm Hg)	*48*	84.4 ± 14.8	(54.6 - 133.0)
Lipid profile	***n***	**Mean ± SD**	**Range**
Total cholesterol (mmol·L^{-1})	*51*	4.9 ± 1.1	(2.2 - 8.1)
LDL-C (mmol·L^{-1})	*51*	2.9 ± 0.9	(0.8 - 5.5)
HDL-C (mmol·L^{-1})	*51*	1.2 ± 0.3	(0.7 - 1.9)
Triglycerides (mmol·L^{-1})	*51*	1.3 ± 0.7	(0.3 - 3.6)
TG:HDL-C	*51*	1.0 ± 0.6	(0.2 - 2.9)
Lipoprotein (a) (mg·dL^{-1})	*51*	54.5 ± 49.4	(2.0 - 232.0)
Apolipoprotein A1 (g·L^{-1})	*51*	1.4 ± 0.2	(0.9 - 1.8)
Apolipoprotein B (g·L^{-1})	*51*	0.9 ± 0.3	(0.4 - 1.8)
Apo B:Apo A	*51*	0.6 ± 0.2	(0.3 - 1.2)
Diabetes indicators	***n***	**Median**	**IQR**
FPG (mmol·L^{-1})	*50*	4.9	(4.5 - 5.6)
HbA1c (%)	*51*	5.7	(5.4 - 5.9)

Values are mean ± standard deviation, except for fasting plasma glucose (FPG) and glycated haemoglobin (HbA1c) which are reported as median and interquartile range (IQR). SBP, systolic blood pressure; mm Hg, millilitre of mercury; DBP, diastolic blood pressure; TC, total cholesterol; mmol·L^{-1}, millimoles per litre; LDL-C, low-density lipoprotein; HDL-C, high-density lipoprotein cholesterol; TC:HDL-C, total cholesterol to high-density lipoprotein cholesterol ratio; TG:HDL-C, triglyceride to high-density lipoprotein cholesterol ratio; mg·dL^{-1}, milligrams per decilitre; g·L^{-1}, grams per litre; Apo B:Apo A, Apolipoprotein B to Apolipoprotein A1 ratio; %, percentage.

3.4.4 Accelerometer-derived physical activity (intensity and volume)

Objectively-derived PA time (LPA and MVPA) reported in min·day^{-1} and steps·day^{-1} are presented in Table 3.3. A larger proportion of awake time was spent in sedentary behaviour (57.3% of daily wear-time [median: 7-hr and 55-min]) compared to time spent physically active. The majority of PA time was performed in the light-intensity band, the minority in the moderate-intensity band and none in the vigorous-intensity band. Only 27.4% of the whole group (n = 14) met the WHO 2010 Global Recommendations on PA for Health [8], with an even smaller proportion (23.5%) achieving the recommended average daily step count of ≥ 10 000 steps [9].

Table 3.3 Accelerometer-derived physical activity data of the whole group and cardiorespiratory fitness of the sub-group.

Accelerometry (*n* = 51)	**Median (IQR)**
Number of activity days measured	5 (5 - 6)
Non-wear time (min·day^{-1})	611 (542 - 662)
Wear time (min·day^{-1})	829 (801 - 898)
Sedentary time (min·day^{-1})	475 (442 - 514)
Total PA (min·day^{-1})	365 (308 - 404)
Intensity bands	
LPA (min·day^{-1})	340 (282 - 374)
MVPA (min·day^{-1})	22 (12 - 30)
Steps·day^{-1}	8 232 (6 032 - 9 871)
International PA health recommendations (*n* = 51)	**% (*n*)**
Sufficiently active women (≥ 150 min·week^{-1} MVPA) [8]	27.4 (14)
Insufficiently active women (< 150 min·week^{-1} MVPA) [8]	72.6 (37)
Sufficiently active women (≥ 10 000 steps·day^{-1}) [9]	23.5 (12)
Insufficiently active women (< 10 000 steps·day^{-1}) [9]	76.5 (39)
Cardiorespiratory fitness (relative VO_{2max})	**Mean ± SD (Range)**
All women (mL·kg^{-1}·min^{-1}) (*n* =46)	23.2 ± 5.4 (11.5 - 35.1)
Sufficiently active women (≥ 150 min·week^{-1} MVPA) [8] (mL·kg−1·min−1) (*n* =14)	24.8 ± 6.3 (11.5 - 34.5)
Insufficiently active women (< 150 min·week^{-1} MVPA) [8] (mL·kg−1·min−1) (*n* = 32)	22.6 ± 4.9 (14.2 - 35.1)
Sufficiently active women (≥ 10 000 steps·day^{-1}) [9] (mL·kg−1·min−1) (*n* =12)	26.3 ± 4.8 (19.0 - 34.5)
Insufficiently active women (≥ 10 000 steps·day^{-1}) [9] (mL·kg−1·min−1) (*n* = 39)	22.1 ± 5.2 (11.5 - 35.1)

Accelerometry values are medians with interquartile range (IQR) in parenthesis. min·day^{-1}, minutes per day; PA, physical activity; LPA, light-intensity physical activity; MVPA, moderate to vigorous-intensity physical activity; steps·day^{-1}; VO_{2max}, maximal aerobic capacity; mL·kg^{-1}·min^{-1}, millilitres per kilogram per minute. International PA health recommendations according to the WHO 2010 Global Recommendations on PA for Health [8] and PA volume measured in steps·day^{-1} [9].

3.4.5 Cardiorespiratory fitness

The mean relative VO_{2max} (mL·kg^{-1}·min^{-1}) of the sub-group of 46 women is presented in Table 3.3. In comparison to the ACSM's age-specific relative VO_{2max} (CRF) categories for women, the group mean CRF value of 23.2 mL·kg^{-1}·min^{-1} falls between the 25th and 30th percentiles for women aged 40 – 49 yrs

(22.1 – 23.3 mL·kg^{-1}·min^{-1}), and is thus rated as "poor" [39]. Noticeably, the difference in relative VO_{2max} (CRF) between the sufficiently and insufficiently active sub-categories according to the WHO guideline of meeting ≥ 150 min·week^{-1} of MVPA, was not statistically significant (p = .202) (Figure 3.2). However, the comparison according to the ≥ 10 000 steps·day^{-1} recommendation [9], was statistically significantly different (p = .019).

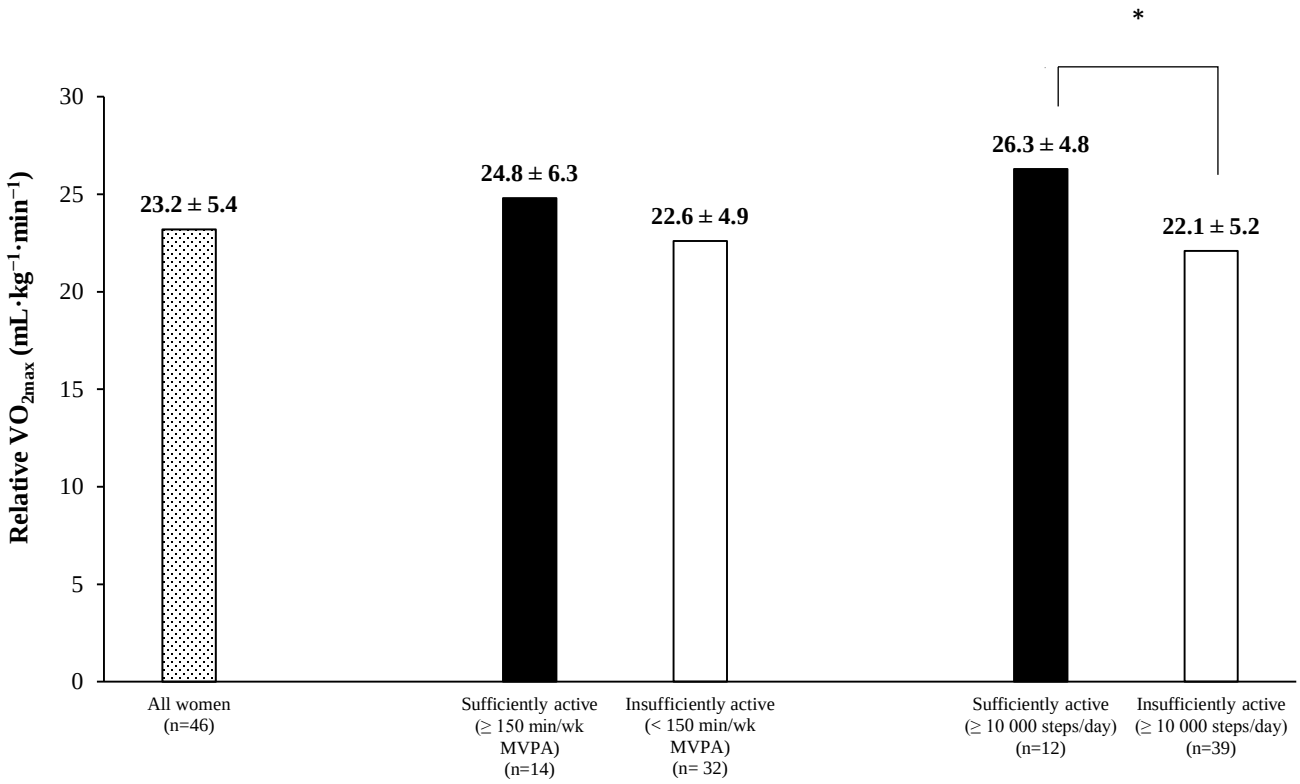

Figure 3.2 Differences in mean relative VO_{2max} (CRF) levels for all women, sufficiently and insufficiently active women according to the WHO 2010 Global Recommendations on PA for Health [8] and sufficiently and insufficiently active women according to the ≥ 10 000 steps·day^{-1} recommendation [9].*, p < .05; statistically significant difference between sub-categories.

When comparing the sub-group of women (n = 46) who completed the graded exercise test to the whole group (n = 51), there were no statistically significant differences in age, SES, behavioural/lifestyle factors, body composition measures (body mass [BM], BMI, FM and %BF), or body fat regional distribution measurements (WC, hip circumference and VAT area), cardiometabolic disease risk outcomes and PA variables (LPA, MVPA and steps·day^{-1}) (all, p > .05).

3.4.6 Associations between physical activity, socio-economic status and behavioural/lifestyle factors

No differences were found for LPA (min·day^{-1}) when comparing women who had completed high/secondary school to those who had completed primary school (327 ± 76 min·day^{-1} vs. 346 ± 75 min·day^{-1}, p = .406). The same result was shown for MVPA (25 ± 18 min·day^{-1} vs. 23 ± 17 min·day^{-1}, p = .711) and steps·day^{-1} (7 458 ± 4 188 vs. 7 724 ± 3 001, p = .816). Women who were employed accumulated significantly more LPA (361 ± 79 min·day^{-1} vs. 295 ± 51 min·day^{-1}, p = .001), as well as steps·day^{-1} (8 871 ± 3 289 vs. 5 655 ± 3 756, p = .002), whereas no statistically significant difference was shown for MVPA (26 ± 16 min·day^{-1} vs. 22 ± 19 min·day^{-1}, p = .351). None of the behavioural/lifestyle factors were statistically significantly associated with PA (p > .05).

3.4.7 Associations between physical activity and cardiorespiratory fitness, and body composition and regional fat distribution measures

Although the magnitude of the associations between LPA, MVPA, steps·day^{-1} and CRF were of small clinical importance, they were not statistically significant (r = 0.17, r = 0.18, r = 0.26, respectively; p > 0.05). Similarly, none of the associations between LPA and body composition, nor those with regional body fat measurements, were statistically significant (p > .05). Although, small clinically important associations between LPA and body composition measures, except for FFSTM (kg), were observed (Figure 3.3a).

Both higher steps·day^{-1} and CRF were associated with reduced body mass, BMI and total adiposity (kg) (p < .05), as well as reduced central obesity measures (WC, CFM [kg] and VAT) (Figure 3.3c and d) and absolute measures of regional body fat (AFM and TFM) (p < .05) (Figure 3.4c and d). Although CRF and FFSTM (kg) was inversely associated (p < .05), a positive association was found with %FFSTM (Figure 3.3c and d). The magnitude of the correlations varied between small (-0.2) and very large (-0.8) for steps·day^{-1} and relative VO_{2max}, although most of the associations were stronger with relative VO_{2max} (CRF).

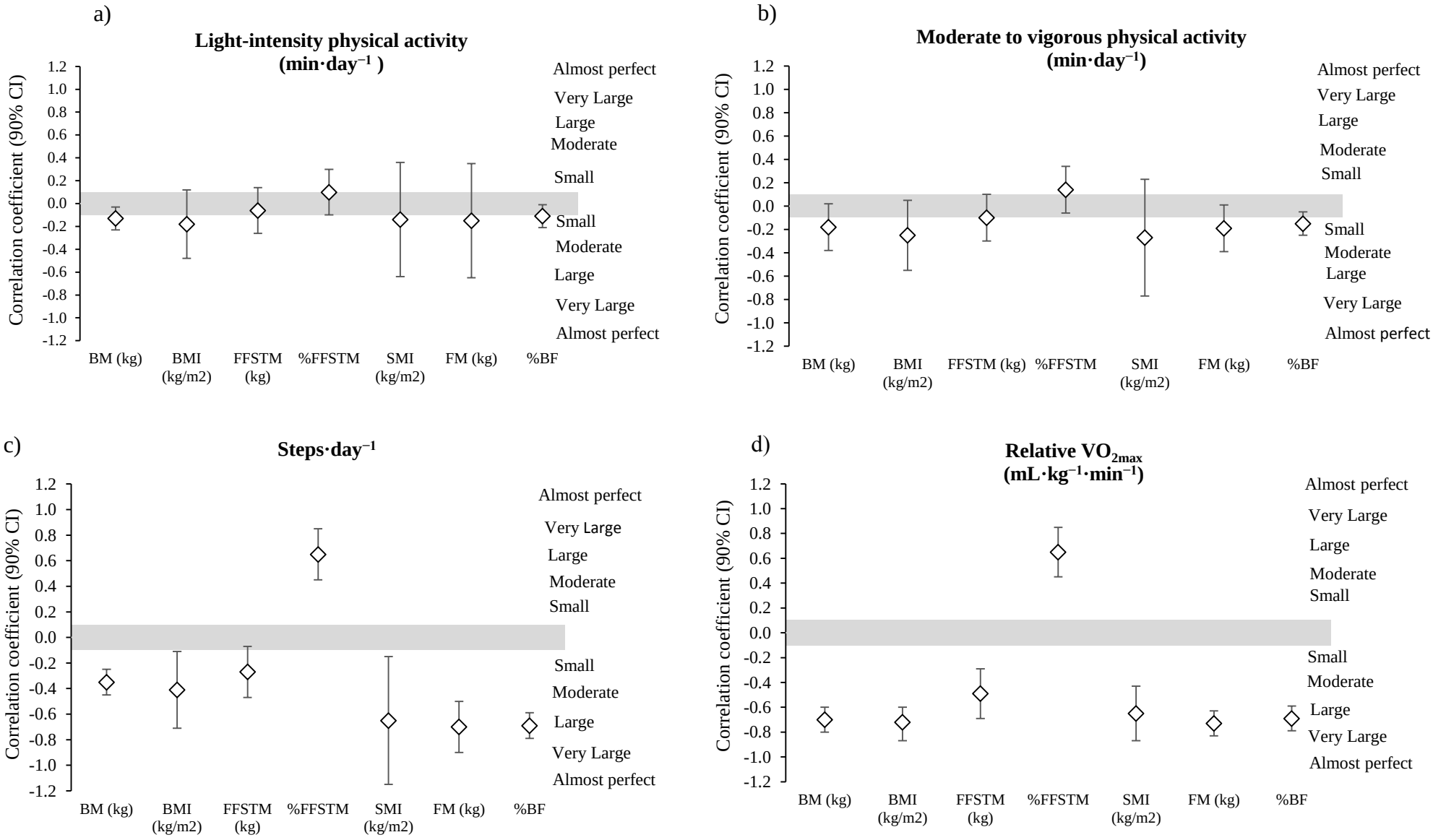

Figure 3.3 Correlation coefficient and 90% confidence intervals in relation to body composition variables and a) light-intensity physical activity (LPA); b) moderate to vigorous-intensity physical activity (MVPA); c) steps·day^{-1} and d) relative VO_{2max} (mL·kg^{-1}·min^{-1}).

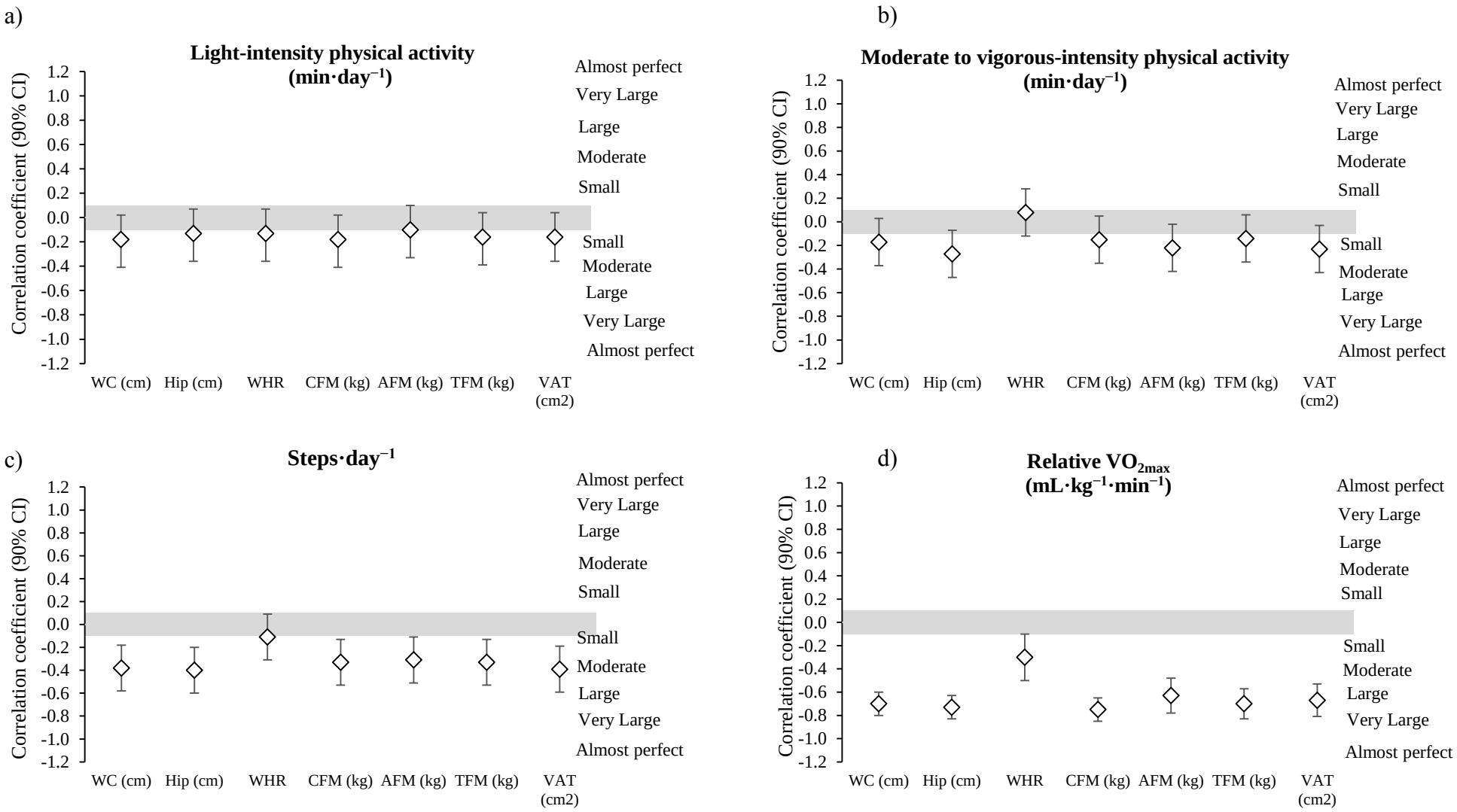

Figure 3.4 Correlation coefficient and 90% confidence intervals in relation to regional fat distribution variables and a) light-intensity physical activity (LPA); b) moderate to vigorous-intensity physical activity (MVPA); c) steps·day^{-1} and d) relative VO_{2max} (mL·kg^{-1}·min^{-1}).

3.4.8 Associations between physical activity, cardiorespiratory fitness, and cardiometabolic risk outcomes

None of the univariate associations between the PA variables, and CRF, and each of the cardiometabolic disease risk outcomes were statistically significant ($p > .05$), even after the adjustment for total FM (kg) (Additional file 1). However, after adjusting for differences in VAT area, serum concentrations of TG and TG:HDL-C were both inversely associated with all PA variables and CRF level ($p < .05$).

Most notably, the magnitude of the unadjusted correlation coefficient (r) between LPA and HDL-C (r = 0.17), and between CRF and HDL-C (r = 0.18), were deemed clinically significant (Additional file 1). The same were observed for MVPA and SBP (r = -0.13), MVPA and DBP (r = -0.16), steps·day^{-1} and SBP (r = -0.13), steps·day^{-1} and DBP (r = -0.14), CRF and SBP (r = -0.22), and CRF and DBP (r = -0.27). When adjusted for total FM (kg) and VAT area, these correlations were trivial ($r < 0.1$).

3.4.9 Multiple regression analysis

Exploration of independent associations of PA (steps·day^{-1}) and CRF (relative VO_{2max}) with body composition were determined using multiple regression analysis (Table 3.4). All models were adjusted for age (yrs) as it was shown to be inversely associated with CRF (r = -0.38, p = .008). Both steps·day^{-1} and CRF level were inversely associated with BMI (steps·day^{-1}: β =-0.25, p = .038) (CRF: β =-0.64, $p <$ .001), whereas only CRF was negatively associated with absolute FM (β = -0.53, p = .002). CRF was also positively associated with %FFSTM (β = 0.69, $p < .001$).

None of the PA variables were independently associated with any of the regional body fat distribution measures. However, CRF was inversely associated with WC (β = -0.63, $p < .001$) and VAT area (β = -0.56, $p < .001$).

Table 3.4 Independent associations (partial correlation coefficients) between physical activity variables and cardiorespiratory fitness level, with body composition and regional body fat distribution measurements.

BMI (kg·m^2)				*p*-value
n = 46	*r* = 0.751	R^2 = 0.565	SEE = 4.90	< **.001**
	β	B	SEE	
Relative VO_{2max} (mL·kg^{-1}·min^{-})	-0.648	-0.847	0.165	< **.001**
Steps·day^{-1}	-0.252	-9.889	4.600	**0.038**
Age (yrs)	-0.097	-0.054	0.066	0.415

FM (kg)				*p*-value
n = 46	*r* = 0.515	R^2 = 0.265	SEE = 14.32	< **.007**
	β	B	SEE	
Relative VO_{2max} (mL·kg^{-1}·min^{-})	-0.534	-1.569	0.484	**0.002**
Steps·day^{-1}	-0.021	-2.632	13.449	0.845
Age (yrs)	-0.090	-0.114	0.194	0.559

%FFSTM				*p*-value
n = 46	*r* = 0.478	R^2 = 0.228	SEE = 9.09	< **.018**
	β	B	SEE	
Relative VO_{2max} (mL·kg^{-1}·min^{-})	0.466	0.848	0.307	**0.008**
Steps·day^{-1}	0.116	6.391	8.538	0.458
Age (yrs)	0.254	0.200	0.123	0.114

WC (cm)				*p*-value
n = 46	*r* = 0.697	R^2 = 0.487	SEE = 12.08	< **.001**
	β	B	SEE	
Relative VO_{2max} (mL·kg^{-1}·min^{-})	-0.635	-1.883	0.408	**0.001**
Steps·day^{-1}	-0.160	-14.238	11.340	0.216
Age (yrs)	-0.046	-0.060	0.164	0.716

VAT area (cm^2)				*p*-value
n = 46	*r* = 0.692	R^2 = 0.480	SEE = 50.03	< **.001**
	β	B	SEE	
Relative VO_{2max} (mL·kg^{-1}·min^{-})	-0.566	-6.902	1.691	< **.001**
Steps·day^{-1}	-0.212	-77.597	46.960	0.106
Age (yrs)	0.026	0.142	0.680	0.835

BMI, body mass index; kg·m^2, kilograms per metred squared; *r*, correlation coefficient; R^2, coefficient of determination; SEE, standard error of estimate; β, partial correlation coefficient; B, parameter estimate; FM, fat mass, kg, kilograms; VO_{2max}, maximal aerobic capacity; mL·kg^{-1}·min^{-1}, millilitres per kilogram per minute; steps·day^{-1}, steps per day; yrs, years; %FFSTM, percentage fat-free soft tissue mass; WC, waist circumference; cm, centimetre; VAT, visceral adipose tissue; cm^2, centimetres squared. *p*-values highlighted in **bold** are statistically significant ($p < .05$).

3.5 Discussion

The principal finding of this small-scale cross-sectional study was the clinically significant and positive associations found between PA intensity time (LPA and MVPA) and daily volume (steps·day^{-1}) with CRF. Irrespective of PA intensity, statistically significant inverse associations between higher steps·day^{-1}, as well as CRF, with total adiposity, measures of regional body fat (AFM and TFM) and central obesity (WC, CFM and VAT area) were observed. However, both steps·day^{-1} and CRF were also inversely associated with FFSTM (kg) and SMI. Independent of VAT area, higher PA time (both LPA and MVPA), volume (steps·day^{-1}) and CRF were all associated with reduced TG and TG:HDL-C serum levels, suggestive of reduced cardiometabolic disease risk among the more active and/or fitter women. Most notably, higher CRF was associated with women who were younger and with reduced total and central adiposity (BMI, FM, WC and VAT area); all of which were independent of PA (steps·day^{-1}).

Although less than a third of the women in the present study met the daily step count recommendation (≥ 10 000 steps·day^{-1}) [9], our results showed that higher steps·day^{-1} was associated with lower total and central adiposity. Similar to these results, although among a larger (n = 151) rural SA sample of women (aged: 15 – 55 yrs), Cook et al. [13] reported a dose-dependent association between BMI and steps·day^{-1}. After adjusting for potential confounders (age, access to a motor vehicle, education, tobacco use and comorbidities) the study showed that for every 5 000 steps·day^{-1}, BMI was 1.4 kg·m^2 lower. The same authors also reported that women (n = 138) (age range: 19 – 56 yrs) with the highest CRF levels had significantly lower %BF [12]. Similar results were shown among a smaller sample of urban SA women (n = 46) (age range: 18 – 45 yrs) [15]. Irrespective of the different methods used to determine CRF level (indirect [12, 15] vs. direct assessment) and %BF (sum of skinfolds [12] vs. DXA [15]), all these findings, including those of the present study, signify the measurable health-related benefits associated with being more active and having a higher CRF level. Having stated this, however, our study revealed that, on average, urban women presented with "very poor" CRF levels [39] which was also lower than previously reported data from a rural (~ 26.7 mL·kg^{-1}·min^{-1}) [12] and an urban SA sample (~ 25.1 mL·kg^{-1}·min^{-1}) [15]. Thus, even though the more active and fitter women presented with more favourable health outcomes, their aerobic fitness, similar to other SA women were rated as "very poor" according to the ACSM's age-specific reference data for women [39]. Thus, it could be postulated that higher CRF levels could be associated with even more pronounced health-related benefits in these populations [48].

Possible reasons for the low aerobic fitness levels found in the present study; may in part, be explained by the lack of vigorous-intensity PA time and the relatively lower FFSTM% to higher BF% (45.8% vs. 47.2%, respectively) among those who took part. Higher PA intensities (≥ 6 METs) require an increase in the number of motor units recruited by the central nervous system resulting in higher oxygen demand and thus cardiac output [49]. However, other factors, e.g. genetics and dietary intake, which fall beyond the scope of the present study, may also contribute to a "very poor" CRF-grading [48].

Even though the majority of awake time (43.7%) spent physically active was performed at LPA (~ 5.5 hours per day), our results failed to show statistically significant associations between LPA and any of the body composition, regional body fat measures and cardiometabolic risk factors for CVD and T2DM. General findings from the literature based on accelerometer data [33], also among SA women [15], provided our motivation for the Freedson cut-points in the present study [33]. However, numerous accelerometer-based cut-points exist, specifically among adult populations, and they vary in terms of the number of activity counts·min^{-1} (e.g. light-intensity, Freedson: 100 - 1952 counts·min^{-1} vs. Troiano: 100 - 2019 counts·min^{-1}) [32]. Using these cut-point values, the differences in our data set are apparent, namely: 340 vs. 314 min·day^{-1} of LPA and 22 vs. 14 min·day^{-1} of MVPA. Thus, it is possible that a failure to identify pertinent predictors of cardiometabolic risk, as in the present study, may be attributed to the application of various PA intensity thresholds.

In the presence of visceral obesity, numerous alterations in serum biochemical parameters exist, e.g. impaired fasting glucose, abnormal liver function and dyslipidaemia [50-52]. This is confirmed by the correlation between an excess accumulation of VAT and an increased risk for CVD [51] and/or T2DM [52]. However, our study showed that independent of VAT area, but not total FM, CRF level and each of the PA variables (time in different intensity bands and steps·day^{-1}) are associated with an improved lipid profile (reduced serum TG and TG:HDL-C concentrations, respectively). Thus, total FM, as opposed to VAT area, seem to play a mediating role between the independent variable (CRF level) and each of the dependent variables (TG and TG:HDL-C). When the effect of total FM was removed, none of the relationships were statistically significant, whereas the opposite was true for VAT area. To our knowledge, this is the first study to measure, and examine DXA-derived VAT area in SA women in relation to behavioural/lifestyle factors such as PA (intensity and volume) and CRF level. Furthermore, these health-related study findings compliment those reported by Dickie et al. [15] which showed that

urban women with higher CRF levels (predicted VO_{2max}) have reduced HOMA-IR (r = -0.41, p = .01), both before and after adjusting for differences in total FM [48]. Collectively, this body of evidence underlines the cardiometabolic health-related benefits associated with higher PA volume and higher CRF levels among overweight and obese women.

Evidence is suggestive that lifestyle intervention programmes aimed exclusively at weight loss goals, should also focus on increasing CRF level [48] while monitoring changes in absolute FM and FFSTM. Given the positive effects of controlled exercise and dietary intake on improving cardiometablic health and adiposity, our challenge is to devise innovative and sustainable health and exercise promotion programmes within communities, while taking into account their personal circumstances and daily challenges. This may require partnerships with government (both national and provincial), universities, non-profit organisations and/or private enterprises to develop and present such programmes. Importantly, volunteers within communities, so-called health champions, should be empowered to lead and manage these programmes themselves and ultimately assume responsibility for the sustainability of such programmes.

Limitations of the present study include the use of a potentially biased sampling method, the small size of the study group, as well as even smaller sub-group of women who completed the maximal incremental exercise test. However, the use of objectively-derived PA variables, VO_{2max} criterion method and DXA-scanning techniques, can all be regarded as strengths of the study. The findings of the present study are preliminary, and thus hypothesis generating. Nevertheless, the study provides valuable insight into the overall health status of women living in an under-resourced urban community in South Africa. It underscores the need to introduce comprehensive lifestyle programmes for women from a young age to attenuate the age-associated progression of cardiometablic disease risk for CVD and T2DM.

3.6 Conclusion

The study highlights the health-related benefits of higher daily PA volume and CRF level, with reduced total adiposity and central obesity among both young and older women residing in an under-resourced urban setting. The challenge to design and implement healthy lifestyle-based interventions for women of all ages and fitness levels requires immediate action. To ensure the buy-in of the community in said

programmes, focus groups, comprising self-nominated community leaders with a vested interest in personal and public health, can provide the foundation for such interventions.

Additional file 1. Associations between physical activity, cardiorespiratory fitness, and cardiometabolic disease risk outcomes.

		SBP	DBP	TC	LDL-C	HDL-C	TG	TG:HDL-C
LPA ($min \cdot day^{-1}$)	Unadjusted	0.05	0.03	0.26	0.26	0.17	-0.01	-0.09
	Adjusted for FM (kg)	0.01	0.04	0.03	0.03	-0.01	-0.02	-0.01
	Adjusted for VAT (cm^2)	0.01	-0.02	0.04	0.05	0.04	**-0.34***	**-0.39***
MVPA ($min \cdot day^{-1}$)	Unadjusted	-0.13	-0.16	-0.05	-0.04	-0.02	-0.02	-0.04
	Adjusted for FM (kg)	0.01	0.07	-0.03	-0.03	-0.03	-0.02	-0.02
	Adjusted for VAT (cm^2)	0.01	0.01	-0.03	-0.03	-0.01	**-0.35***	**-0.39***
Steps$\cdot day^{-1}$	Unadjusted	-0.13	-0.14	0.02	0.03	0.11	-0.19	-0.23
	Adjusted for FM (kg)	-0.01	0.04	-0.01	-0.01	0.01	-0.01	0.01
	Adjusted for VAT (cm^2)	0.01	-0.02	-0.01	-0.01	0.03	**-0.35***	**-0.39***
Relative VO_{2max} ($mL \cdot kg^{-1} \cdot min^{-}$)	Unadjusted	-0.22	-0.27	-0.01	-0.06	0.18	-0.06	-0.10
	Adjusted for FM (kg)	0.01	0.04	-0.04	-0.04	-0.01	-0.02	-0.01
	Adjusted for VAT (cm^2)	0.01	0.05	-0.04	-0.04	0.01	**-0.43***	**-0.46****

Values are Pearson product-moment correlation coefficients (top row, unadjusted values) and partial correlation coefficients (middle row; values adjusted for fat mass (FM) in kilograms (kg); bottom row, values adjusted for visceral adipose tissue area (VAT) in centimetre squared (cm^2). $min \cdot day^{-1}$, minutes per day; LPA, light-intensity physical activity; MVPA, moderate to vigorous-intensity physical activity; steps$\cdot day^{-1}$, steps per day; max.; maximal; VO_{2max}, maximal aerobic capacity; $mL \cdot kg^{-1} \cdot min^{-1}$, millilitres per kilogram per minute; SBP, systolic blood pressure; DBP, diastolic blood pressure; TC, total cholesterol; LDL-C, low-density lipoprotein cholesterol, HDL-C, high-density lipoprotein cholesterol; TG:HDL-C, triglyceride to high-density lipoprotein cholesterol ratio. * $p < .05$; ** $p < .01$.

Associations between physical activity, cardiorespiratory fitness, and cardiometabolic disease risk outcomes (continued).

		Lp (a)	Apo A	Apo B	Apo B:Apo A	FPG	HbA1c
LPA ($min \cdot day^{-1}$)	Unadjusted	-0.03	0.01	0.20	0.18	0.15	0.13
	Adjusted for FM (kg)	-0.03	-0.03	0.01	0.01	-0.01	-0.03
	Adjusted for VAT (cm^2)	-0.02	-0.03	0.02	-0.01	0.07	0.04
MVPA ($min \cdot day^{-1}$)	Unadjusted	-0.01	-0.17	-0.03	0.03	0.06	0.12
	Adjusted for FM (kg)	-0.03	-0.04	-0.01	-0.01	-0.04	-0.02
	Adjusted for VAT (cm^2)	-0.02	-0.02	-0.01	-0.01	0.04	0.05
Steps$\cdot day^{-1}$	Unadjusted	-0.11	-0.12	-0.07	-0.03	-0.07	0.02
	Adjusted for FM (kg)	-0.02	-0.01	-0.01	0.01	-0.04	-0.04
	Adjusted for VAT (cm^2)	0.01	-0.04	0.01	0.01	0.04	0.06
Relative VO_{2max} ($mL \cdot kg^{-1} \cdot min^{-}$)	Unadjusted	0.03	0.03	-0.10	-0.12	-0.07	-0.06
	Adjusted for FM (kg)	-0.03	-0.04	-0.03	-0.02	-0.02	-0.04
	Adjusted for VAT (cm^2)	0.01	-0.03	-0.02	0.01	0.04	0.02

Values are Pearson product-moment correlation coefficients (top row, unadjusted values) and partial correlation coefficients (middle row, values adjusted for fat mass [FM] in kilograms [kg]); bottom row, values adjusted for visceral adipose tissue area [VAT] in centimetre squared [cm^2]). $min \cdot day^{-1}$, minutes per day; LPA, light-intensity physical activity; MVPA, moderate to vigorous-intensity physical activity; steps$\cdot day^{-}1$, steps per day; max., maximal; VO_{2max}, maximal aerobic capacity; $mL \cdot kg^{-1} \cdot min^{-1}$, millilitres per kilogram per minute; Apo A, Apolipoprotein A1; Apo B, Apolipoprotein B; Apo B:Apo A, Apolipoprotein B to Apolipoprotein A1 ratio; FPG, fasting plasma glucose; HbA1c%, haemoglobin A1c%.* $p < .05$; ** $p < .01$.

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CHAPTER 4

ARTICLE THREE:

LOW PHYSICAL HEALTH-RELATED FITNESS POSES GREATER CARDIOMETABOLIC RISK IN WOMEN FROM AN UNDER-RESOURCED URBAN COMMUNITY THAN SEDENTARY TIME

Article to be submitted to the International Journal of Physical Activity and Health and presented in accordance with the author guidelines (Appendix F)

Kasha Dickie, Carla Coetsee, Sharné Nieuwoudt, Louise Engelbrecht, Elmarie Terblanche

Department of Sport Science, Faculty of Medicine and Health Sciences, Stellenbosch University, Private Bag X1, Matieland, 7601, South Africa

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Contributions to the research article

Ms Kasha Dickie was involved in the conception and design of the research study, data cleaning and analysis, the drafting and writing of the manuscript, as well as the general management of the research group. Prof Elmarie Terblanche was involved in the conception and design of the research study, assisted and guided the statistical analysis, and the writing and editing of the manuscript. Dr Carla Coetsee assisted with data collection, and editing of the manuscript. Ms Sharné Nieuwoudt and Ms Louise Engelbrecht assisted with data collection, data cleaning and analysis.

4.1 Abstract

Background: The purpose of this study was to characterise sedentary time (ST) and type, and to examine the independent associations between objectively measured ST, moderate to vigorous-intensity physical activity (MVPA) and physical health-related fitness, with cardiometabolic risk. **Methods:** Fifty-one South African (SA) women (42 ± 13 yrs) completed interviewer-administered lifestyle questionnaires and laboratory-based tests to determine cardiometabolic disease risk profiles. Accelerometers (GT3X ActiGraph) were fitted and worn for ± 5 days. Multivariate linear regression was used to characterise the relationships between ST, MVPA and physical health-related fitness, with cardiometabolic risk. **Results:** No discernible associations between ST and MVPA, nor ST and CRF level, were observed. A moderately strong, inverse association was found between ST and muscular strength (r = -0.35; p = 0.011). Only physical health-related fitness and neither ST, nor MVPA, was independently associated with cardiometabolic risk, though potentially mediated by total and central adiposity. **Conclusions:** Lower CRF and muscular strength, as opposed to ST and MVPA, pose greater cardiometabolic disease risk in women from an under-resourced urban community. Low CRF and muscular strength, as opposed to ST and MVPA, pose greater cardiometabolic disease risk in women from an under-resourced urban community. Although there is somewhat of a minor truth in the "some physical activity is better than nothing" notion, our findings suggest that low levels of physical activity are not sufficient to impact fitness levels to the extent that it would provide some protection against women's risk for future cardiometabolic disease. Furthermore, efforts to improve the overall fitness status of women in under-resourced communities may be ineffective if their dietary habits are not simultaneously addressed, as exercise alone cannot solve the overweight and obesity problem that is prevalent among these women.

Keywords: Sedentarism, maximal aerobic capacity, hand grip strength

4.2 Background

Physical inactivity, an unhealthy diet, and tobacco and alcohol use, are described by the World Health Organization (WHO) as behavioural/lifestyle factors associated with increased risk for non-communicable disease (NCD).[1] The effects of such behaviours may result in obesity, hypertension, dyslipidaemia and glucose intolerance, and when clustered together are referred to as the metabolic syndrome (MetS).[2] Similarly, prolonged bouts of sedentary time (ST) characterised by an energy expenditure of ≤ 1.5 metabolic equivalents[3] are also linked to deleterious health effects.[4,5,6] Of particular interest are the findings from a meta-analysis among adults, highlighting the independent and positive association between higher ST and increased cardiometabolic risk for cardiovascular disease (CVD) and type 2 diabetes mellitus (T2DM), which remained even after adjusting for differences in moderate to vigorous-intensity physical activity (MVPA) time.[7] Such findings indicate the health-related benefits in targeting the reduction of ST. The latter differs in definition to physical inactivity which refers to individuals who perform insufficient amounts of MVPA.[3] In light of this, targeting ST as an additional public health strategy to the current MVPA behavioural recommendations (i.e. ≥ 150 min/week of MVPA),[24] in managing NCD-risk, warrants further investigation.

Recognised as modifiable behaviours, ST and MVPA are important predictors of cardiometabolic risk.[40] Cardiorespiratory fitness (CRF), considered a physiological entity comprised of an individual's genetic potential and physical activity behaviour, is an equally important predictor of cardiometabolic health. Results from a large adult population-based study[39] indicated statistically significant associations between low MVPA and CRF levels, and high clustered cardiometabolic risk. Notably, even after adjustment for MVPA and ST, CRF remained the most important predictor for clustered cardiometabolic risk. The continuous clustered cardiometabolic risk score (CCMRS), as opposed to the traditional binary MetS criteria, is beneficial as it portrays an individual's progressive increase in risk better when more risk factors are present.

To our knowledge, little is known about sedentary behaviour among South Africans.[8] Only two studies[9,10] highlighted the negative impact of ST on cardiometabolic health of urban-dwelling obese women. Of major concern, is the high prevalence of severe obesity (BMI: ≥ 35 kg/m^2) among adult South African

(SA) women as compared to their male counterparts (20.0% vs. 3.0%, respectively),[11] and moreover, the irrefutable negative health implications associated with excess adiposity.[12] Recent evidence suggests that a moderate-high cardiorespiratory fitness (CRF) level, may in part, counteract the negative consequences associated with obesity.[13] In addition, the importance of increased muscular strength and reduced cardiometabolic risk for CVD.[38] As components of physical-health related fitness, there remains a scarcity of data on CRF and muscular strength among adults in SA. Therefore, there is a compelling need to characterise ST and physical health-related fitness among women who are already obese. Furthermore, it should be determined whether high levels of ST and low levels of CRF and muscular strength relate to higher levels of total and central adiposity. Collectively, all these factors have the propensity to negatively impact overall cardiometabolic risk for CVD and T2DM, as well as health-related quality of life.

Thus, the aim of this study was two-fold: i) to characterise ST (time and type) in urban women; and ii) to examine the independent associations between ST, MVPA and physical health-related fitness (CRF level and muscular strength), with cardiometabolic risk. We hypothesise that objectively measured high ST, low MVPA, and low measures of physical health-related fitness, are independently associated with an unfavourable cardiometabolic disease risk profile in urban women.

4.3 Methods

4.3.1 Study design, participants, and sampling method

This cross-sectional study included a convenience sample of residents from Cloetesville (Stellenbosch, Western Cape, South Africa), regarded an under-resourced urban living area.[14] Using the chain sampling approach and assistance from a community representative, 73 women were recruited from the local community centre, health clinic and faith groups. Inclusion criteria were women aged between 18–64 yrs who were not pregnant or lactating, had no apparent physical and psychological diseases and were not using T2DM medication. Although rapid HIV-testing was not performed, participants were asked if they were receiving treatment for HIV. A total of 12 participants were excluded for reasons including angina,

pregnancy and T2DM medication use, 10 women were excluded due to invalid accelerometer data and 5 women chose not to complete the maximal exercise test. Approval of the study was granted by the Human Research (Humanities) Ethics Committee of Stellenbosch University (Ref. No.: SU-HSD-004704).

4.3.2 Procedures

Lifestyle-questionnaires included the WHO STEPwise approach to chronic disease risk factor surveillance instrument and the Sedentary Behaviour Questionnaire (SBQ), the latter shown to be a valid and reliable adult assessment tool.[15] Both questionnaires were explained to each participant in their preferred language (Afrikaans or English) on the first day of testing. Resting blood pressure (BP) was measured in three successive intervals (Omron® HBP-1100, Omron Healthcare, Mannheim, Germany) and a fasting blood sample drawn to determine plasma glucose level (FPG), glycated haemoglobin (HbA1c) and serum lipid concentrations. Body mass (BM) and standing height, were measured using a calibrated electronic scale (Seca® 813, Hamburg, Germany) and sliding steel anthropometer (Seca® 711, Hamburg, Germany). Waist circumference (WC) at the level of the umbilicus was also recorded, whereas DXA (Discovery-W®, software version 13.4.1; Hologic, Bedford, MA) was used to measure whole body composition (fat-free soft tissue mass [FFSTM] and fat mass [FM]), as well as regional body fat distribution (central, appendicular, and trunk).[16] Skeletal muscle index (SMI = ASM/height^2) according to the guidelines set by the European Working Group on Sarcopenia in Older People (EWGSOP)[17] and VAT area (cm^2)[18] were also determined.

Each participant was instructed to wear an ActiGraph GT3X accelerometer (ActiGraph LLC, Pensacola, Florida) on their right hip attached to an elastic belt during waking hours for 7-days. Due to the monitor being non-water resistant, participants were instructed not to wear it when bathing or swimming. Recording of activity counts commenced 2-hrs after the monitor was fitted with time sampling intervals set at 60-sec epochs. Each ActiGraph data file (*.agd) was downloaded onto a personalised computer and processed in Microsoft Excel® using a custom-written program ('ACTILIFE', http://actigraphcorp.com/products-showcase/software/actilife/). Data was included only if participants met the minimum requirement of ≥ 600-min of monitor wear time on ≥ 3-days.[19] Wear time was determined by subtracting non-wear time from 24-hrs, where non-wear time was defined as an interval

of ≥ 60 consecutive min with zero activity counts allowing for intervals of 1–2-min of relatively low activity counts/min (i.e. < 100). According to Freedson[20] cut-points, ST reported in min/day was defined as < 100 counts/min, whereas MVPA as ≥ 1952 counts/min.

Physical health-related fitness components included muscular strength (kg) determined using a hand grip dynamometer (Takei Digital Hand Grip 5401, Niigata City, Japan) and CRF level (relative VO_{2max}) determined using an incremental exercise test performed to exhaustion on the h/p/Cosmos Saturn® treadmill (Nussdorf-Traunstein, Germany) along with the COSMED Quark CPET metabolic system (Rome, Italy).

Informed by the International Diabetes Federation (IDF) MetS criteria[21] a clustered cardiometabolic risk score (CCMRS), indicative of additional risk over and above the sum of the risk associated with each aberration,[21] was generated by standardising each individual risk factor (i.e. subtracting the sample mean from the participant's mean value and then dividing by the standard deviation of the sample [z-score]). Consequently, the standardised values for BP, WC, TG, log FPG, and the inverse of HDL-C, were added and the total divided by the denominator equal to the number of risk factors included (i.e. x = 5). A positive CCMRS meant a less preferable cardiometabolic disease risk profile.

4.3.3 Statistical analyses

Using STATISTICA version 13.3 (StatSoft Inc. Tulsa, OK, USA) the descriptive data are presented as means ± standard deviations or percentages. Non-gaussian distributed data (ST type, accelerometer-data, FPG, and HbA1c) are presented as medians with interquartile range and normalised by log-transformation for parametric analyses. Differences in weekday vs. weekend day ST behavioural types were determined using Student *t*-tests. Group differences between the 51 vs. 46 participants who completed the CRF test, were assessed using Chi-squared tests (categorical variables) and Student *t*-tests (age and asset index). One-way analysis of variance (ANOVA) was used to determine if there were any differences between ST type, accelerometer data, muscular strength and cardiometabolic risk between the whole group (n = 51) and the sub-group (n = 46). The level of statistical significance was set at $p < 0.05$.

To explore the univariate associations between objectively measured ST in relation to i) MVPA, and ii) physical health-related fitness (muscular strength and CRF level), Pearson product-moment correlation coefficients (*r*) and 90% confidence intervals were calculated. Qualitative inferences for the probability of each "true" or "clinically significant" association using prescribed threshold values (< 0.1, trivial; 0.1–0.3, small; > 0.3–0.5, moderate; > 0.5–0.7, large; > 0.7–0.9, very large) were also determined.[22] The same analysis was completed between ST and body composition, regional fat, individual cardiometabolic risk outcomes and CCMRS, both before and after adjusting for fat mass [kg] and VAT area [cm^2]). These results informed the forward stepwise multiple regression analyses to detect the presence of independent associations between ST, MVPA, and physical health-related fitness, with individual cardiometabolic risk outcomes and CCMRS.

According to Cohen,[23] and at a power of 80% and statistical significance of 5%, a sample size of 38–68 participants was required to detect medium to large effect sizes for a maximum of four predictor variables in each multiple regression analysis. A variance inflation factor (< 3) was used to assess for multi-collinearity between the dependent variables.

4.4 Results

4.4.1 Socio-demographics, socio-economic status, behavioural/lifestyle factors and physical health-related fitness

Socio-demographics, socio-economic status (SES) and behavioural/lifestyle factors are shown in Table 4.1. Even though the majority of women were employed, little over a third had completed secondary school (grade 12). Few consumed alcohol (≥ 4 drinks/month), with even fewer reporting habitual smoking. On average, women possessed 86% of the personal and household wealth items listed in the questionnaire. Internet connectivity (88.2%; *n* = 45) and ownership of a motor vehicle (47.1%; *n* = 24) were the two most frequently absent items.

Table 4.1 Socio-demographics, socio-economic status and behavioural/lifestyle factors.

Socio-demographics	***n* = 51**
Age (yrs)	42 ± 13 (18 - 64)
Education	***n* = 51**
Completed grade 7 (%) (*n*)	66.7 (34)
Completed grade 12 and/or tertiary education (%) (*n*)	33.3 (17)
Employment	***n* = 51**
Employed (%) (*n*)	60.8 (31)
Unemployed (%) (*n*)	23.5 (13)
Retirees/ Homemakers (%) (*n*)	9.8 (5)
Students (%) (*n*)	5.9 (3)
Behavioural/lifestyle factors	***n* = 51**
Consumers of alcohol (%) (*n*)	25.5 (13)
Smokers (%) (*n*)	21.6 (11)
Asset index (number of assets out of a possible 14)	12 ± 2 (6 - 13)

Values for age and asset index are mean ± standard deviations with range in parenthesis.

Self-report sedentary behaviours (type) on a typical weekday and weekend day are presented in Table 4.2. Irrespective of week vs. weekend day, time spent watching television was the highest of the self-reported sedentary behaviours (Figure 4.1). Likewise, and specifically during a typical weekday, time spent seated while listening to music, talking on the phone, driving/riding a car, bus or train, and reading, also ranked high (median: 180 min/day). Less time was spent in the remainder of sedentary behaviours (i.e. playing computer/video games, doing paperwork/office work, playing a musical instrument, and doing arts/crafts). Only one sedentary behaviour, namely time spent doing paperwork/office work, was statistically significantly different between week vs. weekend day ($p = 0.020$).

Table 4.2 Self-report sedentary behaviours (type) on a typical weekday and weekend day.

Time spent siting (min/day)	**Weekday (*n* = 51)**	**Weekend day (*n* = 51)**	***p*-value**
Watching television	300 (240 - 360)	300 (240 - 360)	*0.223*
Listening to music	180 (60 - 240)	240 (120 - 300)	*0.219*
Talking on the phone	180 (120 - 240)	180 (120 - 240)	*0.448*
Diving/riding in a car, bus, or train	180 (120 - 240)	180 (120 - 300)	*0.498*
Reading	180 (120 - 240)	120 (60 - 240)	*0.085*
Playing computer/video games	120 (60 - 240)	60 (60 - 240)	*0.740*
Doing paperwork/ office work	60 (60 - 240)	60 (60 - 60)	***0.020****
Playing a musical instrument	60 (60 - 60)	60 (60 - 60)	*0.842*
Doing arts and crafts	60 (60 - 60)	60 (60 - 60)	*0.484*

Values are medians with interquartile range in parenthesis. min/day, minutes per day. All values were normalised by log transformation for parametric analyses. * indicates p-value < 0.05.

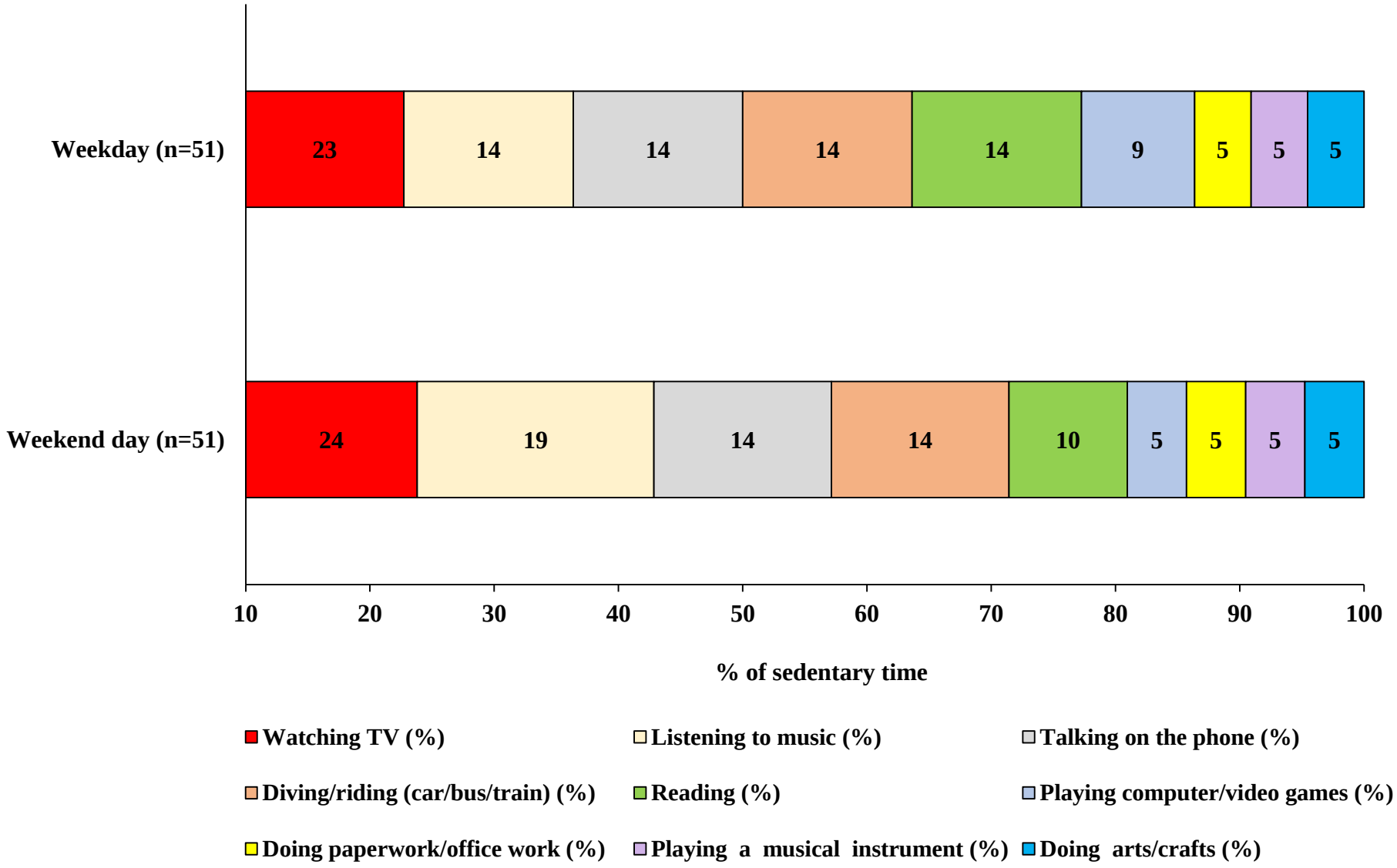

Figure 4.1 The proportion of self-reported sedentary time spent on a typical week vs. weekend day (n = 51).

Objectively measured ST and MVPA (min/day) are presented in Table 4.3. While wearing the accelerometer, women spent a larger proportion of awake time sedentary (57.3%; ~7.8 hr/day) vs. physically active (2.7%; ~22 min/day). Thus, most of the women (72.6%) fail to meet the MVPA WHO global health recommendations.[24] In comparison to international age- and sex-specific CRF classifications, their relative VO_{2max} (23.2 ± 5.4 $mL \cdot kg^{-1} \cdot min^{-}$) was rated as "poor" and fell between the 25th and 30th percentiles (22.1 – 23.3 $mL \cdot kg^{-1} \cdot min^{-1}$).[26] Similarly, muscular strength was also rated "poorly" (26.5 ± 5.1 kg) and considerably lower than ≥ 54.0 kg which is rated as "good".[25]

Table 4.3 Accelerometer-derived sedentary and moderate to vigorous-intensity physical activity time, cardiorespiratory fitness and muscular strength.

Accelerometry	***n* = 51**
Number of activity days measured	5 (5 - 6)
Non-wear time (min/day)	611 (542 - 636)
Wear time (min/day)	829 (801 - 898)
Sedentary time (min/day)	475 (442 - 514)
MVPA (min/day)	22 (12 - 30)
Cardiorespiratory fitness	***n* = 46**
Relative VO_{2max} ($mL \cdot kg^{-1} \cdot min^{-1}$)	23.2 ± 5.4 (11.5 - 35.1)
Muscular strength	***n* = 51**
Dominant hand grip strength (kg)	26.5 ± 5.1 (13.6 - 38.8)

Values for accelerometry data are medians with inter-quartile range in parenthesis. min/day, minute per day; MVPA, moderate to vigorous-intensity physical activity; %, percentage. Cardiorespiratory fitness and muscular strength values are mean ± standard deviation with range in parenthesis. VO_{2max}, maximal aerobic capacity; $mL \cdot kg^{-1} \cdot min^{-1}$, millilitres per kilogram per minute; kg, kilogram.

No statistically significant differences in age, SES, height, any of the body composition measures (BM, BMI, FM, %BF, WC and VAT area), or any of the individual cardiometabolic risk outcomes and CCMRS were found between the whole group and the sub-group of women who completed the CRF test (all, $p > 0.05$). In accordance with BMI categories, the majority of women were either obese or overweight (56.9% and 25.5%, respectively), whereas the minority was either normal weight (13.7%) or underweight (3.9%).

DXA-derived mean %BF was just below 50% of total BM (47.2 ± 7.2%), thus rated as "very poor" and shown to fall below the 1st percentile (> 39.1%) of age- and sex-related classifications.[25] Although 26.0% of the women were sarcopenic according to the international EWGSOP standards (SMI: ≤ 5.76 kg/m^2), none were considered BMI-obese.[17] However, when using the lower SA sarcopenia-specific cut-point (SMI: ≤ 4.94 kg/m^2), the proportion was lower (22.0%; *n* = 11) and included both younger and older women (age range: 18 – 52 yrs).[26]

Table 4.4 Body composition and regional body fat distribution measurements.

Body composition	***n***	**Mean ± SD**	**Range**
Height (m)	*51*	1.56 ± 0.1	1.37 - 1.69
Body mass (kg)	*51*	76.2 ± 18.8	37.7 - 127.0
BMI (kg/m^2)	*51*	31.3 ± 7.2	15.1 - 53.1
Fat-free soft tissue mass (kg)	*50*	33.8 ± 6.5	21.8 - 57.9
Fat-free soft tissue mass (%)	*50*	45.8 ± 6.0	33.4 - 64.3
SMI (kg/m^2)	*50*	6.5 ± 1.0	4.4 - 9.4
Fat mass (kg)	*50*	36.6 ± 13.0	9.0 - 68.6
Body fat (%)	*50*	47.2 ± 7.0	24.3 - 61.1
Regional body fat distribution	***n***	**Mean ± SD**	**Range**
Waist circumference (cm)	*51*	88.7 ± 16.2	57.4 - 138.3
CFM (kg)	*50*	18.9 ± 7.0	4.2 - 39.3
CFM (% FM)	*50*	53.1 ± 4.8	41.2 - 63.0
AFM (kg)	*50*	17.7 ± 6.5	4.8 - 36.2
AFM (% FM)	*50*	50.0 ± 5.1	39.4 - 60.5
VAT area (cm^2)	*51*	151.7 ± 66.2	19.2 - 418.0

Values are mean ± standard deviation (SD). m, metres; kg, kilograms; BMI, body mass index; SMI, skeletal muscle mass; %, percentage; CFM, central fat mass; AFM, appendicular fat mass; VAT, visceral adipose tissue; cm^2, centimetres squared.

In accordance with the IDF risk cut-off criteria for WC (≥ 80 cm),[21] the group presented with high cardiometabolic risk (88.7 ± 16.2 cm). %CFM was higher than %AFM (53.1% vs. 50.0%, respectively), and VAT area ranged between 19.2 – 418.0 cm^2.

4.4.2 Cardiometabolic risk outcomes and clustered cardiometabolic risk score

The individual cardiometabolic risk outcomes are presented in Table 4.5, with frequency distributions of the individual and CCMRS depicted in Figure 4.2 and 4.3, respectively. According to international diagnostic criteria, mean DBP (84.4 ± 14.8 mm Hg) was indicative of stage 1 hypertension,[27] whereas HbA1c (≥ 5.7%) that of prediabetes.[28] Mean serum HDL-C was below and plasma Lp (a) above their respective ideal values.[29,30]

Table 4.5 Individual cardiometabolic risk outcomes.

Blood pressure	**Ideal value**	**Mean ± SD**	**Range**
SBP (mm Hg) (*n* = 48)	< 120	128.0 ± 20.0	93.3 - 183.0
DBP (mm Hg) (*n* = 48)	< 80	84.4 ± 14.8	54.6 - 133.0
Lipid profile	**Ideal value**	**Mean ± SD**	**Range**
TC (mmol/L) (*n* = 51)	< 5.0	4.9 ± 1.1	2.2 - 8.1
LDL-C (mmol/L) (*n* = 51)	< 3.0	2.9 ± 0.9	0.8 - 5.5
HDL-C (mmol/L) (*n* = 51)	≥ 1.3	1.2 ± 0.3	0.7 - 1.9
TG (mmol/L) (*n* = 51)	< 1.7	1.3 ± 0.7	0.3 - 3.6
TG:HDL-C (*n* = 51)	< 2.0	1.0 ± 0.6	0.2 - 2.9
Lp (a) (mg/dL) (*n* = 51)	< 50.0	54.5 ± 49.4	2.0 - 232.0
Diabetes indicators	**Ideal value**	**Median**	**Interquartile range**
FPG (mmol/L) (*n* = 50)	< 5.6	4.9	4.5 - 5.6
HbA1c (%)(*n* = 51)	< 5.7	5.7	5.4 - 5.9

Values for blood pressure and lipid profile are unadjusted means ± standard deviation (SD), whereas values for indicators for diabetes are medians and interquartile range. SBP, systolic blood pressure; mm Hg, millilitres of mercury; DBP, diastolic blood pressure; TC, total cholesterol; mmol.L, millimoles per litre; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol;TG, triglyceride; TG:HDL-C, triglycerides to high-density lipoprotein cholesterol ratio; Lp (a), lipoprotein a; mg/dL, milligrams per decilitre; FPG, fasting plasma glucose; HbA1c, glycated haemoglobin.

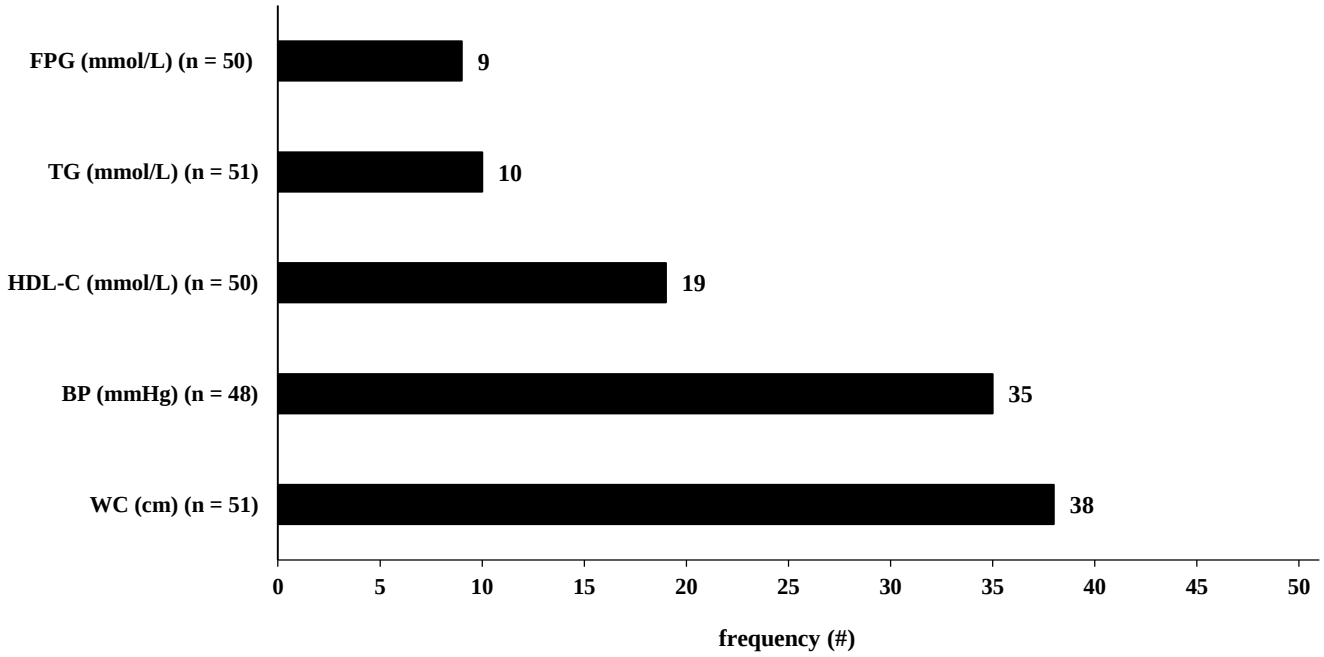

Figure 4.2 The number of women with cardiometabolic risk scores outside their ideal values.

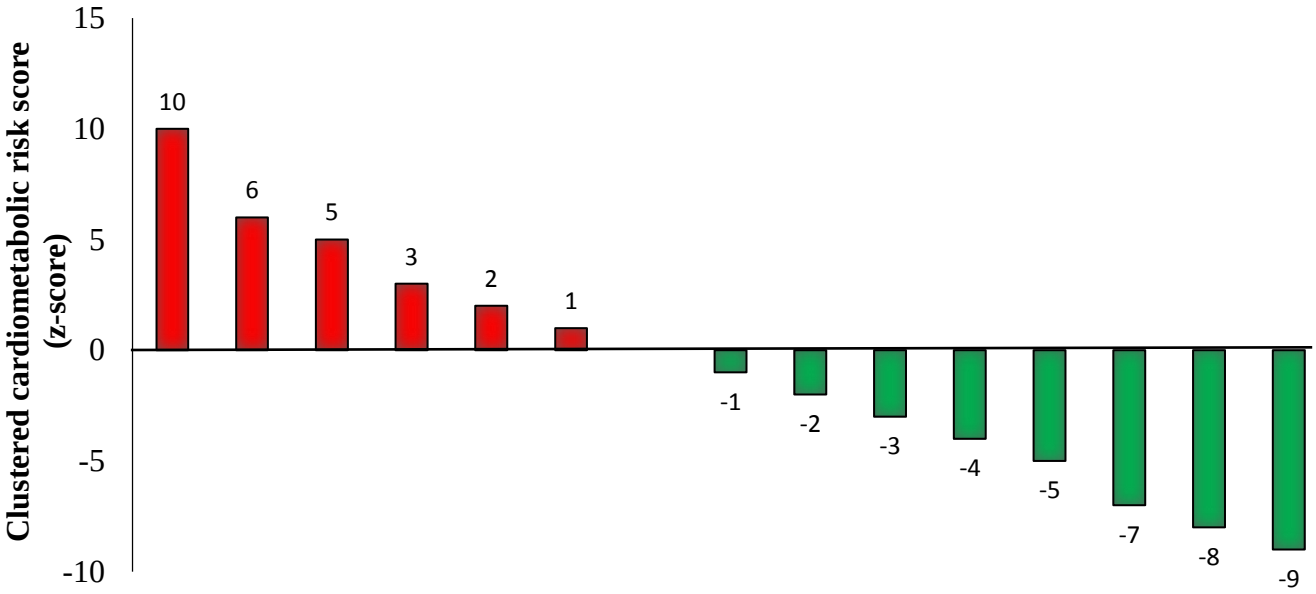

Figure 4.3 A frequency distribution of positive (red) vs. negative (green) clustered cardiometabolic risk scores (CCMRS) of all the women. A positive CCMRS implies a less preferable cardiometabolic disease risk profile, while a negative CCMRS indicates a more preferable cardiometabolic disease risk profile.

4.4.3 Associations between sedentary time, socio-demographics, socio-economic status, and behavioural/lifestyle factors

Objectively measured ST and age were not related (r = 0.07; p = 0.588). Women who were employed accumulated less ST per day compared to the unemployed women (463 ± 12 min/day vs. 505 ± 14 min/day; p = 0.051). None of the other SES or behavioural/lifestyle factors were statistically significantly associated with ST (p > 0.05).

4.4.4 Associations between sedentary time, MVPA and physical health-related fitness

Neither MVPA, nor CRF correlated with objectively measured ST (Table 4.6). However, muscular strength was statistically significantly and inversely associated with ST (r = -0.35; p = 0.011) (Figure 4.4).

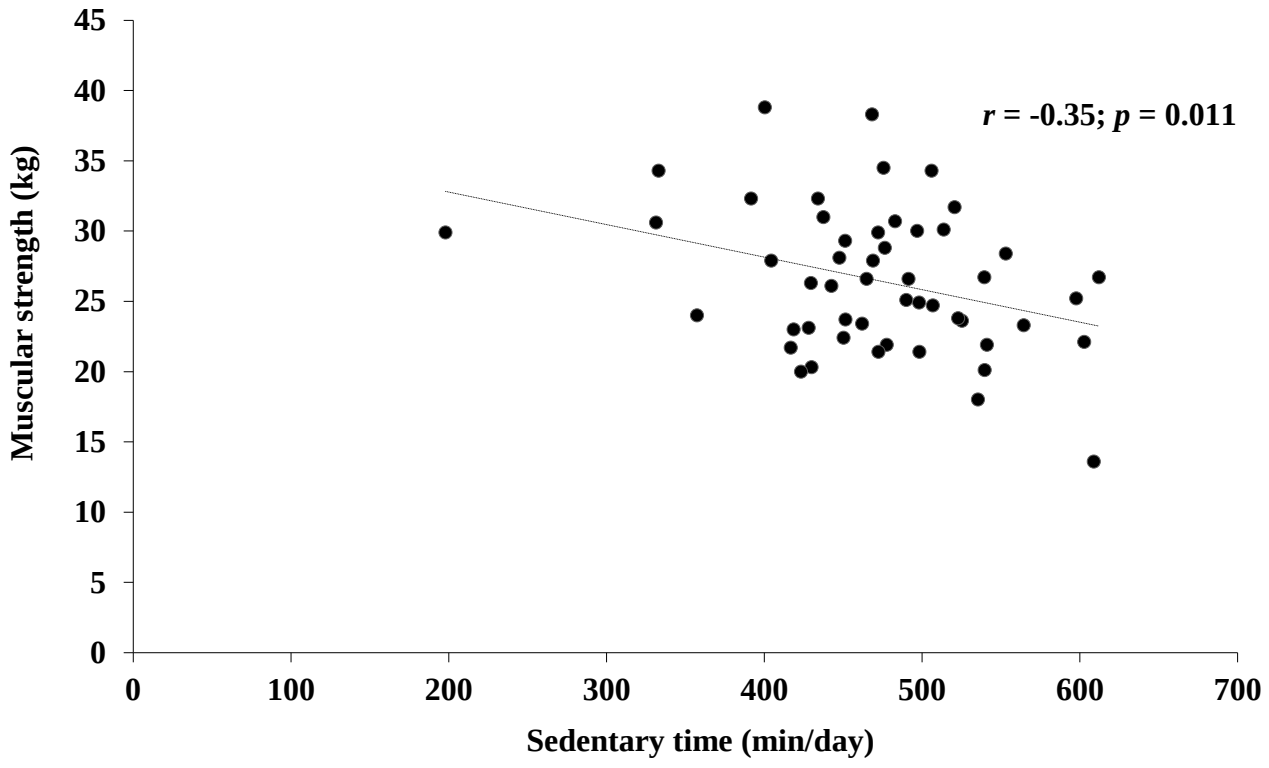

Figure 4.4 The inverse association between objectively measured sedentary time and muscular strength as a component of health-related physical fitness.

4.4.5 Associations between sedentary time, body composition, and regional body fat distribution measures

None of the univariate associations between any of the body composition distribution measures were significantly correlated with ST (all, $p > 0.05$) (Table 4.6). Small clinically significant inverse associations between ST and FFSTM (kg), and SMI (kg/m^2) were observed.

Table 4.6 Correlation coefficients between objectively measured sedentary time and behavioural/lifestyle measures, body composition and regional body fat distribution measures.

	n	Correlation coefficient (90% CI)	Magnitude-based inference
Behavioural/lifestyle measures			
MVPA (min/day)	*51*	-0.02 (-0.25; 0.21)	Trivial
Cardiorespiratory fitness ($mL \cdot kg^{-1} \cdot min^{-1}$)	*46*	-0.04 (-0.27; 0.19)	Trivial
Muscular strength (kg)	*51*	**-0.35*(-0.54; -0.13)**	**Small**
Body composition			
Body mass (kg)	*51*	-0.08 (-0.31; 0.16)	Trivial
BMI (kg/m^2)	*51*	-0.07 (-0.30; 0.17)	Trivial
Fat-free soft tissue mass (kg)	*50*	**-0.18 (-0.40; 0.06)**	**Small**
Fat-free soft tissue mass (%)	*50*	-0.02 (-0.25; 0.21)	Trivial
SMI (kg/m^2)	*50*	**-0.16 (-0.38; 0.08)**	**Small**
Fat mass (kg)	*50*	-0.07 (-0.30; 0.17)	Trivial
Body fat (%)	*50*	0.01 (-0.22; 0.24)	Trivial
Regional body fat distribution measures			
Waist circumference (cm)	*51*	-0.07 (-0.30; 0.17)	Trivial
CFM (kg)	*50*	-0.08 (-0.31; 0.16)	Trivial
CFM (%)	*50*	-0.06 (-0.29; 0.18)	Trivial
AFM (kg)	*50*	-0.05 (-0.28; 0.19)	Trivial
AFM (%)	*50*	0.08 (-0.16; 0.31)	Trivial
TFM (kg)	*50*	-0.08 (-0.31; 0.16)	Trivial
TFM (%)	*50*	-0.03 (-0.26; 0.23)	Trivial
VAT area (cm^2)	*50*	-0.06 (-0.29; 0.18)	Trivial

min/day, minute per day; moderate to vigorous-intensity physical activity; $mL \cdot kg^{-1} \cdot min^{-1}$, millilitres per kilogram per minute; kg, kilogram; BMI, body mass index; kg/m^2, kilogram per metre squared; %, percentage; SMI, skeletal mass index; CFM, central fat mass; AFM, appendicular fat mass; TFM, trunk fat mass; VAT, visceral adipose tissue; cm^2, centimetres squared. *r*-values highlighted in **bold** indicate clinically significant effect size; * indicates *p*-value < 0.05.

4.4.6 Associations between sedentary time, individual cardiometabolic risk outcomes, and clustered cardiometabolic risk

None of the univariate associations between ST and any of the individual cardiometabolic risk outcomes presented in Table 4.7 were statistically significantly correlated (all, $p > 0.05$). However, after adjusting for differences in VAT area (cm^2), ST correlated positively with serum TG ($r = 0.36$; $p = 0.048$), TG:HDL-C ($r = 0.41$; $p = 0.020$) and also with CCMRS ($r = 0.65$; $p < 0.001$). When adjusting for differences in total FM (kg) and VAT area (cm^2), CCMRS was strongly correlated with ST ($r = 0.46$ and $r = 0.65$; $p < 0.001$).

Table 4.7 Associations between objectively measured sedentary time with individual cardiometabolic risk outcomes and clustered cardiometabolic risk score.

	Unadjusted (±90% CI)	**Magnitude-based inference**	***Adjusted for FM (kg) (±90% CI)***	**Magnitude-based inference**	***Adjusted for VAT area (cm^2) (±90% CI)***	**Magnitude-based inference**
SBP (*n* = 48)	**-0.11 (-0.34; 0.13)**	**Small**	-0.01 (-0.25; 0.23)	Trivial	0.02 (-0.22; 0.26)	Trivial
DBP (*n* = 48)	**-0.18 (-0.40; 0.06)**	**Small**	-0.01 (-0.25; 0.23)	Trivial	0.02 (-0.22; 0.26)	Trivial
TC (*n* = 51)	**-0.18 (-0.40; 0.06)**	**Small**	-0.01 (-0.25; 0.23)	Trivial	-0.01 (-0.25; 0.23)	Trivial
LDL-C (*n* = 51)	**-0.20 (-0.41; 0.03)**	**Small**	0.02 (-0.21; 0.25)	Trivial	0.01 (-0.22; 0.24)	Trivial
HDL-C (*n* = 51)	-0.08 (-0.31; 0.16)	Trivial	0.01 (-0.22; 0.24)	Trivial	0.01 (-0.22; 0.24)	Trivial
TG (*n* = 51)	0.01 (-0.22; 0.24)	Trivial	-0.02 (-0.25; 0.21)	Trivial	**0.36* (0.14; 0.55)**	**Moderate**
TG:HDL-C (*n* = 51)	0.01 (-0.22; 0.24)	Trivial	-0.01 (-0.25; 0.23)	Trivial	**0.41* (0.20; 0.59)**	**Moderate**
Lp (a) (*n* = 51)	-0.04 (-0.27; 0.19)	Trivial	-0.04 (-0.27; 0.19)	Trivial	-0.03 (-0.26; 0.20)	Trivial
FPG (*n* = 50)	-0.03 (-0.26; 0.20)	Trivial	-0.04 (-0.27; 0.20)	Trivial	0.01 (-0.22; 0.24)	Trivial
HbA1c (*n* = 51)	-0.02 (-0.25; 0.21)	Trivial	-0.03 (-0.26; 0.20)	Trivial	0.03 (-0.20; 0.26)	Trivial
Clustered cardiometabolic risk score (n = 47)	-0.07 (-0.30; 0.17)	Trivial	**0.46** (0.24; 0.63)**	**Moderate**	**0.65** (0.48; 0.77)**	**Large**

Values are Pearson product-moment correlation coefficients with 90% confidence interval in brackets (second column) & Partial correlation coefficients with 90% confidence interval in brackets (fourth column, values adjusted for fat mass [FM] in kilograms [kg]; sixth column, values adjusted for visceral adipose tissue [VAT] area in centimetres squared [cm^2]). SBP, systolic blood pressure; DBP, diastolic blood pressure; TC, total cholesterol; LDL-C, low-density lipoprotein cholesterol, HDL-C, high-density lipoprotein cholesterol; TG, triglyceride; TG:HDL-C, triglyceride to high-density lipoprotein cholesterol ratio; Lp (a), lipoprotein (a); FPG, fasting plasma glucose; HbA1c, glycated haemoglobin. *r*-values highlighted in **bold** indicate clinically significant effect size; * indicates *p*-value < 0.05; ** indicates *p*-value < 0.01.

4.4.7 Multiple regression analysis

Separate multivariate regression models were used to explore the independent associations of ST, MVPA and physical health-related fitness (CRF level and muscular strength), with the following dependent variables: i) serum TG and TG:HDL-C concentrations as individual markers of cardiometabolic risk; and ii) CCMRS (Table 4.8). Only muscular strength was independently associated with serum TG concentration ($\beta = -0.34$; $p = 0.033$), however, after adjusting for VAT area (cm^2) the association was no longer statistically significant ($p > 0.05$). CRF level was independently associated with CCMRS ($\beta = -0.37$; $p = 0.008$), but not when adjusted for total FM (kg) and VAT area (cm^2).

Table 4.8 Correlation coefficients of independent associations between physical health-related fitness (muscular strength and cardiorespiratory fitness) with serum triglyceride and clustered cardiometabolic risk score.

TG (mmol/L)				
n = 46	*r* = 0.315	R^2 = 0.099	S.E.E = 0.759	***p* = 0.033**
	B	B	S.E.E	*p*-value
Dominant hand grip strength (kg)	-0.347	0.055	0.025	**0.033**
Relative VO_{2max} ($mL \cdot kg^{-1} \cdot min^{-1}$)	-0.024	-0.003	0.021	0.873
Sedentary time (min/day)	0.098	0.932	1.493	0.536

Clustered cardiometabolic risk score				
n = 46	*r* = 0.486	R^2 = 0.236	S.E.E = 0.520	***p* = 0.010**
	B	B	S.E.E	*p*-value
Relative VO_{2max} ($mL \cdot kg^{-1} \cdot min^{-1}$)	-0.377	-0.039	0.614	**0.008**
Dominant hand grip strength (kg)	0.252	0.029	0.016	0.092
Sedentary time (min/day)	-0.058	-0.402	1.006	0.691

TG, triglyceride; mmol.L, millimoles per litre; *r*, correlation coefficient; R^2, coefficient of determination; SEE, standard error of estimate; β, partial correlation coefficient; B, parameter estimate; kg, kilogram; VO_{2max}, maximal aerobic capacity; $mL \cdot kg^{-1} \cdot min^{-1}$, millilitres per kilogram per minute; min/day, minutes per day. *p*-values highlighted in **bold** are statistically significant ($p < 0.05$).

4.5 Discussion

The main findings of this cross-sectional study indicate that the women spent the majority of their time awake in sedentary mode (± 7.8 hr/day) with as much as ± 5 hr/day spent watching television. Subsequently, the women presented with poor CRF and muscle strength, which were independently associated with increased cardiometabolic risk for CVD and T2DM. Contrary to our research hypothesis, ST and MVPA were not associated with cardiometabolic risk.

To our knowledge this is the first SA cross-sectional study to characterise sedentary behaviour both subjectively and objectively among urban-dwelling women. Although national prevalence estimates exist, these relate to "physical inactivity"[1] which differs in definition to sedentary behaviour.[3] Given that sedentary behaviour is regarded as an independent risk factor for morbidity and mortality,[7] the paucity

of SA-specific data is concerning, especially given the 14% NCD-related mortality estimate attributed to physical inactivity.[1] Our results provide insight as to the types of sedentary behaviours, most importantly television viewing as the most prominent, as well as the high proportion of sedentarism among the women living in a low socio-economic urban setting. These findings are in agreement with previous reports on accelerometer-derived ST (± 8.5 hr/day) and self-report sitting time (± 3 hr/day) among other adult women from under-resourced urban settings.[10,11]

Even though the majority of women who took part in the present study were mostly sedentary, insufficiently active and unfit, no discernible associations between ST and MVPA, nor ST and CRF level were observed. A reason for this finding may, in part, relate to the narrow ranges of time spent sedentary and moderately active. Alternatively, both physical-health fitness measures presented with larger data ranges. Such that an inverse and moderately strong association between ST and muscular strength (r = -0.35; p = 0.011) along with small clinically significant inverse associations between ST and FFSTM (kg) and, ST and SMI (kg/m^2) were found. These results indicate that high ST is an independent risk factor for low muscle mass, and thus offers a reasonable explanation underpinning the "poor" muscular strength rating achieved by most women in the study.

The high proportion of physical inactivity (72.6%) in the present study differed greatly from previous SA studies which reported high levels of self-report MVPA among urban women (61.0% and 75.0%).[9,31] Most likely, this divergence can be ascribed to our objective measurements opposed to self-report estimates. Importantly, low levels of physical activity are associated with higher risk for sarcopenia. Most unexpectedly, it was younger women in our study with suspected sarcopenia which is contrary to the generalised deficits in skeletal muscle mass and strength associated with ageing.[32] Although we cannot infer cause and effect, the younger women had statistically significantly higher %BF and lower CRF in comparison to those who were sufficiently active and of similar age. There is strong evidence in the literature that an increase in skeletal muscle mass as a result of muscular strength (resistance) exercise training contributes towards the maintenance or increase in resting energy expenditure, as well as improvement in glucose tolerance among prediabetics.[33] Thus, it is important to introduce resistance training from a young age, especially given the risks associated with sarcopenic obesity. At the same time the importance of high CRF levels must be emphasised, as recent findings indicated that moderate-high CRF is a powerful marker of cardiometabolic health status among overweight/obese women (BMI

≥ 25 kg/m^2) who also present with impaired fasting insulin or undiagnosed T2DM.[36] Also characterised as the "Fat-but-Fit" paradigm,[37] this inference is not aimed at diminishing the importance of preventing obesity but rather aims to offer a practical means to improving cardiometabolic health among women who are highly unfit, and thus have the potential to show significant improvements in CRF given exposure to aerobic exercise programmes.

Despite most of the women being BMI-obese (56.9%, n = 29) and presenting with high total adiposity (%BF: 47.2 ± 7.0%), objectively-measured ST did not associate with any of the adiposity measures (all, $p > 0.05$). However, when adjusting for differences in adiposity, higher serum lipid concentrations (TG and TG:HDL-C) and CCMRS correlated positively with ST (all, $p < 0.05$). This finding highlights the potential mediating role of adiposity between high ST and raised cardiometabolic disease risk. Our results are in agreement with previous large-scale international studies,[34,35] as well as a small-scale SA study,[9] which hypothesised that the mediation effects are partly associated with a reduction in lipoprotein lipase activity during extended bouts of sedentary time. However, given the low socio-economic status of the women in our study we cannot negate the potential influence of dietary intake on serum lipid concentrations. For example, a cheaper high-carbohydrate low-fat diet is negatively associated with reduced HDL-C and higher TG serum concentrations.[41]

The strengths of the present study include the use of high precision measurement techniques (DXA scanner, accelerometry and maximal exercise treadmill test). Moreover, the inclusion of the CCMRS strengthens the study, as the use of a continuous score as opposed to cut-points used by the IDF[21], is a truer reflection of the overall risk of an individual. Its use also accounts for the progressive CVD and T2DM risk increase with increasing MetS risk factors. However, limitations in its use include the lack of consensus that exists with regards to which risk factors to include, as well as the definition of women who are "high risk." In general, the attributed risk is specific to only the study sample being studied, and thus not based on any specific biological measure. Other limitations include our use of a small sample of convenience, which was further reduced due to the non-adherence of accelerometer data specifications (n = 10) and those who refused the maximal exercise test (n = 5), as well the inability to estimate insulin resistance. Nevertheless, the small sample size was deemed adequate according to the power calculation. Furthermore, the cross-sectional design of the study limited any causal conclusions to be drawn which limits the generalisability of these findings to all women in South Africa. Although beyond the scope of

the present study, our inability to characterise other equally important behavioural/lifestyle factors, e.g. dietary intake, which are also known to influence body composition, should also be taken into account.

4.6 Conclusion

Low CRF and muscular strength, as opposed to ST and MVPA, pose greater cardiometabolic disease risk in women from an under-resourced urban community. Although there is somewhat of a minor truth in the "some physical activity is better than nothing" notion, our findings suggest that low levels of physical activity are not sufficient to impact fitness levels to the extent that it would provide some protection against women's risk for future cardiometabolic disease. Furthermore, efforts to improve the overall fitness status of women in under-resourced communities may be ineffective if their dietary habits are not simultaneously addressed, as exercise alone cannot solve the overweight and obesity problem that is prevalent among these women.

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CHAPTER 5

GENERAL DISCUSSION AND CONCLUSIONS:

5.1 Introduction

Under the supervision of Prof Elmarie Terblanche, Bradley Fryer, a previous Stellenbosch University Sport Science doctoral student (2014 – 2016) identified the high proportion of obesity, hypertension, and particularly T2DM among residents residing in Cloetesville - a neighbouring and low-resourced suburb to the University town of Stellenbosch (Western Cape Province, South Africa). Data captured by the local public health community clinic task force indicated as much as 65.0% of the adult day clinic patients having at least one NCD (2013). Given this observation, as well as Bradley's professional interests as an allied health professional (i.e. biokineticist), he implemented a community-based lifestyle intervention and assessed its effects on physiological, psychological and health-related outcomes in adults living with T2DM in this community. The outcomes revealed the effectiveness of a structured community-based intervention in assisting T2DM individuals to better manage themselves and reduce their overall health risk for other NCDs, e.g. cardiovascular disease (CVD) (Fryer, 2016).[174]

Following on from Bradley's project, the SUNWELL Community Health Programme was established in June 2015 and is run by students and staff in the Department of Sport Science. The programme offers an equal opportunity for all community members to participate in weekly exercise classes and learn about leading a healthy, active, and safe lifestyle. The mission of the SUNWELL Community Health Programme is consistent with the United Nations 3rd Sustainable Developmental Goal, which states: "*To ensure healthy lives and promote well-being at all ages*".

Our involvement in this community over the last 4 years made us acutely aware of the general poor health and physical conditioning of the adults, as well as their dire need for more and proper health care services. Though, we also realised that we need more in-depth knowledge about the individuals we want to serve, before we can implement interventions and hopefully make a meaningful difference in this community. This in keeping with the sentiments spoken by Prof Jimmy Volmink, the Dean of our Faculty of Medicine and Health Sciences who said: "*To have an impact (e.g. in a community) - one must first generate knowledge (e.g. about that specific community)*" (FMHD, 17 Oct 2019). Thus, conceptualisation of the larger research project, which includes the present doctoral study, began early in 2016. The expectation is that the findings of the study will provide context-specific information which can be used to design

appropriate community-based interventions, as well as guide the aims and objectives of the SUNWELL Community Health Programme.

5.2 Motivation for the cross-sectional study

Research on the health status of populations can be done via large, community-based, cohort and epidemiological studies, or with smaller, cross-sectional studies. In case of the former, one attempts to gather as much information as possible, in as large samples as possible. The advantage of these types of studies is that they usually have high external validity, in other words, the findings can be generalised to the larger population. However, these studies are time- and resource dependent, which, among other, can exclude the use of gold standard tests and measurements. Cross-sectional studies, usually done on a smaller scale than cohort and epidemiological studies, includes individuals, in a particular setting (e.g. clinical, hospital, school, community, etc.), who meet a set of inclusion and exclusion criteria. Cross-sectional studies can be completed in a shorter period of time, is usually less time- and money dependent and are often conducted when planning a cohort study, or as a baseline in a cohort study. The major advantage of this type of study is that one can implement more elaborate and gold standard tests and measurements (i.e. high internal validity) and gain in-depth knowledge about a specific group of individuals; the downside is that this study design lacks external validity.

Therefore, the decision to embark on a small-scale cross-sectional study in a specific community outside Stellenbosch, was primarily motivated by the mission of the SUNWELL Community Health Programme, as explained in the previous section. This study design afforded us the opportunity to use sophisticated and high-precision objective measurements to determine body composition and regional fat distribution (e.g. DXA-scan), PA variables and ST (accelerometry), as well as CRF and muscular strength (e.g. VO_{2max} and hand grip strength test, respectively). An advantage of using "direct" measures was our ability to exclude potential participant bias which is evident in previously published epidemiological studies using "indirect" and subjective behavioural/lifestyle data (e.g. self-report PA questionnaires[108, 176]). Furthermore, the use of "proxy" indices for obesity (e.g BMI and WC) are also confounded by the assumption that BMI is a surrogate measure of body fatness.

Although the use of the "direct" measures limited the sample size of this doctoral study, it provided us with a rich data set and comprehensive picture of the overall health status of women from a low-resourced urban community. Furthermore, the study was purposely limited to women, as they fulfil vital roles in the community as income-earners, child-bearers and minders. Moreover, the main findings presented in this dissertation contribute to the knowledge base of the general health of urban women in SA and focuses specifically on a (previously) under-studied sub-population.

5.3 Combined findings of the doctoral dissertation

This study aimed to characterise modifiable behavioural/lifestyle factors namely, PA and sedentary behaviour, as well as physical health-related fitness components (CRF and muscular strength) in relation to cardiometabolic disease risk for CVD and T2DM in urban-dwelling women from an under-resourced community (Cloetesville, Stellenbosch) in the Western Cape. In addition, we determined which of physical activity, sedentarism and health-related fitness levels are predictors of obesity and other cardiometabolic disease risk outcomes associated with CVD and T2DM. The main objectives of this dissertation and primary findings are highlighted in Table 5.1.

Table 5.1 The main objectives of this dissertation and primary findings.

No.	Objective	Ch.	Cross-sectional research findings
1	To characterise PA levels and patterns in women from an under-developed urban residential setting.	2	- Less than a third of the women (27.4%) met the WHO Global Health Recommendations for MVPA using accelerometry. - The majority of PA time reported by all the women was work-related (74.2%) and performed at moderate-intensity, whereas travel (20.0%) and leisure PA time (5.8%) were proportionally less. - Sufficiently active women reported significantly higher leisure PA time compared to those who were insufficiently active.
2	To determine whether women who are sufficiently active have a more favourable cardiometabolic disease risk profile compared to those who are insufficiently active.	2	- Although overweight, sufficiently active women had a significantly lower BMI, FM, AFM and hip circumference, compared to their obese and insufficiently active counterparts. - Although no statistically significant group differences were found for any of the cardiometabolic disease risk outcomes, clinically significant differences were observed for DBP, FPG levels, as well as serum LDL-C and Lp (a) concentrations. - Overall, cardiometabolic disease risk among the sufficiently active women was lower than those demmed insufficiently active.
3	To investigate the associations between different PA intensities (LPA and MVPA) and volume (steps/day) with CRF.	3	- Irrespective of PA intensity and volume, the associations with CRF were positive and clinically significant, although not statistically significant.

No.	Objective	Ch.	Cross-sectional research findings
4	To examine both PA (intensities and volume) and CRF in relation to body composition, regional body fat measures, and cardiometabolic disease risk outcomes for CVD and T2DM in urban-dwelling women.	3	- Clinically significant associations between PA intensities and cardiometabolic risk outcomes were observed. - Independent of PA volume, higher CRF was associated with younger women who also presented with reduced measures of total (BMI and FM) and central adiposity (WC and VAT area). - Steps/day and CRF were inversely associated with FFSTM and SMI.
5	To characterise sedentary behaviour (time and type) in urban-dwelling women.	4	- An average of 7.8 hr/day of objectively measured awake time was spent sedentary (57.3% of awake time). - Irrespective of weekday vs. weekend day, an average of 5 hr/day was reportedly spent sedentary while watching television.
6	To examine the independent associations between objective ST, MVPA and physical health-related fitness (CRF and muscular strength), with cardiometabolic risk.	4	- No significant association was detected between ST and MVPA, or ST and CRF, however, a moderately strong and inverse association was observed between ST and muscular strength. - Only physical health-related fitness and neither ST, nor MVPA, was independently associated with cardiometabolic risk; this association is potentially mediated by total (FM) and central (VAT area) adiposity.

No.; number; Ch.; chapter; PA, physical activity; SA, South African; %, percentage; WHO, World Health Organization; MVPA, moderate to vigorous-intensity physical activity; BMI, body mass index; FM, fat mass; AFM, appendicular fat mass; DBP, diastolic blood pressure; FPG, fasting plasma glucose; LDL-C, low-density lipoprotein; Lp (a), lipoprotein a; LPA, light-intensity physical activity; steps/day, steps per day; CRF, cardiorespiratory fitness; CVD, cardiovascular disease; T2DM, type 2 diabetes mellitus; WC, waist circumference; VAT, visceral adipose tissue; FFSTM, fat-free soft tissue mass; SMI, skeletal muscle index; hr/day, hours per day; vs.; versus; ST, sedentary time.

5.4 The presence of obesity and other cardiometabolic disease risk factors for cardiovascular disease and type 2 diabetes mellitus in women from a low socio-economic urban community

The descriptive data presented in this dissertation indicates the high proportion of obesity (56.9%; *n* = 29/51) among urban-dwelling women residing in Cloetesville. Our novel use of highly sophisticated and more reliable measures (e.g. DXA-derived adiposity measures) confirmed the high levels of both obesity (%BF: 47.2% ± 7.0%) and central adiposity (%CFM: 53.1% ± 4.8%) among women in this study.

In addition to obesity-related risk for CVD and T2DM, a relatively high proportion of women were hypertensive (60.4%; *n* = 29/48). More importantly, only 23.0% (*n* = 3/13) of those already diagnosed with hypertension and reporting their use of anti-hypertensive medication were normotensive on examination. This finding is in agreement with Manning et al.[24] who reported on urban-dwelling women in the larger metropolitan area of Cape Town. The majority (83.4%) of their women were hypertensive while receiving anti-hypertensive pharmacological treatment. Yet, on the day of investigation their mean BP levels were high (SBP: 145.6 ± 21.0 mm Hg and DBP: 84.5 ± 12.0 mm Hg). As speculated by Manning et al.[24], our findings (Table 5.2) support their notion that weight status, poor compliance of anti-hypertensive treatment regimes and insufficient PA levels, may have contributed to the overall high proportion of poor BP control. All these factors raise overall CVD and T2DM risk among women who are already obese and hypertensive.

Table 5.2 Potential factors contributing to poor blood pressure control in women in the present study.

Factors	**Chapter**	**Main finding**
Weight status	Chapter 2	High level of obesity among the women (i.e. %BF: 47.2% ± 7.0%).
Insufficient PA levels	Chapter 2	Insufficiently active women (i.e. ≤ 30 min/day of MVPA) had clinically significant higher DBP levels.
Poor compliance of anti-hypertensive treatment regimes	Chapter 3	Only 3 out of 13 women using anti-hypertensive medication were normotensive on examination.

The presentation of dyslipidaemia, and in particular the relatively high percentage of women with elevated Lp (a) concentrations (74.5%; *n* = 38/51) in the present study also requires specific attention as it contributes to an increased overall risk for CVD and T2DM (i.e. > 50 mg/dL). Furthermore, the relatively low mean HDL-C serum concentration (< 1.3 mmol/L) highlights the absence of a potential cardio-protective effect which is commonly associated with higher concentrations (i.e. ≥ 1.3 mmol/L).[160] Lastly, the presence of prediabetes (39.2%; *n* = 20/51), according to HbA1c values ≥ 5.7%, as well as undiagnosed T2DM (11.7%; *n* = 6/51) according to an HbA1c of ≥ 6.5%, must also be noted. Both results indicate the presence of uncontrolled plasma glucose levels among the majority of women in this study (50.9%; *n* = 26/51) (median [IQR] HbA1c: 5.7% [5.4 – 5.9]). Our results concur with those previously reported by Matsha et al.[155] and re-emphasise the high proportion of undiagnosed T2DM among urban-dwelling women as young as 30-yrs of age.[155]

Overall, our descriptive cross-sectional data emphasise the high proportions of recognisable intermediate NCD-risk factors, namely: obesity, hypertension, dyslipidaemia and prediabetes among the entire group of urban-dwelling women (Figure 5.1). Very importantly, the presence of these risk factors extended over a wide age range (i.e. 26 to 64 years).

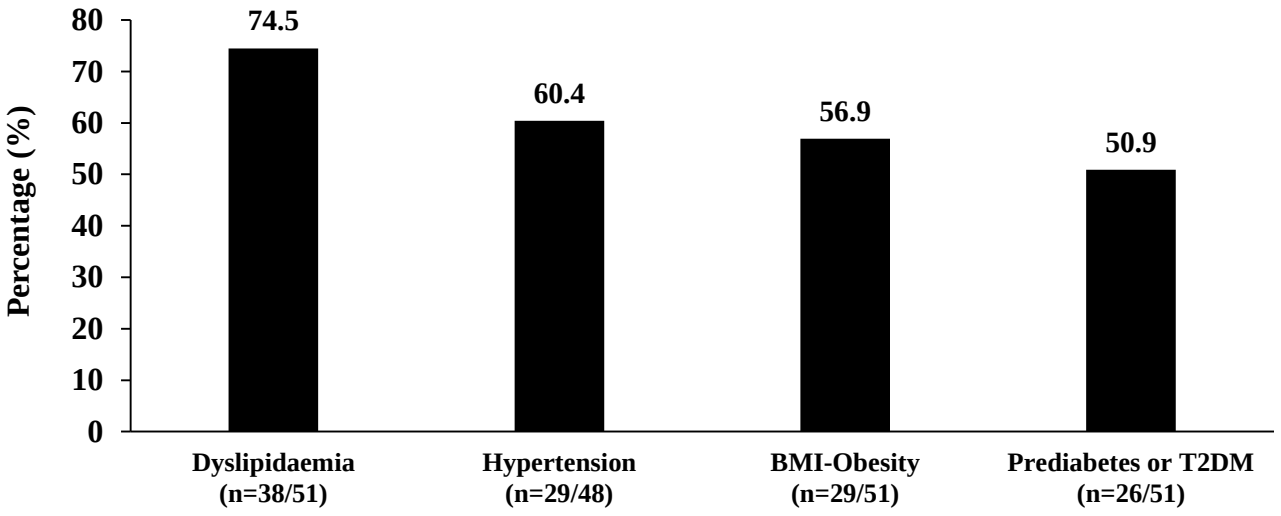


Figure 5.1 Percentage (%) of intermediate cardiometabolic disease risk factors associated with CVD and T2DM among the entire group of urban-dwelling women.

Our study, as well as those by Manning et al.[24] and Matsha et al.[155] draw attention to the need to promote, if not incentivise, routine health-risk screening at an early age. Evidence pertaining to the rollout of a novel SA health-incentive programme, under the auspices of a prominent private health care funder (i.e. Discovery Health's Vitality Programme) highlights the pragmatic approach to raising awareness of NCD-risk and incentivised management thereof.[161] To some degree, however, this excludes the majority of South Africans (82%)[177] and especially those living in low-socio economic settings, as the cost of private health care and incentive programme membership is unattainable.

According to the latest "Poverty Trends in South Africa" a steady rise has been reported since 2015. More than half of South Africans are regarded as poor, with the poverty headcount increasing to 56% from 53% in 2011.[177] An amount of 992 ZAR per person per month was shown to represent the upper bound poverty line in 2015 prices, which translates into ≥ 30.4 million citizens living in poverty. Thus, poverty is an important and recognisable barrier to public health (and education) in South Africa, and argubly more so on women compared to men, because of the multiple roles and responsibilities that women are expected to fulfil. In most instances, the total monthly medical healthcare premium for one adult (i.e. ≥ 2029 ZAR/month) amounts to more than their monthly and/or household income. Even with income derived from government subsidies, e.g. child grant (410 ZAR/month); childminders grant (700 ZAR/month); pension grant for senior citizens (≥ 60 yrs) (1900 ZAR/month); and disability grants (1910 ZAR/month), the cost of private health care remains too high. The same applies to the price of food. Save for 19 non-taxed SA food items (e.g. dried beans and mealies [corn], samp, maize meal [corn], rice, brown bread, vegetables, fruits, vegetable oil, mealie rice [corn], tinned pilchards, legumes and pulses, lentil, eggs, milk, cultured milk, milk powder and dairy powder blend), all other food stuffs are taxed and thus more expensive. Furthermore, a lot of the non-taxed food items consist of a high proportion of refined carbohydrates (e.g. corn) and poor quality fats (e.g. unsaturated vegetable oil) and these are specifically linked to obesity and cardiometabolic risk for CVD and T2DM.[175] Those living below the poverty line, specifically in low-income (poorer) SA communities are often forced to consume these ominous nutrients, which may partly be due to their cheaper cost, but also due to individuals' lack of nutritional knowledge and/or inaccessibility to healthier foodstuffs. Thus, one could argue that national government's attempt to reduce the cost of some food items may assist those who fall below the poverty line, but at the same time negatively affecting the already high prevalence of obesity and risk for NCDs.

Pending the institutionalisation of SA's National Health Insurance [6] plan in 2026, the description of primary health care services satisfyingly includes both "health promotion" and "disease prevention". To a certain extent, the Western Cape On Wellness (WoW!) Inititative, a provincially funded public health and wellness promoting programme initiated in 2015, is an example of how primary health care services may look like in future. The WoW! Programme addresses both individual health behavioural and social determinants of wellness, in an effort to create enabling environments to prevent, reduce and better manage the burden of obesity and NCDs. The initiative follows a settings-based approach which includes worksites, primary healthcare community clinics, schools, communities and public spaces. Public health activities range from free and fun physical activities to basic health and wellness screening in specific communities.

Interestingly, the WoW! Intiative was being launched at the same time as the SUNWELL Community Health Programme. Soon after, the SUNWELL Community Health group became a proud community club member of the WoW! Initiative. The collaboration brings together three vested role players: the Cloetesville community, Stellenbosch University and the Western Cape Department of Health (WCDoH) representing provincial/local government. To date, the collaboration has enabled eight members of the Cloetesville community group to become WoW! Health Champions. The training they received was created and presented by a consortium of public health experts and academics from local universities and the WCDoH. This then empowered the WoW! and SUNWELL Health Champions to arrange and coordinate activities for themselves and their fellow community club members. The activities aim to promote a physically active lifestyle, healthy eating habits, and healthy weight management

Given the positive and proactive strides already made by the WCDoH, it seems imperative for the national health department and policy-makers to pilot similar health-based and collaborative initiatives such as the WoW! Intiative and the SUNWELL Community Health Programme. At the same time, government should seek partnerships with universities, non-profit organisations and/or private enterprises to develop and present such programmes on a sustainable basis. Furthermore, such initiatives will create the opportunity to make tertiary trained exercise specialists (i.e. biokineticists) part of the allied public health team, which currently includes physiotherapists, occupational therapists and dieticians. Together, these allied health professionals can make significant contributions to the health and wellness of communities, especially if they are based in areas which are easily accessible by the public.

5.5 Physical inactivity, physical health-related fitness and sedentarism in women from a low socio-economic urban community

Physical inactivity is recognised as a key risk factor for NCD and according to the WHO the fourth leading global cause of premature mortality.[1] Within a SA context, an estimated 14.0% of total NCD-related mortalities have been attributed to levels of physical inactivity.[1]

The results from the current study indicate the majority of the women as insufficiently active (72.5%), or alternatively described as those not meeting the WHO 2010 Global Recommendations on PA for Health[17] and thus, physically inactive. In comparison to the results from the WHO commissioned World Health Survey on South Africa, our results indicate a lower proportion of sufficiently active women (27.4% vs. 58.0%).[99,100] However, it is important to mention that beyond the larger number of women investigated, their use of a self-report PA instrument is limiting (i.e. IPAQ). A major limitation includes the reliance on subjective recall and thus the possibility of over-reporting of time spent physically active,[108] as well as over-estimating the intensity of reported PA. Our own results have shown similar tendencies, as the difference between the GPAQ-derived and accelerometer PA data differed greatly. The average self-report MVPA time for the entire group was ~50 min/day, compared to the lower ~22min/day MVPA measured objectively. What's more is the over-estimation of self-report MVPA time reported by the insufficiently active women (i.e. ~41 min/day [GPAQ] vs. ~18 min/day [accelerometry]). Thus, our results question the validity of previous SA studies[15,16,17] in which self-report PA time was captured; however, at the same time we are also cognisant of the limitations associated with our use of pre-determined accelerometer cut-points.[89] Therefore, our ability to draw direct comparisons with other SA studies,[10,13,125] which used different cut-points,[90,91] is limited.

Despite the above mentioned limitations associated with the use of subjective PA data, recent study findings using the GPAQ describe the majority of urban women[10,14] as sufficiently active (61.0% and 75.0%) according to the WHO Global PA criteria.[17] More importantly, however, the majority of these women are described as BMI-obese. Similary, our results indicate that the sufficiently active women were also overweight. Thus a serious concern is the questionable effectiveness of meeting current international PA criteria as a means to reducing excess adiposity which is associated with increased

cardiometabolic disease risk for CVD and T2DM. Alarmingly, this is an assumption on which the "*Strategy for the Prevention and Management of Obesity [2015 – 2020]*" policy document is based, namely, that increasing physical activity levels is a way to address the national obesity problem.[8]

Evidence from large randomised clinical trials[178,179] found that women who meet global PA recommendations through aerobic exercise training programmes showed no statistically significant changes in body weight over a 6-month period. In fact, there is strong evidence indicating that dietary restriction is vitally important to affect weight loss in those who are already sufficiently active, and even more in those who are insufficiently active and obese. Results from a meta-analysis on "weight-loss interventions" determined the rate of weight-loss to be similar between caloric-restriction alone (0.98 kg/week), and when combined with exercise (1.0 kg/week).[180] Notably, the rate of weight loss observed in both interventions exceeded that which was achieved by exercise alone (0.2 kg/week). Such findings support the inference that the majority of weight loss from the combination of exercise and caloric restriction can be attributed to caloric restriction. However, this finding does not negate the importance of meeting global PA recommendations, especially given the role PA plays in weight maintenance,[181] as well as increasing CRF,[182] which increases in direct response to aerobic exercise training.[178]

In chapter 3, the significant health-related benefits associated with higher daily PA volume (steps/day) and CRF level, in the presence of reduced BM, BMI and total FM, were highlighted. These findings are thus different to those previously published[9,14] and indicate a higher percentage of women who are physically inactive according to international recommendations.[17] Although limited by our use of cross-sectional data, our results indicate that meeting MVPA guidelines of ≥ 150 min/week counteracts the adverse effect of excess weight (i.e. BM or total FM) on cardiometabolic disease risk for CVD and T2DM. Most notably, our results do not inform whether an increase in total adiposity is the cause or consequence of insufficient PA levels and thus provide no definitive answers to the questions raised in the "*Strategy for the Prevention and Management of Obesity [2015 – 2020]*" policy document aimed at reducing the national obesity problem.[8] Alternatively, our results highlight the importance of developing strategies aimed at incorporating the use of daily step count PA recommendations[18] over and above the use of the MVPA criteria,[17] as well as increasing CRF level as means to lowering NCD-related risk for CVD and T2DM. To our knowledge, our descriptive data presented in chapter 3 confirms previous SA results, also among urban women and presenting with low or "poorly" rated CRF level.[94] Furthermore, muscular strength (chapter 4), an additional component of physical health-related fitness and not often

included as an outcome variable, was rated as "poor" among women and is therefore of equal concern than poor levels of aerobic fitness.

In terms of sedentarism, the results from the current study indicate the larger proportion of awake time spent sedentary as opposed to physically active among the women investigated. In particular, 57.3% of daily wear-time was spent sedentary. The self-reported data showed that women spent most of their time during the week and weekend watching television. What's more is the inference drawn by Cook et al.[10] and the propensity of higher levels of sedentarism among SA women residing in urban vs. rural settings. Thus, our results compliment those previously reported among other urban-dwelling women.[14,92] However, having used both objective and subjective sedentary behaviour measurement instruments, our data presented in chapter 4 provides a novel description of time spent sedentary, as well as the types of sedentary behaviours.

These findings raise pertinent questions as to the likely factors contributing to the poor physical health of the women in the present study. One could speculate about the influence of ongoing and rapid epidemiological transition which South Africa,[4,5] similar to other sub-Saharan African countries, continues to undergo. Underpinning this over-arching continental challenge, are those linked to the lack of daily PA associated with other work- and leisure-related activities, which are largely influenced by technology (e.g. computer games and television). Plus, those factors linked to an individual's geographical location relative to total time spent travelling (e.g. extended travel time to and from work and/or other purposeful places) and the mode of transport used (e.g. motorised transport or walking). On the other hand, there are other pressing challenges for under-resourced communities, namely the lack of an inclusive PA environment (e.g. limited access to exercise facilities and issues of safety) and the lack of a social community network to promote PA.[8]

5.6 Understanding patterns of physical activity and sedentary behaviour

Our combined presentation of objective and subjective PA and sedentary time lends itself to improving our understanding of time awake (i.e. behaviour). In particular, the self-reported PA time generated from

our administration of the GPAQ indicating work-related PA time as the highest of the three PA domains. Although, when the sample of women were categorised according to activity level, the sufficiently active sub-group reported significantly more leisure PA time compared to the insufficiently active sub-group.

Of most concern, however, was the subjective account of time spent sedentary while watching television. Thus, highlighting the need to explore the women's barriers to PA. One could speculate that lack of knowledge about the detrimental effects of excessive amounts of sedentary time, or perhaps reasons pertaining to physical safety and lack of time and/or facilities to participate in leisure/recreational PA, may possibly explain their sedentary lifestyles. Therefore it is suggested that public health interventions targeting PA domains in which time is already spent physically active, such as walking to the shop or to work, but at a faster pace. At the same time, public awareness of the negative health-associated effects of time spent sitting, must be increased.

5.7 Application of the associations between physical activity, sedentary time and physical health-related fitness, with cardiometabolic disease risk for cardiovascular disease and type 2 diabetes mellitus in women from a low socio-economic urban community

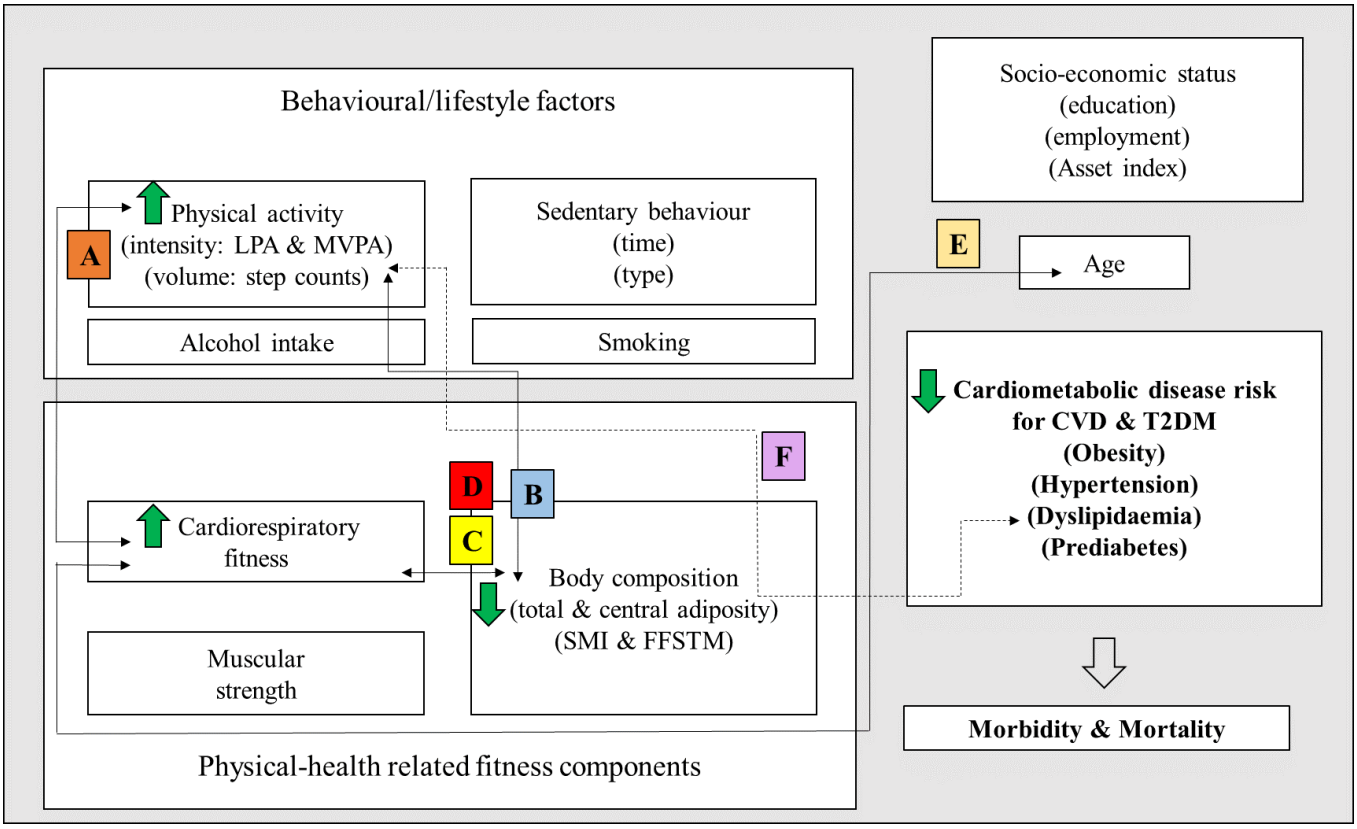
Firstly, clinically significant and positive associations were found between higher PA time (both LPA and MVPA) and volume (steps counts per day) with higher CRF level (Figure 5.2). As CRF is described as a physiological measure that reflects a combination of PA behaviour and innate genetic potential, we could argue that the higher PA levels achieved by the more active women are effective enough to maintain their relatively higher CRF levels compared to their less active and unfit counterparts. However, as a whole group, the women's CRF levels were relatively "poor" when compared to international rating criteria.

Secondly, statistically significant inverse associations, highlighted in chapter 3, between higher step counts per day with lower total (AFM and TFM) and central obesity measures (WC, CFM, and VAT area) is promising and points to the favourable health benefits associated with higher levels of daily PA (Figure 5.2).

Thirdly, and similar to the above finding, statistically significant inverse associations were shown between the same obesity outcomes measured with CRF level (Figure 5.2). Therefore, the message is clear: higher PA and CRF levels are associated with more pronounced health-related benefits, most notably, reduced adiposity levels and cardiometabolic disease risk for CVD and T2DM. Given that PA or exercise alone is not an effective strategy for weight loss, we hypothesize that women who are physically active are more aware of what constitutes a healthy lifestyle and therefore it is probable that they also have healthier dietary habits.

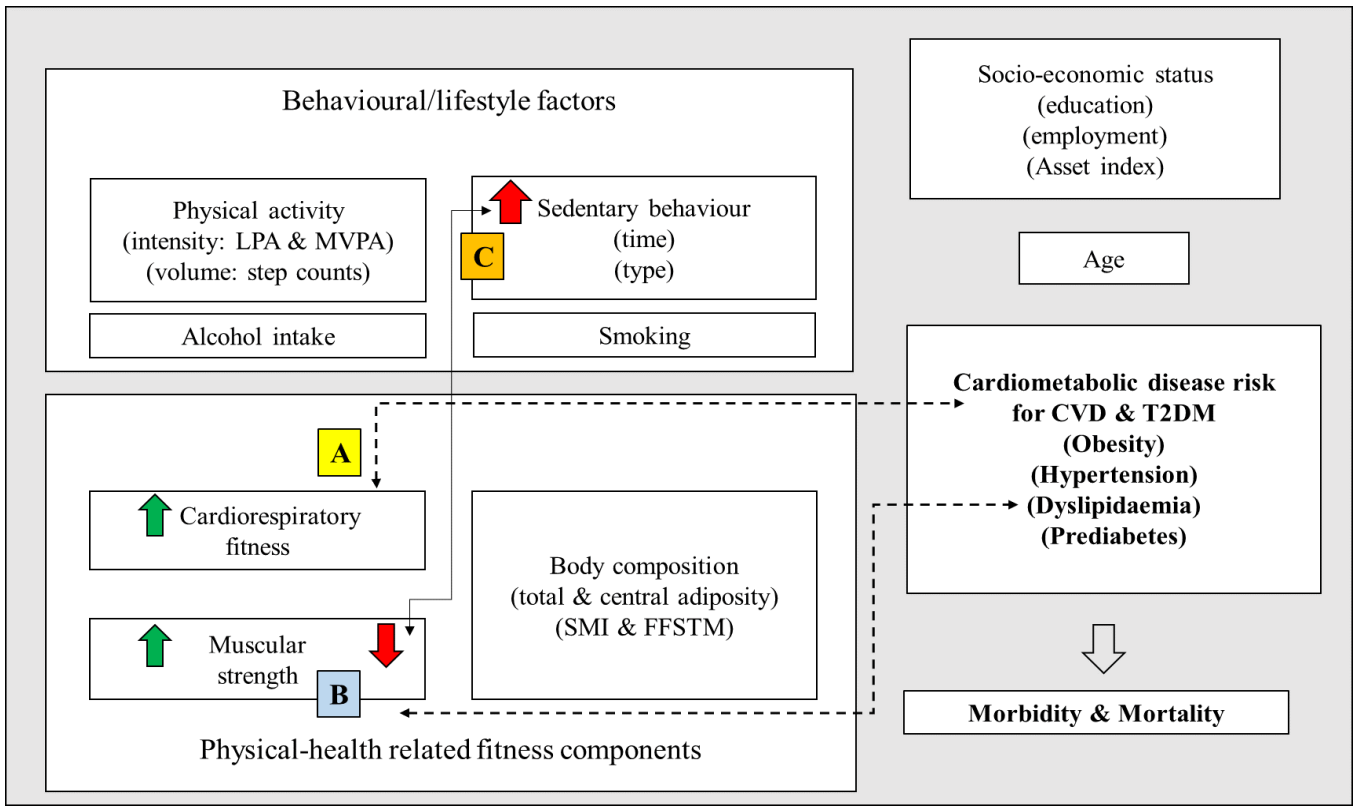
Fourthly, independent of central adiposity (i.e. VAT area), higher PA time (i.e. LPA and MVPA) and daily PA volume (i.e. steps/day) (Figure 5.2), as well as higher CRF level (Figure 5.3), were all associated with reduced serum lipid concentrations (i.e. TG or TG:HDL-C). Thus, suggestive of reduced cardiometabolic disease risk among the more active and/or fitter women who took part in the study. Most notably, higher CRF level was associated with women who were younger and with reduced total and central adiposity.

Lastly, the application of the results in chapter 3 and 4 should be viewed as exploratory, and thus aimed at generating hypotheses for a future follow-up (longitudinal) study. Our results provide valuable insight as to the direction of the relationships explored between PA and CRF as modifiable behavioural/ lifestyle factors and obesity-related risk for CVD and/or T2DM, specifically among urban-dwelling women from an under-resourced SA community. It is equally important to stress that clinically significant results are not necessary statistically significant and given our interest in cardiometabolic health-related outcomes, one could argue that clinical significant results, for example lower DBP, is far more important then statistical significance between two different groups with differing DBP levels.[183] Lastly, the use of effect sizes is not dependent on sample size as is the case with probability testing, thus in support of the small sample used and significant differences found between the activity sub-groups highlighted in chapter 2.



Ch. 3	A	Clinically significant, positive associations	Higher PA time (LPA and MVPA) Higher PA volume (steps/day)	Higher CRF level
	B	Statistically significant, negative associations	Higher PA volume (steps/day)	Lower total adiposity (AFM and TFM) Lower central adiposity (WC, CFM, VAT)
	C	Statistically significant, negative associations	Higher CRF level	Lower total adiposity (AFM and TFM) Lower central adiposity (WC, CFM, VAT)
	D	Statistically significant, negative associations	Higher CRF level	Lower SMI Lower FFSTM
	E	Statistically significant, negative associations	Higher CRF level	Age
	F	Statistically significant, negative associations	Higher PA time (LPA and MVPA) Higher PA volume (steps/day)	Reduced TG Reduced TG:HDL-C (both independent of central adiposity)

Figure 5.2 Independent associations between PA variables and CRF level with body composition measures as intermediate risk factors for cardiometabolic disease such as CVD and T2DM.



Ch. 4	A	Statistically significant, negative associations	Higher CRF level	Lower clustered cardiometabolic risk score (independent of MVPA and ST)
	B	Statistically significant, negative associations	Higher muscular strength	Reduced TG serum concentrations (independent of MVPA and ST)
	C	Statistically significant, negative associations	Higher ST	Lower muscular strength

Figure 5.3 Independent associations between physical-health-related measures and cardiometabolic disease risk for CVD and T2DM.

5.8 Novel findings

To my knowledge the novel findings of the study indicate that less than a third of the women met the WHO Global Health Recommendations for MVPA using accelerometry. Secondly, that even though the sufficiently active sub-group of women were on average "overweight", they presented with more favourable body composition and regional body fat measures, as well as reduced cardiometabolic disease risk when compared to their insufficiently active counterparts. Following on from these, the secondary findings indicated the associations between PA intensities and volume; and CRF level, were positive and showed clinically important associations, although they were not statistically significant. Independent of steps/day, higher CRF level was associated with women who were younger and with reduced measures of adiposity. Alternatively, higher physical health-related fitness, as opposed to ST and MVPA, was independently associated with reduced cardiometabolic risk but potentially mediated by adiposity.

5.9 Strengths and limitations

As mentioned in each of the study chapters presented, our novel use of the sophisticated measurement equipment (e.g. DXA-scanner, accelerometry and VO_{2max}) afforded us the opportunity to characterise body composition and regional fat distribution, PA level and CRF level objectively and with high accuracy. This is especially significant considering that, to our knowledge, little is known about the behavioural/lifestyle factors impacting the health of (previously) under-studied sub-population.

Notable limitations include the cross-sectional study design, our sample of convenience, as well as relatively smaller sample sizes when classifying our activity sub-groups according to the WHO PA recommendations. A priori power and sample size calculations were computed by a biostatistican before ethical approval of the study was attained. Although the sample size of the cohort constituted 200 participants, the cost to complete the testing protocol was too expensive for the approved research study budget (Appendix B). The merits of including a larger sample size with fewer tests and measurements were weighed against the use of a smaller sample size, inclusive of more tests and measurements. It was decided to limit the sample size and rather provide an in-depth and comprehensive picture of the health status of the women from the community of interest. The sample is therefore not representative of the particular community and the results are thus not generalisable to the larger population.

One must also state that although there is a lack of universally accepted PA measurement methods, accelerometer derived PA estimates offer numerous advantages, compared to self-report PA estimates. Importantly however, the variation in cut-points defined makes comparison with other research studies challenging. Furthermore, the loss of PA and ST data due to some participants' non-compliance in the wearing of their accelerometer requires consideration.

Lastly, it is important to highlight our awareness of other factors which are critically importantly in the context of this study, but which fall beyond the scope of the current dissertation (e.g. poor dietary practices,[23,24,25] food insecurity,[26] exercise,[27,28] genetic influences,[29,30,31] sleep deprivation,[32] chemical and air pollutants[33]). All of which, contribute towards the prevalence of cardiometabolic disease risk for both CVD and T2DM in adults.

Overall, our results provide valuable insight as to the direction of the relationships between behavioural/lifestyle factors (i.e. LPA, MVPA, steps/day, ST and physical health-related fitness components) and obesity-related risk for CVD and/or T2DM, specifically in women living in an under-resourced and low socio-economic urban community.

5.10 Recommendations for future research studies

5.10.1 Follow-up study and longitudinal studies

Prior to the design and implementation of a context-specific behavioural/lifestyle intervention study, a follow-up investigation of the same parameters using the same methodological approach among the entire group of women is required. These results would prove beneficial and assist in answering questions related to both changes in cardiometabolic disease risk for CVD and T2DM, as well as weight status over time. For example, it is imperative to understand whether an increase in total adiposity is the cause or consequence of insufficient PA levels. Such information would indicate whether the "*Strategy for the Prevention and Management of Obesity [2015 – 2020]*" policy document, aimed at reducing the national obesity problem, needs to be reformulated.

5.10.2 Barriers to physical activity and healthy behaviour change

We acknowledge that the success of designing and implementing a context-specific behavioural/lifestyle intervention is dependent on our understanding of the community's specific barriers to PA and healthy dietary habits. Furthermore, one also needs to investigate other equally important behavioural/lifestyle factors (e.g. poor dietary practices,[23,24,25] food insecurity,[26] sleep deprivation[32]), which have all been shown previously to contribute towards the prevalence of cardiometabolic disease risk for both CVD and T2DM in adults.

5.11 Conclusion

Within the current SA context, this dissertation has important implications. Given that the higher PA levels achieved by the more active women were shown to be effective to maintain their relatively higher CRF levels, in comparison with their less active and unfit counterparts, the importance of raising awareness among community dwellers of the current PA guidelines is underlined. Furthermore, the statistically significant inverse associations between both higher PA and higher CRF levels and lower obesity measures and lower serum lipid concentrations (and independent of central adiposity) highlights the need for public health messaging campaigns centred on modifiable behavioural/lifestyle changes. For example, a campaign aimed at public health messaging entitled: "*Move more and sit less*". Which speaks to the application of a context-specific intervention-based study aimed at increasing daily PA, reducing time spent sedentary, and developing strategies to increase physical health-related fitness, and thus to measure direct effects potentially caused by the intervention being studied.

To conclude, context-specific intervention-based studies should aim to encourage an increase in daily PA (LPA, MVPA, and steps/day), while at the same time reducing sedentary behaviours, and developing strategies to increase physical health-related fitness components, namely CRF and muscular strength.

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Appendix A: Ethical Approval

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NOTICE OF APPROVAL

30 May 2017

Project number: SU-HSD-004704

Project title: RELATIONSHIPS BETWEEN LIFESTYLE FACTORS, CARDIOMETABOLIC HEALTH, COGNITIVE FUNCTIONING AND CARDIORESPIRATORY FITNESS IN SOUTH AFRICAN WOMEN FROM A LOW SOCIOECONOMIC COMMUNITY.

Dear Prof E. Terblanche

Your response to the modifications received on 19 May 2017 was reviewed and approved by the REC: Humanities via expedited review procedures.

Please note the following about your approved submission:

Ethics approval period: 24 May 2017 – 23 May 2018

Please take note of the General Investigator Responsibilities attached to this letter. You may commence with your research after complying fully with these guidelines.

If the researcher deviates in any way from the proposal approved by the REC: Humanities, the researcher must notify the REC of these changes.

Please use your SU project number (SU-HSD-004704) on any documents or correspondence with the REC concerning your project.

Please note that the REC has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

FOR CONTINUATION OF PROJECTS AFTER REC APPROVAL PERIOD

Please note that a progress report should be submitted to the Research Ethics Committee: Humanities before the approval period has expired if a continuation of ethics approval is required. The Committee will then consider the continuation of the project for a further year (if necessary).

If you have any questions or need further help, please contact the REC office at cgraham@sun.ac.za

Sincerely,

Clarissa Graham

REC Coordinator: Research Ethics Committee: Human Research (Humanities)

National Health Research Ethics Committee (NHREC) registration number: REC-050411-032.
The Research Ethics Committee: Humanities complies with the SA National Health Act No.61 2003 as it pertains to health research. In addition, this committee abides by the ethical norms and principles for research established by the Declaration of Helsinki (2013) and the Department of Health Guidelines for Ethical Research: Principles Structures and Processes (2nd Ed.) 2015. Annually a number of projects may be selected randomly for an external audit.

Appendix B: Approved Budget

Test/measurement	Parameter	Service provider	# of participants	Cost per sample	# of samples	TOTAL COST
Study advertisement and recruitment						
Study advertisement pack	A3 black and white flyers: drop-off at the church groups, the public health clinic, community centre, and hand to Community Champion [Appendix C]	Wizards Printing Company, Stellenbosch			500 flyers	**R 500**
Transport fee to advertise study	Student's motor vehicles	Driver's of motor vehicles (PhD students: Kasha &/or Sharné)		R40/trip	10 trips	**R 400**
Telephone expense	Confirmation of testing visits	Sport Science department		R500/month	3 months	**R 1 500**
Pre-screening health tests						
Nurses consultation fee		Campus Health	60	R 63	60	**R 3 750**
Pregnancy urine screening test		Campus Health	60	R 20	60	**R 1 200**
Blood sampling						
Fasting bloods	Lipogram	PathCare, Stellenbosch	60	R 430	60	**R 25 776**
	Lipoprotein (a)	PathCare, Stellenbosch	60	R 197	60	**R 11 826**
	Apolipoprotein B	PathCare, Stellenbosch	60	R 132	60	**R 7 890**
	Apolipoprotein A1	PathCare, Stellenbosch	60	R 143	60	**R 8 568**
	Fasting Plasma Glucose	PathCare, Stellenbosch	60	R 54	60	**R 3 228**
	HbA1c%	PathCare, Stellenbosch	60	R 226	60	**R 13 566**
	High-sensitivity C-reactive protein	PathCare, Stellenbosch	60	R 173	60	**R 10 374**
	Interleukin 6	PathCare, Stellenbosch	60	R 316	60	**R 18 966**
Questionnaire booklet						
Paper, printing & ring binder	20 x A4 pages & prints (front and back) (black and white)	Wizards (Printing Company,Stell.)	60	R 35	60	**R 2 100**
Participant letter, informed consent & feedback letter	8 x A4 pages & prints (front and back) (black and white)	Wizards (Printing Company,Stell.)	60	R 10	60	**R 600**
Body composition						
DEXA-scan		Coetzenburg Imaging Centre, Stellenbosch	60	R 500	60	**R 30 000**
Cognitive testing	CNS: Vital Signs™	CNS - Vital signs (online)	60	R 270	60	**R 16 200**
Physical activity instruments	ActiLife™	ActiLife - license fee			1	**R 25 000**
Dietary intake analysis instruments						
24-hr/Food-frequency questionnaire	SA MRC FoodFinder III™ license & software		60	R1750 (once off)	1	**1750**
Portion and picture toolkit			60	R800 (once off)	1	**R 800**
Participant costs						
Post study gift (Waterbottle)		Crazy Store, Stellenbosch		R 25	60	**R 1 500**
Food pack	Low-GI Sasko Roll, Cheese & fresh tomatoe, Granny Smith Apple (medium sixed) & Water (still) (500ml)	Pick 'n Pay, Stellenbosch	x 2 visits (R20/visit)	R 40	60	**R 2 400**
Transport fees						
Visit 1 testing: Fetch and drop off	Student's motor vehicles (x4 participants)	Driver's of motor vehicles (PhD students: Kasha &/or Sharné)	60	R 84	20	**R 1 680**
Visit 2 testing: Fetch and drop off	Student's motor vehicles (x4 participants)	Driver's of motor vehicles (PhD students: Kasha &/or Sharné)	60	R 40	20	**R 800**
					GRAND TOTAL:	**R 190 374**

Appendix C: Actual Expenses

Test/measurement	Parameter	Service provider	# of participants	Cost per sample	# of samples	TOTAL COST
Study advertisement and recruitment						
Study advertisement pack	A3 black and white flyers: drop-off at the church groups, the public health clinic, community centre, and hand to Community Champion (Appendix C)	Wizards Printing Company, Stellenbosch			500 flyers	**R 0**
Transport fee to advertise study	Student's motor vehicles	Driver's of motor vehicles (PhD students: Kasha &/or Sharné)		R40/trip	10 trips	**R 0**
Telephone expense	Confirmation of testing visits	Sport Science department		R500/month	3 months	**R 818**
Champion Finder Fee	Fee per participant who completed the 2-days of testings	Anonymous		R50/participant	36	**R 1 800**
Pre-screening health tests						
Nurses consultation fee	Collaboration with Campus Health Services to no payment renedered	Campus Health	60	R 63	60	**R 0**
Pregnancy urine screening test		Campus Health	60	R 20	60	**R 0**
Blood sampling						
Fasting bloods	Lipogram	PathCare, Stellenbosch	60	R 430	60	**R 105 231**
	Lipoprotein (a)	PathCare, Stellenbosch	60	R 197	60	
	Apolipoprotein B	PathCare, Stellenbosch	60	R 132	60	
	Apolipoprotein A1	PathCare, Stellenbosch	60	R 143	60	
	Fasting Plasma Glucose	PathCare, Stellenbosch	60	R 54	60	
	HbA1c%	PathCare, Stellenbosch	60	R 226	60	
	High-sensitivity C-reactive protein	PathCare, Stellenbosch	60	R 173	60	
	Interleukin 6	PathCare, Stellenbosch	60	R 316	60	
Questionnaire booklet						
Paper, printing & ring binder	20 x A4 pages & prints (front and back) (black and white)	Wizards (Printing Company,Stell.)	60	R 35	60	**R 3 000**
Participant letter, informed consent & feedback letter	8 x A4 pages & prints (front and back) (black and white)	Wizards (Printing Company,Stell.)	60	R 10	60	
Body composition						
DEXA-scan		Coetzenburg Imaging Centre, Stellenbosch	60	R 500	60	**R 30 000**
Cognitive testing	CNS: Vital Signs™	CNS - Vital signs (online)	60	R 270	60	**R 15 929**
Physical activity instruments	ActiLife™	ActiLife - license fee		R22 529 (once off)	1	**R 22 529**
	Courier expense to ship load equipment to & from the UK			R1508 + R869		**R 2 377**
Dietary intake analysis instruments						
24-hr/Food-frequency questionnaire	SA MRC FoodFinder III™ license & software		60	R1750 (once off)	1	**1750**
Portion and picture toolkit			60	R800 (once off)	1	**R 800**
Participant costs						
Post study gift (Waterbottle)	Sponsored so no cost incurred	Crazy Store, Stellenbosch		R 25	60	**R 0**
Food pack	Low-GI Sasko Roll, Cheese & fresh tomatoe, Granny Smith Apple (medium sixed) & Water (still) (500ml)	Pick 'n Pay, Stellenbosch	x 2 visits (R20/visit)	R 40	60	**R 2 400**
Transport fees						
Visit 1 testing: Fetch and drop off	Student's motor vehicles (x4 participants)	Driver's of motor vehicles (PhD students: Kasha &/or Sharné)	60	R 84	20	**R 4 221**
Visit 2 testing: Fetch and drop off	Student's motor vehicles (x4 participants)	Driver's of motor vehicles (PhD students: Kasha &/or Sharné)	60	R 40	20	
					GRAND TOTAL:	**R 190 855**

Appendix D: Author guidelines for Article One

BMC Public Health Journal

1.1 Criteria for submitting a research article

Research articles should report on original primary research, but may report on systematic reviews of published research provided they adhere to the appropriate reporting guidelines which are detailed in our editorial policies. Please note that non-commissioned pooled analyses of selected published research will not be considered. Studies reporting descriptive results from a single institution will only be considered if analogous data have not been previously published in a peer reviewed journal and the conclusions provide distinct insights that are of relevance to a regional or international audience.

Authors who need help depositing and curating data may wish to consider uploading their data to Springer Nature's Research Data Support or contacting our Research Data Support Helpdesk. Springer Nature's Research Data Support provides data deposition and curation to help authors follow "good practice" in sharing and archiving of research data, and can be accessed via an online form. The services provide secure and private submission of data files, which are curated and managed by the Springer Nature Research Data team for public release, in agreement with the submitting author. These services are provided in partnership with figshare. Checks are carried out as part of a submission screening process to ensure that researchers who should use a specific community-endorsed repository are advised of the best option for sharing and archiving their data. Use of Research Data Support is optional and does not imply or guarantee that a manuscript will be accepted.

1.2 Preparing your manuscript

The information below details the section headings that you should include in your manuscript and what information should be within each section.

Please note that your manuscript must include a 'Declarations' section including all of the subheadings (please see below for more information).

1.2.1 Title page

The title page should: present a title that includes, if appropriate, the study design e.g."A versus B in the treatment of C: a randomized controlled trial", "X is a risk factor for Y: a case control study", "What is the impact of factor X on subject Y: A systematic review"or for non-clinical or non-research studies a

description of what the article report list the full names and institutional addresses for all authors if a collaboration group should be listed as an author, please list the Group name as an author. If you would like the names of the individual members of the Group to be searchable through their individual PubMed records, please include this information in the "Acknowledgements" section in accordance with the instructions below indicate the corresponding author

1.2.2 Abstract

The Abstract should not exceed 350 words. Please minimize the use of abbreviations and do not cite references in the abstract. Reports of randomized controlled trials should follow the CONSORT extension for abstracts. The abstract must include the following separate sections:

- Background: the context and purpose of the study
- Methods: how the study was performed and statistical tests used
- Results: the main findings
- Conclusions: brief summary and potential implications
- Trial registration: If your article reports the results of a health care intervention on human participants, it must be registered in an appropriate registry and the registration number and date of registration should be in stated in this section. If it was not registered prospectively (before enrollment of the first participant), you should include the words 'retrospectively registered'. See our editorial policies for more information on trial registration

1.2.3 Keywords

Three to ten keywords representing the main content of the article.

1.2.4 Background

The Background section should explain the background to the study, its aims, a summary of the existing literature and why this study was necessary or its contribution to the field.

1.2.5 Methods

The methods section should include:

- the aim, design and setting of the study
- the characteristics of participants or description of materials

- a clear description of all processes, interventions and comparisons. Generic drug names should generally be used. When proprietary brands are used in research, include the brand names in parentheses
- the type of statistical analysis used, including a power calculation if appropriate

1.2.6 Results

This should include the findings of the study including, if appropriate, results of statistical analysis which must be included either in the text or as tables and figures.

1.2.7 Discussion

This section should discuss the implications of the findings in context of existing research and highlight limitations of the study.

1.2.8 Conclusions

This should state clearly the main conclusions and provide an explanation of the importance and relevance of the study reported.

1.2.9 List of abbreviations

If abbreviations are used in the text they should be defined in the text at first use, and a list of abbreviations should be provided.

1.2.10 Declarations

All manuscripts must contain the following sections under the heading 'Declarations':

- Ethics approval and consent to participate
- Consent for publication
- Availability of data and materials
- Competing interests
- Funding
- Authors' contributions
- Acknowledgements
- Authors' information (optional)

Please see below for details on the information to be included in these sections. If any of the sections are not relevant to your manuscript, please include the heading and write 'Not applicable' for that section. Ethics approval and consent to participate. Manuscripts reporting studies involving human participants, human data or human tissue must: include a statement on ethics approval and consent (even where the need for approval was waived) include the name of the ethics committee that approved the study and the committee's reference number if appropriate. Studies involving animals must include a statement on ethics approval.See our editorial policies for more information.

If your manuscript does not report on or involve the use of any animal or human data or tissue, please state "Not applicable" in this section.

1.2.11 Consent for publication

If your manuscript contains any individual person's data in any form (including any individual details, images or videos), consent for publication must be obtained from that person, or in the case of children, their parent or legal guardian. All presentations of case reports must have consent for publication. You can use your institutional consent form or our consent form if you prefer. You should not send the form to us on submission, but we may request to see a copy at any stage (including after publication). See our editorial policies for more information on consent for publication.If your manuscript does not contain data from any individual person, please state "Not applicable" in this section.

1.2.12 Availability of data and materials

All manuscripts must include an 'Availability of data and materials' statement. Data availability statements should include information on where data supporting the results reported in the article can be found including, where applicable, hyperlinks to publicly archived datasets analysed or generated during the study. By data we mean the minimal dataset that would be necessary to interpret, replicate and build upon the findings reported in the article. We recognise it is not always possible to share research data publicly, for instance when individual privacy could be compromised, and in such instances data availability should still be stated in the manuscript along with any conditions for access. Data availability statements can take one of the following forms (or a combination of more than one if required for multiple dataset.

- The datasets generated and/or analysed during the current study are available in the [NAME] repository, [PERSISTENT WEB LINK TO DATASETS]

- The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.
- All data generated or analysed during this study are included in this published article [and its supplementary information files].
- The datasets generated and/or analysed during the current study are not publicly available due [REASON WHY DATA ARE NOT PUBLIC] but are available from the corresponding author on reasonable request.
- Data sharing is not applicable to this article as no datasets were generated or analysed during the current study.
- The data that support the findings of this study are available from [third party name] but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of [third party name].
- Not applicable. If your manuscript does not contain any data, please state 'Not applicable' in this section. More examples of template data availability statements, which include examples of openly available and restricted access datasets, are available here.

BioMed Central also requires that authors cite any publicly available data on which the conclusions of the paper rely in the manuscript. Data citations should include a persistent identifier (such as a DOI) and should ideally be included in the reference list. Citations of datasets, when they appear in the reference list, should include the minimum information recommended by DataCite and follow journal style. Dataset identifiers including DOIs should be expressed as full URLs. For example: Hao Z, AghaKouchak A, Nakhjiri N, Farahmand A. Global integrated drought monitoring and prediction system (GIDMaPS) data sets. figshare. 2014. http://dx.doi.org/10.6084/m9.figshare.853801

With the corresponding text in the Availability of data and materials statement:
The datasets generated during and/or analysed during the current study are available in the [NAME] repository, [PERSISTENT WEB LINK TO DATASETS].[Reference number]
If you wish to co-submit a data note describing your data to be published in BMC Research Notes, you can do so by visiting our submission portal. Data notes support open data and help authors to comply with funder policies on data sharing. Co-published data notes will be linked to the research article the data support (example). For more information please email our Research Data Team.

1.2.13 Competing interests

All financial and non-financial competing interests must be declared in this section. See our editorial policies for a full explanation of competing interests. If you are unsure whether you or any of your co-authors have a competing interest please contact the editorial office. Please use the authors initials to refer to each authors' competing interests in this section. If you do not have any competing interests, please state "The authors declare that they have no competing interests" in this section.

1.2.14 Funding

All sources of funding for the research reported should be declared. The role of the funding body in the design of the study and collection, analysis, and interpretation of data and in writing the manuscript should be declared.

1.2.15 Authors' contributions

The individual contributions of authors to the manuscript should be specified in this section. Guidance and criteria for authorship can be found in our editorial policies. Please use initials to refer to each author's contribution in this section, for example: "FC analyzed and interpreted the patient data regarding the hematological disease and the transplant. RH performed the histological examination of the kidney, and was a major contributor in writing the manuscript. All authors read and approved the final manuscript."

1.2.16 Acknowledgements

Please acknowledge anyone who contributed towards the article who does not meet the criteria for authorship including anyone who provided professional writing services or materials. Authors should obtain permission to acknowledge from all those mentioned in the Acknowledgements section.See our editorial policies for a full explanation of acknowledgements and authorship criteria. If you do not have anyone to acknowledge, please write "Not applicable" in this section. Group authorship (for manuscripts involving a collaboration group): if you would like the names of the individual members of a collaboration Group to be searchable through their individual PubMed records, please ensure that the title of the collaboration Group is included on the title page and in the submission system and also include collaborating author names as the last paragraph of the “Acknowledgements” section. Please add authors in the format First Name, Middle initial(s) (optional), Last Name. You can add institution or country information for each author if you wish, but this should be consistent across all authors. Please note that

individual names may not be present in the PubMed record at the time a published article is initially included in PubMed as it takes PubMed additional time to code this information.

1.2.17 Authors' information

This section is optional.You may choose to use this section to include any relevant information about the author(s) that may aid the reader's interpretation of the article, and understand the standpoint of the author(s). This may include details about the authors' qualifications, current positions they hold at institutions or societies, or any other relevant background information. Please refer to authors using their initials. Note this section should not be used to describe any competing interests.

1.2.18 Footnotes

Footnotes can be used to give additional information, which may include the citation of a reference included in the reference list. They should not consist solely of a reference citation, and they should never include the bibliographic details of a reference. They should also not contain any figures or tables. Footnotes to the text are numbered consecutively; those to tables should be indicated by superscript lower-case letters (or asterisks for significance values and other statistical data). Footnotes to the title or the authors of the article are not given reference symbols. Always use footnotes instead of endnotes.

1.2.19 References

Examples of the Vancouver reference style are shown below. See our editorial policies for author guidance on good citation practice. Web links and URLs: All web links and URLs, including links to the authors' own websites, should be given a reference number and included in the reference list rather than within the text of the manuscript. They should be provided in full, including both the title of the site and the URL, as well as the date the site was accessed, in the following format: The Mouse Tumor Biology Database. http://tumor.informatics.jax.org/mtbwi/index.do. Accessed 20 May 2013. If an author or group of authors can clearly be associated with a web link, such as for weblogs, then they should be included in the reference.

Example reference style:

- Article within a journal

  Smith JJ. The world of science. Am J Sci. 1999;36:234-5.

- Article within a journal (no page numbers)

  Rohrmann S, Overvad K, Bueno-de-Mesquita HB, Jakobsen MU, Egeberg R, Tjønneland A, et al. Meat consumption and mortality - results from the European Prospective Investigation into Cancer and Nutrition. BMC Medicine. 2013;11:63.

- Article within a journal by DOI

  Slifka MK, Whitton JL. Clinical implications of dysregulated cytokine production. Dig J Mol Med. 2000; doi:10.1007/s801090000086.

- Article within a journal supplement

  Frumin AM, Nussbaum J, Esposito M. Functional asplenia: demonstration of splenic activity by bone marrow scan. Blood 1979;59 Suppl 1:26-32.

- Book chapter, or an article within a book

  Wyllie AH, Kerr JFR, Currie AR. Cell death: the significance of apoptosis. In: Bourne GH, Danielli JF, Jeon KW, editors. International review of cytology. London: Academic; 1980. p. 251-306.

- OnlineFirst chapter in a series (without a volume designation but with a DOI)

  Saito Y, Hyuga H. Rate equation approaches to amplification of enantiomeric excess and chiral symmetry breaking. Top Curr Chem. 2007. doi:10.1007/128_2006_108.

- Complete book, authored

  Blenkinsopp A, Paxton P. Symptoms in the pharmacy: a guide to the management of common illness. 3rd ed. Oxford: Blackwell Science; 1998.

- Online document

  Doe J. Title of subordinate document. In: The dictionary of substances and their effects. Royal Society of Chemistry. 1999. http://www.rsc.org/dose/title of subordinate document. Accessed 15 Jan 1999.

- Online database

Healthwise Knowledgebase. US Pharmacopeia, Rockville. 1998. http://www.healthwise.org. Accessed 21 Sept 1998.

- Supplementary material/private homepage
  Doe J. Title of supplementary material. 2000. http://www.privatehomepage.com. Accessed 22 Feb 2000.

- University site
  Doe, J: Title of preprint. http://www.uni-heidelberg.de/mydata.html (1999). Accessed 25 Dec 1999.

- FTP site
  Doe, J: Trivial HTTP, RFC2169. ftp://ftp.isi.edu/in-notes/rfc2169.txt (1999). Accessed 12 Nov 1999.

- Organization site
  ISSN International Centre: The ISSN register. http://www.issn.org (2006). Accessed 20 Feb 2007.

- Dataset with persistent identifier
  Zheng L-Y, Guo X-S, He B, Sun L-J, Peng Y, Dong S-S, et al. Genome data from sweet and grain sorghum (Sorghum bicolor). GigaScience Database. 2011. http://dx.doi.org/10.5524/100012.

1.2.20 Figures, tables and additional files

See General formatting guidelines for information on how to format figures, tables and additional files.

Appendix E: Author guidelines for Article Two

International Journal for Behavioural Nutrition and Physical Activity (IJBNPA)

1.1 Criteria for submitting a research article

Cover letters must include the names and emails of at least 4 potential reviewers. These must be from a different institution to the first author and not have published with any member of the writing group in the previous 3 years. Cover letters must contain a rationale for how the manuscript is novel, why it is relevant to the journal, and how the research contributes to the field or advances the evidence base. All

studies testing the effect of an intervention have to be registered with a trials registry to be eligible for peer review. We STRONGLY recommend prospective registration but will consider retrospectively registered trials with appropriate justification. For completed randomized controlled trials, IJBNPA requires the submission of a populated CONSORT checklist and flow diagram. The flow diagram should be included in the main body of the text and the checklist should be provided as an additional file. Both the flow diagram and the checklist should be referenced in the text. Submissions received without these elements will be returned to the authors as incomplete. A Word file of the checklist and flow diagram can be downloaded here. For all intervention components, authors are required to use the TIDieR Checklist, which should be provided as an additional file. The TIDieR Checklist is available to download as a PDF and a Word file. For observational studies, IJBNPA requires the submission of a populated STROBE checklist (http://strobe-statement.org/index.php?id=available-checklists) along with the manuscript. For observational studies that focus on nutrition, the checklist should be modified to reflect the revised STROBE-nut guidelines:

(http://journals.plos.org/plosmedicine/article?id=10.1371/journal.pmed.1002036).
The completed checklist should be provided as an additional file.

For all empirical studies, info regarding how the sample was recruited, how representative the sample was of the target group, how the analysed sample differed from the recruited sample and how any missing data were handled should be made available to editors/reviewers; these materials should be uploaded as an addtional file at the time of submission. There is no specific word limit, but articles should be as concise as possible. Articles that exceed 5000 words are rarely published. If an article is accepted for publication, the submitting author will be asked to provide at least one tweet of about 100 characters, together with your (or an institute) Twitter name which will be used to help publicise the paper at the point of publication. More general formatting guidelines can be found here.

International Journal of Behavioral Nutrition and Physical Activity strongly encourages that all datasets on which the conclusions of the paper rely should be available to readers. We encourage authors to ensure that their datasets are either deposited in publicly available repositories (where available and appropriate) or presented in the main manuscript or additional supporting files whenever possible. Please see Springer Nature's information on recommended repositories. Where a widely established research community expectation for data archiving in public repositories exists, submission to a community-endorsed, public

repository is mandatory. A list of data where deposition is required, with the appropriate repositories, can be found on the Editorial Policies Page.

1.2 Preparing your manuscript

The information below details the section headings that you should include in your manuscript and what information should be within each section. Please note that your manuscript must include a 'Declarations' section including all of the subheadings (please see below for more information).

1.2.1 Title page

The title page should present a title that includes, if appropriate, the study design e.g.:"A versus B in the treatment of C: a randomized controlled trial", "X is a risk factor for Y: a case control study", "What is the impact of factor X on subject Y: A systematic review" or for non-clinical or non-research studies a description of what the article reports list the full names and institutional addresses for all authors if a collaboration group should be listed as an author, please list the Group name as an author. If you would like the names of the individual members of the Group to be searchable through their individual PubMed records, please include this information in the “Acknowledgements” section in accordance with the instructions below indicate the corresponding author

1.2.2 Abstract

The Abstract should not exceed 350 words. Please minimize the use of abbreviations and do not cite references in the abstract. Reports of randomized controlled trials should follow the CONSORT extension for abstracts. The abstract must include the following separate sections:

- Background: the context and purpose of the study
- Methods: how the study was performed and statistical tests used
- Results: the main findings
- Conclusions: brief summary and potential implication

Trial registration: If your article reports the results of a health care intervention on human participants, it must be registered in an appropriate registry and the registration number and date of registration should be in stated in this section. If it was not registered prospectively (before enrollment of the first participant),

you should include the words 'retrospectively registered'. See our editorial policies for more information on trial registration

1.2.3 Keywords

Three to ten keywords representing the main content of the article.

1.2.4 Background

The Background section should explain the background to the study, its aims, a summary of the existing literature and why this study was necessary or its contribution to the field.

1.2.5 Methods

The methods section should include:

- the aim, design and setting of the study
- the characteristics of participants or description of materials
- a clear description of all processes, interventions and comparisons. Generic drug names should generally be used. When proprietary brands are used in research, include the brand names in parentheses the type of statistical analysis used, including a power calculation if appropriate

1.2.6 Results

This should include the findings of the study including, if appropriate, results of statistical analysis which must be included either in the text or as tables and figures.

1.2.7 Discussion

This section should discuss the implications of the findings in context of existing research and highlight limitations of the study.

1.2.8 Conclusions

This should state clearly the main conclusions and provide an explanation of the importance and relevance of the study reported.

1.2.9 List of abbreviations

If abbreviations are used in the text they should be defined in the text at first use, and a list of abbreviations should be provided.

1.2.10 Declarations

All manuscripts must contain the following sections under the heading 'Declarations':

- Ethics approval and consent to participate
- Consent for publication
- Availability of data and materials
- Competing interests
- Funding
- Authors' contributions
- Acknowledgements
- Authors' information (optional)

Please see below for details on the information to be included in these sections. If any of the sections are not relevant to your manuscript, please include the heading and write 'Not applicable' for that section. Ethics approval and consent to participate. Manuscripts reporting studies involving human participants, human data or human tissue must:

- include a statement on ethics approval and consent (even where the need for approval was waived)
- include the name of the ethics committee that approved the study and the committee's reference number if appropriate
- Studies involving animals must include a statement on ethics approval.

See our editorial policies for more information.

If your manuscript does not report on or involve the use of any animal or human data or tissue, please state "Not applicable" in this section.

1.2.11Consent for publication

If your manuscript contains any individual person's data in any form (including any individual details, images or videos), consent for publication must be obtained from that person, or in the case of children, their parent or legal guardian. All presentations of case reports must have consent for publication. You can use your institutional consent form or our consent form if you prefer. You should not send the form

to us on submission, but we may request to see a copy at any stage (including after publication). See our editorial policies for more information on consent for publication.

If your manuscript does not contain data from any individual person, please state “Not applicable” in this section.Availability of data and materials

All manuscripts must include an ‘Availability of data and materials’ statement. Data availability statements should include information on where data supporting the results reported in the article can be found including, where applicable, hyperlinks to publicly archived datasets analysed or generated during the study. By data we mean the minimal dataset that would be necessary to interpret, replicate and build upon the findings reported in the article. We recognise it is not always possible to share research data publicly, for instance when individual privacy could be compromised, and in such instances data availability should still be stated in the manuscript along with any conditions for access.

Data availability statements can take one of the following forms (or a combination of more than one if required for multiple datasets):

- The datasets generated and/or analysed during the current study are available in the [NAME] repository, [PERSISTENT WEB LINK TO DATASETS]
- The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.
- All data generated or analysed during this study are included in this published article [and its supplementary information files].
- The datasets generated and/or analysed during the current study are not publicly available due [REASON WHY DATA ARE NOT PUBLIC] but are available from the corresponding author on reasonable request.
- Data sharing is not applicable to this article as no datasets were generated or analysed during the current study.
    - The data that support the findings of this study are available from [third party name] but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of [third party name].

- Not applicable. If your manuscript does not contain any data, please state 'Not applicable' in this section.

More examples of template data availability statements, which include examples of openly available and restricted access datasets, are available here.

BioMed Central also requires that authors cite any publicly available data on which the conclusions of the paper rely in the manuscript. Data citations should include a persistent identifier (such as a DOI) and should ideally be included in the reference list. Citations of datasets, when they appear in the reference list, should include the minimum information recommended by DataCite and follow journal style. Dataset identifiers including DOIs should be expressed as full URLs. For example: Hao Z, AghaKouchak A, Nakhjiri N, Farahmand A. Global integrated drought monitoring and prediction system (GIDMaPS) data sets. figshare. 2014. http://dx.doi.org/10.6084/m9.figshare.853801
With the corresponding text in the Availability of data and materials statement:
The datasets generated during and/or analysed during the current study are available in the [NAME] repository, [PERSISTENT WEB LINK TO DATASETS].[Reference number]

If you wish to co-submit a data note describing your data to be published in BMC Research Notes, you can do so by visiting our submission portal. Data notes support open data and help authors to comply with funder policies on data sharing. Co-published data notes will be linked to the research article the data support (example).
For more information please email our Research Data Team.

1.2.12 Competing interests

All financial and non-financial competing interests must be declared in this section. See our editorial policies for a full explanation of competing interests. If you are unsure whether you or any of your co-authors have a competing interest please contact the editorial office. Please use the authors initials to refer to each authors' competing interests in this section. If you do not have any competing interests, please state "The authors declare that they have no competing interests" in this section.

1.2.13 Funding

All sources of funding for the research reported should be declared. The role of the funding body in the design of the study and collection, analysis, and interpretation of data and in writing the manuscript should be declared.

1.2.14 Authors' contributions

The individual contributions of authors to the manuscript should be specified in this section. Guidance and criteria for authorship can be found in our editorial policies. Please use initials to refer to each author's contribution in this section, for example: "FC analyzed and interpreted the patient data regarding the hematological disease and the transplant. RH performed the histological examination of the kidney, and was a major contributor in writing the manuscript. All authors read and approved the final manuscript."

1.2.15 Acknowledgements

Please acknowledge anyone who contributed towards the article who does not meet the criteria for authorship including anyone who provided professional writing services or materials. Authors should obtain permission to acknowledge from all those mentioned in the Acknowledgements section. See our editorial policies for a full explanation of acknowledgements and authorship criteria. If you do not have anyone to acknowledge, please write "Not applicable" in this section. Group authorship (for manuscripts involving a collaboration group): if you would like the names of the individual members of a collaboration Group to be searchable through their individual PubMed records, please ensure that the title of the collaboration Group is included on the title page and in the submission system and also include collaborating author names as the last paragraph of the “Acknowledgements” section. Please add authors in the format First Name, Middle initial(s) (optional), Last Name. You can add institution or country information for each author if you wish, but this should be consistent across all authors. Please note that individual names may not be present in the PubMed record at the time a published article is initially included in PubMed as it takes PubMed additional time to code this information.

1.2.16 Authors' information

This section is optional.You may choose to use this section to include any relevant information about the author(s) that may aid the reader's interpretation of the article, and understand the standpoint of the author(s). This may include details about the authors' qualifications, current positions they hold at

institutions or societies, or any other relevant background information. Please refer to authors using their initials. Note this section should not be used to describe any competing interests.

1.2.17 Footnotes

Footnotes can be used to give additional information, which may include the citation of a reference included in the reference list. They should not consist solely of a reference citation, and they should never include the bibliographic details of a reference. They should also not contain any figures or tables. Footnotes to the text are numbered consecutively; those to tables should be indicated by superscript lower-case letters (or asterisks for significance values and other statistical data). Footnotes to the title or the authors of the article are not given reference symbols. Always use footnotes instead of endnotes.

1.2.18 References

Examples of the Vancouver reference style are shown below. See our editorial policies for author guidance on good citation practice. Web links and URLs: All web links and URLs, including links to the authors' own websites, should be given a reference number and included in the reference list rather than within the text of the manuscript. They should be provided in full, including both the title of the site and the URL, as well as the date the site was accessed, in the following format: The Mouse Tumor Biology Database. http://tumor.informatics.jax.org/mtbwi/index.do. Accessed 20 May 2013. If an author or group of authors can clearly be associated with a web link, such as for weblogs, then they should be included in the reference. Example reference style:

- Article within a journal
  Smith JJ. The world of science. Am J Sci. 1999;36:234-5.

- Article within a journal (no page numbers)
  Rohrmann S, Overvad K, Bueno-de-Mesquita HB, Jakobsen MU, Egeberg R, Tjønneland A, et al. Meat consumption and mortality - results from the European Prospective Investigation into Cancer and Nutrition. BMC Medicine. 2013;11:63.

- Article within a journal by DOI
  Slifka MK, Whitton JL. Clinical implications of dysregulated cytokine production. Dig J Mol Med. 2000; doi:10.1007/s801090000086.

- Article within a journal supplement

  Frumin AM, Nussbaum J, Esposito M. Functional asplenia: demonstration of splenic activity by bone marrow scan. Blood 1979;59 Suppl 1:26-32.

- Book chapter, or an article within a book

  Wyllie AH, Kerr JFR, Currie AR. Cell death: the significance of apoptosis. In: Bourne GH, Danielli JF, Jeon KW, editors. International review of cytology. London: Academic; 1980. p. 251-306.

- OnlineFirst chapter in a series (without a volume designation but with a DOI)

  Saito Y, Hyuga H. Rate equation approaches to amplification of enantiomeric excess and chiral symmetry breaking. Top Curr Chem. 2007. doi:10.1007/128_2006_108.

- Complete book, authored

  Blenkinsopp A, Paxton P. Symptoms in the pharmacy: a guide to the management of common illness. 3rd ed. Oxford: Blackwell Science; 1998.

- Online document

  Doe J. Title of subordinate document. In: The dictionary of substances and their effects. Royal Society of Chemistry. 1999. http://www.rsc.org/dose/title of subordinate document. Accessed 15 Jan 1999.

- Online database

  Healthwise Knowledgebase. US Pharmacopeia, Rockville. 1998. http://www.healthwise.org. Accessed 21 Sept 1998.

- Supplementary material/private homepage

  Doe J. Title of supplementary material. 2000. http://www.privatehomepage.com. Accessed 22 Feb 2000.

- University site

  Doe, J: Title of preprint. http://www.uni-heidelberg.de/mydata.html (1999). Accessed 25 Dec 1999.

- FTP site

  Doe, J: Trivial HTTP, RFC2169. ftp://ftp.isi.edu/in-notes/rfc2169.txt (1999). Accessed 12 Nov 1999.

- Organization site

  ISSN International Centre: The ISSN register. http://www.issn.org (2006). Accessed 20 Feb 2007.

- Dataset with persistent identifier

  Zheng L-Y, Guo X-S, He B, Sun L-J, Peng Y, Dong S-S, et al. Genome data from sweet and grain sorghum (Sorghum bicolor). GigaScience Database. 2011. http://dx.doi.org/10.5524/100012.

1.2.19 Figures, tables and additional files

See General formatting guidelines for information on how to format figures, tables and additional files.

Appendix F: Author guidelines for Article Three

Journal of Physical Activity and Health

Prior to submission, please carefully read and follow the submission guidelines detailed below. Authors must submit their manuscripts through the journal's ScholarOne online submission system.

1.1 Authorship Guidelines

The Journals Division at Human Kinetics adheres to the criteria for authorship as outlined by the International Committee of Medical Journal Editors*:

Each author should have participated sufficiently in the work to take public responsibility for the content. Authorship credit should be based only on substantial contributions to:

a. Conception and design, or analysis and interpretation of data; and
b. Drafting the article or revising it critically for important intellectual content; and
c. Final approval of the version to be published.

Conditions a, b, and c must all be met. Individuals who do not meet the above criteria may be listed in the acknowledgments section of the manuscript. *Uniform requirements for manuscripts submitted to biomedical journals. (1991). New England Journal of Medicine, 324, 424–428.

1.2 Open Access

Human Kinetics is pleased to allow our authors the option of having their articles published Open Access. In order for an article to be published Open Access, authors must complete and return the Request for Open Access form and provide payment for this option. To learn more and request Open Access, click here.

1.3 Manuscript Guidelines

Journal of Physical Activity and Health (JPAH) is a peer-reviewed journal. Manuscripts reporting Original Research, Public Health Practice, Technical Notes, Brief Reports, or Reviews will be reviewed by at least two reviewers with expertise in the topical field, and the review process usually takes 6 to 8 weeks. A double-blind method is used for the review process, meaning authors and reviewers remain unknown to each other.

All types of manuscripts submitted to JPAH are judged on the following primary criteria: adherence to accepted scientific principles and methods, the significant or novel contribution to research or practice in the field of physical activity, clarity and conciseness of writing, and interest to the readership. There are no page charges to contributors.

Manuscripts generally should not exceed 25 pages (~5,000 words including everything except title and abstract pages; the word limit includes the reference section). Reviews should not exceed a total of 30 pages and Brief Reports should not exceed 15 pages. Major exceptions to these criteria must be approved through the Editorial Office before submission. Submissions should not include more than 10 tables/graphics, and should follow the Uniform Requirements for Manuscripts Submitted to Biomedical Journals (visit ICMJE for more detail). JPAH welcomes and encourages the submission of supplementary materials to be included with the article. These files are placed online and can be accessed from the JPAH website. Supplemental material can include relevant appendices, tables, details of the methods (e.g., survey instruments), or images. Contact the Editorial Office for approval of any supplemental materials.

1.4 Standardized Publication Reporting Guides

JPAH highly recommends that authors refer to relevant published reporting guidelines for different types of research studies. Examples of reporting guidelines include:

- Consolidated Standards of Reporting Trials (CONSORT)
- Meta-analysis of Observational Studies in Epidemiology (MOOSE)
- Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)
- STrengthening the Reporting of OBservational studies in Epidemiology (STROBE)
- Improving the Quality of Web Surveys: The Checklist for Reporting Results of Internet E-Surveys (CHERRIES)

Manuscripts must be submitted in Microsoft Word® (*.doc) or rich text (*.rtf) format only. Do not submit a .pdf file. Graphics should be submitted in .tif or .jpg formats only. Before submitting, authors should complete the Manuscript Submission Checklist (see below). Authors may be asked to provide Human Kinetics with photo-ready graphics and/or a hard copy of the text. Authors are responsible for confirming the accuracy of the final copy, particularly the accuracy of references, and to retain a duplicate copy to

guard against loss. Final review of the pre-published text is the responsibility of the authors. Authors of manuscripts accepted for publication must transfer copyright to Human Kinetics, as applicable.

1.5 Cover Letter

Submissions must include a cover letter stating that the manuscript has not been previously published (except in abstract form), is not presently under consideration by another journal, and will not be submitted to another journal before a final editorial decision from JPAH is rendered. Full names, institutional affiliations, and email addresses of all authors, as well as the full mailing address, telephone number, and fax number of the corresponding author, must be provided. Authors must also provide a statement disclosing any relevant financial interests related to the research.

1.6 Manuscript Types

Original Research

A manuscript describing the methods and results of a research study (quantitative or qualitative), including the background and purpose of the study, a detailed description of the research design and methods, clear and comprehensive presentation of results, and discussion of the salient findings.

Public Health Practice

A manuscript describing the development or evaluation of a public health intervention to increase or promote physical activity in a community setting, or a study that describes translation of research to practice.

Technical Note

A short article that presents results related to a new or modified method or instrument related to physical activity measurement or an important experimental observation.

Brief Reports

A short article (15 or fewer pages), usually presenting the preliminary or novel results of an original research study or public health practice program.

Reviews

Manuscripts that succinctly review the scientific literature on a specific topic. Traditional narrative reviews are discouraged. However, well-conducted systematic reviews and meta-analyses are highly encouraged. The Editorial Office may recruit reviews on specific topics. All review articles must have approval from the Editorial Office prior to submission.

1.7 Manuscript Sections

The order of submission must be (1) Title page, (2) Abstract, (3) Text, (4) Acknowledgments, (5) Funding source, (6) References, (7) Tables, (8) Figures/Graphics.

1.7.1 Title Page

The manuscript must include a title page that provides the full title, a brief running head, manuscript type (see definitions above), three to five key words not used in the title of the manuscript, abstract word count, manuscript word count (inclusive of all pages except the abstract and title page), date of manuscript submission, and full names of authors, their institutional or corporate affiliations, and e-mail addresses.

1.7.2 Abstract

All manuscripts must have a structured abstract of no more than 200 words. Required headings are (1) Background, (2) Methods, (3) Results, and (4) Conclusions.

1.7.3 Text

The entire manuscript must be double-spaced, including the abstract, references, and tables. Line numbers must appear on each page in the left margin. A brief running head is to be included on the upper right corner of each page; page numbers must appear on the bottom right corner of each page.

For studies involving human subjects, the Methods section must include statements regarding institutional approval of the protocol and obtaining informed consent. For studies using animals, the Methods section must include a statement regarding institutional approval and compliance with governmental policies and regulations regarding animal welfare.

1.7.4 Acknowledgments

Provide the names, affiliations, and the nature of the contribution for all persons not included as an author who played a critical role in the study.

1.7.4 Funding Source/Trial Registration

Details of all funding sources for the work should be provided (including agency name, grant numbers, etc.). Provide the registry name and registration number for all clinical trials (see JPAH Ethics Policies below). Example: "This work was supported by a grant (grant #) from the National Cancer Institute, National Institutes of Health. This study is registered at www.clinicaltrials.gov (No. xxxxx)."

1.7.5 References

For reference lists, authors must follow the guidelines found in the American Medical Association Manual of Style: A Guide for Authors and Editors (10th ed.). Examples of reference style: Journal articles: Surname of first author, initials, then surname and initials of each coauthor; title of article (capitalize only the first word and proper nouns), name of the journal (italicized and abbreviated according to style of Index Medicus), year, volume, and inclusive page numbers.

- Melby CL, Osterberg K, Resch A, Davy B, Johnson S, Davy K. Effect of carbohydrate ingestion during exercise on post-exercise substrate oxidation and energy intake. Int J Sport Nutr Exerc Metab. 2002;12:294–309.

- Book references: Author(s) as above, title of book (italicized and all major words capitalized), city and state/province of publication, publisher, and year.

- Pearl AJ. The Female Athlete. Champaign, Ill: Human Kinetics; 1993.

Chapter in an edited book: Same as book references, but add the name of the chapter author(s) and title of chapter (capitalize first word and proper nouns) before the book information and inclusive page numbers.

- Perrin DH. The evaluation process in rehabilitation. In: Prentice WE, ed. Rehabilitation Techniques in Sports Medicine. 2nd ed. St Louis, Mo: Mosby Year Book; 1994:253–276.

1.7.6 Tables

Each table must be accompanied by an explanatory title so that it is intelligible without specific reference to the text. Column headings and all units of measure must be labeled clearly within each table; abbreviations and acronyms must be fully explained in the table or footnotes without reference to the text.

1.7.7 Figures/Graphics

Graphics should be prepared with clean, crisp lines, and be camera-ready. For shading, stripe patterns or solids (black and white) are better choices than colors. Graphics created on standard computer programs will be accepted. Graphics should be submitted in .tif or .jpg formats only. Each figure and photo must be properly identified. A hard copy may be requested. If photos are used, they should be black and white, clear, and show good contrast.

Appendix G: Study Advertisement Flyer

DO YOU WANT TO KNOW YOUR HEALTH STATUS?

You are invited to participate in an exciting
STELLENBOSCH UNIVERSITY RESEARCH STUDY!

YOU CAN PARTICIPATE IN THE STUDY IF YOU FULFILL THE FOLLOWING CRITERIA

- Female
- Between the ages 18-64 years of age
- South African
- Living in Cloetesville
- No known diseases
- No injuries that prevent you from walking
- Not pregnant or breastfeeding

You only need to attend 2 sessions and you will receive information that is valued at approximately R2000!!!

Contact us

Ms Kasha Dickie
Email: kdickie@sun.ac.za
Cell: 0828814436

Ms Sharné Nieuwoudt
Email:15617572@sun.ac.za
Cell: 0723558146

Please call me's gladly accepted

Appendix H: Participation Letter and Informed Consent

UNIVERSITEIT•STELLENBOSCH•UNIVERSITY
jou kennisvennoot • your knowledge partner

STELLENBOSCH UNIVERSITY
CONSENT TO PARTICIPATE IN RESEARCH

RELATIONSHIPS BETWEEN LIFESTYLE FACTORS, CARDIOMETABOLIC HEALTH, COGNITIVE FUNCTIONING AND CARDIORESPIRATORY FITNESS IN SOUTH AFRICAN WOMEN FROM A LOW SOCIOECONOMIC COMMUNITY

You are asked to participate in a research study conducted by Prof E Terblanche (PhD) from the Department of Sport Science at Stellenbosch University. Aspects of this research project will form part of the theses of two PhD in Sport Science students (Ms S Nieuwoudt and Ms K Dickie) in the Department of Sport Science. You were selected as a possible participant in this study because you are a female between the ages of 18 and 64 years.

1. PURPOSE OF THE STUDY

To investigate the health status and certain lifestyle factors among adult women in your community, and identify specific health behaviours where intervention is needed to manage, or at least reduce, the risk of obesity, high blood sugar, high blood pressure and other diseases of lifestyle.

2. PROCEDURES

If you volunteer to participate in the study, we ask your permission to conduct the following tests and measurements:

1. measure your resting blood pressure, height, weight, waist and hip circumference;
2. a urine-pregnancy test (this is a compulsary test if you want to participate in the study).
3. take a blood sample of 12 mL taken by a qualified nurse from a vein in your arm with a sterile needle and blood tubes to determine various indicators of your health;
4. measure the amount of muscle and fat in various parts of your body. This test will require you to lie on a table, dressed in a hospital gown, while a scanner takes pictures of your whole body (almost like an X-ray). For your safety, this test may not be performed if you are pregnant or breast-feeding. It is for this reason that the pregnancy test is compulsory.
5. assess the strength of the grip in both your hands with a hand-held device;
6. walk or run on a treadmill for at least 6 min while the speed of the treadmill is gradually increased. During this test you will wear a safety harness around the upper part of your body to prevent you from falling and hurting yourself. We will also fit an elastic band around your chest to measure your heart rate, as

well as a mask over your mouth and nose so that we can analyse the air that you are breathing out. You will be able to breath freely through the mask. We will ask you to walk or run for as long as you can, however, you can stop the test by pressing a red knob on the treadmill when you feel too tired to go on. The treadmill will then safely come to a halt. Although you will wear a safety harness, there will also be two persons next to the treadmill who will prevent you from falling and hurting yourself.

7. sit in front of a computer and complete a series of computer tests in your choice of English or Afrikaans. These tests will determine your ability to recognise certain patterns or pictures on the screen, as well as how quickly you respond to the changing patterns and pictures. This battery of tests will take you 30 min to complete.
8. wear a device on your hip for seven full days so that we can determine how much time you spend sitting, standing and lying down. You will also be asked to keep a diary of your physical activity during these seven days.
9. sit by a table and, with the help of one of the researchers, complete questionnaires on your housing, finances, education, employement, general health, family health history, activity level, nutrition and mental well being.

The tests above will be completed over two days seperated by seven full days. All the tests and measurements will be done by staff at the Stellenbosch Campus Health Clinic, Winelands Radiology and the Sport Physiology Laboratory at the Department of Sport Science on the Stellenbosch University campus. Once you have been booked for your testing days you will be transported from a central venue in Cloetesville to all testing facilities at 8:00 on the scheduled day. You will also be transported back to the central venue in Cloetesville once all testing is complete (approximately 16:00 on each testing day). We will provide you with food and drink during the day.

3. POTENTIAL RISKS AND DISCOMFORTS

There are no serious risks involved in the tests and procedures. No procedures performed in the study will be harmful to you as the participant. The only invasive procedure includes the venous blood sample that that will be drawn during your first session. However, you may experience dizziness and/or nausea during the exercise test on the treadmill. If so, the exercise test will be stopped immediately. In the event that something does go wrong, all researchers involved are certified in first aid level 1 and basic life support and are equipped and qualified to handle medical emergencies.

4. POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

The results of all the measurements and tests will be summarised and given to you in an ‘easy to understand booklet’. This booklet will help you to learn about your brain health as well as your cardiovascular health and to make positive changes to improve these factors. If there are any of your results, which raises our concerns, we will advise you to speak to a doctor or nurse at your local clinic.

We will also be providing feedback to you after the study regarding how you can improve your health, for example tips on how to remain active, decrease blood pressure and improve your body measurements. After this study you will be equipped to also help those around you in how they can remain healthy and improve their physical activity levels – you can help educate your family, friends and community on how to remain fit and healthy.

Furthermore, the results of this study will also allow us as researchers to determine the health status of women in your community, which will provide baseline data for future studies. It will also give us valuable information

on how we can improve the SUNWELL health programme of the Department of Sport Science which is currently running in your community.

5. PAYMENT FOR PARTICIPATION

You will receive no compensation for your participation in this study. However, we will provide food packs during the two days. In addition, you will receive a participation gift at the end of the study.

Should you incur any research-related injury or incident; all costs will be covered by the insurance of Stellenbosch University. To this end, you may contact Mr Van Kerwel (wvankerwel@sun.ac.za), 021 808 2809 for information on the issue of compensation and coverage of medical expenses in the event of a research-related injury.

6. CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Confidentiality will be maintained by assigning a research number to each participant so no one will be identified using their names. The research number, and not your name, will be used on all documents and questionnaires. The data collected will be stored in a computer which is password protected and only the researchers and the postgraduate students will have access to it. This computer will be locked in an office.

You will receive a report on your results on completion of the study. The findings of the study will be published in scientific journals and confidentiality will be maintained in that your (or any other participant's) name will not be mentioned. Selected results will form part of the research theses of the two postgraduate students. The department will keep the data for a period of 5-years and then it will be destroyed.

7. PARTICIPATION AND WITHDRAWAL

All testing procedures and assessments will be explained thoroughly to you beforehand. You may also choose whether to be a part of this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences. You may also refuse to answer any questions, or complete any of the tests, and still remain in the study. The investigator may withdraw you from this research if circumstances arise which warrant doing so. This may happen if you are pregnant, get injured or if there are any adverse events during or after the exercise tests.

8. IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact any of the following persons:

Prof Elmarie Terblanche (Principle investigator) by 021 808 4817. E-mail: et2@sun.ac.za
Dr Zarko Krkeljas (Co-investigator) by 021 808 2818. Email: zarko@sun.ac.za
Dr Carla Coetsee (Co-investigator) by 021 808 3915. Email: 15365484@sun.ac.za
Ms Kasha Dickie (PhD student) by 021 808 4718 Email: kdickie@sun.ac.za
MS Sharné Nieuwoudt (PhD student) by 021 808 2818. E-mail: 15617572@sun.ac.za

Mr Anthony Clarke (MSc student) by 021 808 2818. E-mail: 17199352@sun.ac.za
Mr Kyle Basson (MSc student) by 021 808 2818. E-mail: 16484258@sun.ac.za
Mr Matthew Shone (MSc student) by 021 808 2818. E-mail: 17648890@sun.ac.za

9. RIGHTS OF RESEARCH SUBJECTS

You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research subject, contact Ms Maléne Fouché [mfouche@sun.ac.za; 021 808 4622] at the Division for Research Development.

SIGNATURE OF RESEARCH SUBJECT OR LEGAL REPRESENTATIVE

The information above was described to me _____by _____ in _____ (language) and I am in command of this language or it was satisfactorily translated to me. I was given the opportunity to ask questions and these questions were answered to my satisfaction.

I hereby consent voluntarily to participate in this study. I have been given a copy of this form.

_____
Name of Subject/Participant

_____
Name of Legal Representative (if applicable)

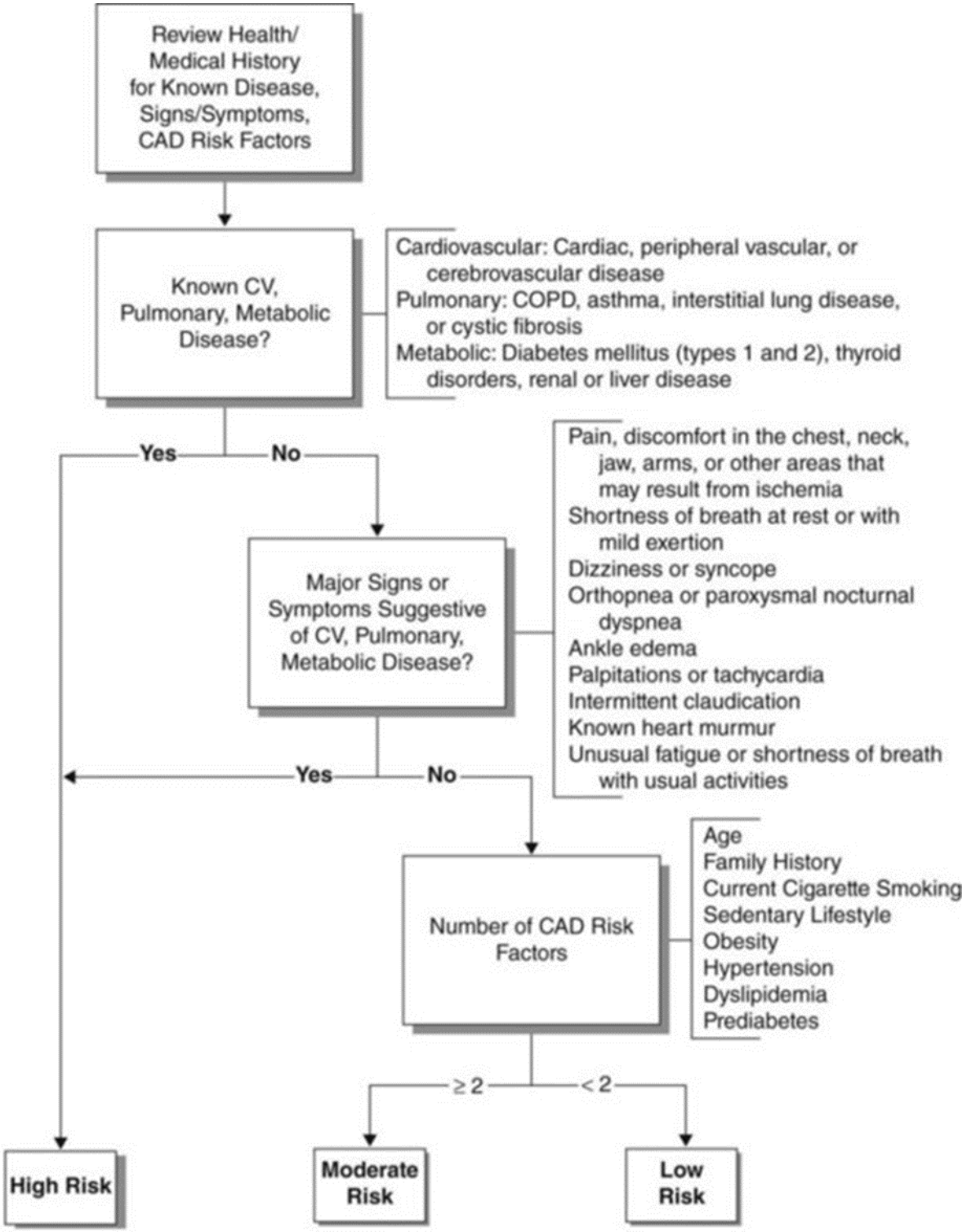
_____ _____
Signature of Subject/Participant or Legal Representative **Date**

SIGNATURE OF INVESTIGATOR

I declare that I explained the information given in this document to _____ and/or *his/her* representative _____ . *He/she* was encouraged and given ample time to ask me any questions. This conversation was conducted in *Afrikaans/English* and no translator was used.

_____ _____
Signature of Investigator **Date**

Appendix I: ACSM Logic Model for Health Risk Stratification (2014)



Appendix J: Pre-participation Health Questionnaire (PAR-Q)

PAR-Q and You

Yes	No	Questions
☐	☐	1.Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?
☐	☐	2.Do you feel pain in your chest when you do physical activity?
☐	☐	3.In the past month, have you had chest pain when you were not doing physical activity?
☐	☐	4.Do you lose your balance because of dizziness or do you ever lose consciousness?
☐	☐	5.Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?
☐	☐	6.Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
☐	☐	7.Do you know of any other reason why you should not do physical activity?

If you answered

YES to one of the questions	NO to all of the questions
Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES. • You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice. • Find out which community programs are safe and helpful for you.	If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can: • Start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go. • Take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell one of the researchers. Ask whether you should change your physical activity plan.

DELAY BECOMING MUCH MORE ACTIVE: If you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or if you are or may be pregnant – talk to your doctor before you start becoming more active.

☐ You may progress with the maximal exercise test.

Or ☐ You require medical clearance prior to completing the maximal exercise test.

Appendix K: ACSM Atherosclerotic Disease Classification (2010)

Participant Code:_____

Date and Time:_____

Instructions: Assess your health needs by marking all true statements.

History, you have had:

__ a heart attack

__ heart surgery

__ cardiac catheterization

__ coronary angioplasty (PTCA)

__ pacemaker/implantable cardiac defibrillator/rhythm disturbance

__ heart valve disease

__ heart failure

__ heart transplantation

__ congenital heart disease

Symptoms:

__ You experienced chest discomfort with exertion.

__ You experience unreasonable breathlessness.

__ You experience dizziness, fainting, blackouts.

__You experience ankle swelling

__You experience unpleasant awareness of a forceful or rapid heart rate

__ You take heart medications.

Other health issues:

__ You have diabetes.

__ You have asthma or other lung disease.

__You have burning or cramping sensation in your lower legs when walking short distance.

__ You have musculoskeletal problems that limit your physical activity.

__ You have concerns about the safety of exercise.

__ You take prescription medication(s) and/or HIV treatment

__You are pregnant and/or lactating.

If you marked any of the statements in this section, consult your healthcare provider before engaging in exercise.

Cardiovascular Risk Factors:

__ You are a woman older than ≥ 55-years.

__ You smoke or quit smoking in the previous 6 months.

__ Your blood pressure is > 140/90mm Hg.

__ You don't know your blood pressure.

__ You take blood pressure medication.

__Your blood cholesterol level is 5.18mmol/L

__ You do not know your cholesterol level.

__ You have a close blood relative who had a heart attack or heart surgery before age 55 (father or brother) or age 65 (mother or sister).

__ You are physically inactive (i.e.: you get < 30 minutes of physical activity on at least 3 days per week).

__ You have a BMI ≥ 30kg/m^2.

__You have pre-diabetes

__You don’t know if you have pre-diabetes

If you marked 2 or more of the statements in this section, consult your healthcare provider before engaging in exercise.

__ None of the above is true.

Appendix L: Informed Consent for Pregnancy Test

RESEARCH TITLE:

RELATIONSHIPS BETWEEN LIFESTYLE FACTORS, CARDIOMETABOLIC HEALTH, COGNITIVE FUNCTIONING AND CARDIORESPIRATORY FITNESS IN SOUTH AFRICAN WOMEN FROM A LOW SOCIOECONOMIC COMMUNITY

Consent:

I, _____, hereby give consent to complete a pregnancy test conducted by Stellenbosch Campus Health Clinic for the study titled, **RELATIONSHIPS BETWEEN LIFESTYLE FACTORS, CARDIOMETABOLIC HEALTH, COGNITIVE FUNCTIONING AND CARDIORESPIRATORY FITNESS IN SOUTH AFRICAN WOMEN FROM A LOW SOCIOECONOMIC COMMUNITY.** I understand that I will be excluded from the study if my pregnancy test is positive, as the radiation from the DXA scanner, however minute, may be harmful to my baby. I understand that I will be referred to Cloetesville Community Clinic or my general practitioner for counselling and follow-up. I understand that all the information collected during the study will be treated with the strictest confidentiality. I understand that for data verification and quality control purposes, regulatory authorities and/or members of the Research Ethics Committee may be allowed access to my personal data under conditions of strict confidentiality.

I have read and have had explained to me the procedure described. I have had an opportunity to ask questions and my questions have been answered in a satisfactory way. I understand that I am free to withdraw from this study at any time.

Name: _____ Signature: _____ Date: _____

Email: _____ Telephone number: _____

Date of birth: _____

Appendix M: WHO STEPS Instrument

STEPS Instrument

Overview

Introduction

This is the generic STEPS Instrument which sites/countries will use to develop their tailored instrument. It contains the:

- CORE items (unshaded boxes)
- EXPANDED items (shaded boxes).

Core Items

The Core items for each section ask questions required to calculate basic variables. For example:

- current daily smokers
- mean BMI.

Note: All the core questions should be asked, removing core questions will impact the analysis.

Expanded items

The Expanded items for each section ask more detailed information. Examples include:

- use of smokeless tobacco
- sedentary behaviour.

Guide to the columns

The table below is a brief guide to each of the columns in the Instrument.

Column	Description	Site Tailoring
Number	This question reference number is designed to help interviewers find their place if interrupted.	Renumber the instrument sequentially once the content has been finalized.
Question	Each question is to be read to the participants	• Select sections to use. • Add expanded and optional questions as desired.
Response	This column lists the available response options which the interviewer will be circling or filling in the text boxes. The skip instructions are shown on the right hand side of the responses and should be carefully followed during interviews.	• Add site specific responses for demographic responses (e.g. C6). • Change skip question identifiers from code to question number.
Code	The column is designed to match data from the instrument into the data entry tool, data analysis syntax, data book, and fact sheet.	This should never be changed or removed. The code is used as a general identifier for the data entry and analysis.

Participant Identification Number ⌊_⌋⌊_⌋⌊_⌋ ⌊_⌋⌊_⌋⌊_⌋ ⌊_⌋⌊_⌋⌊_⌋

WHO STEPS Instrument
for Chronic Disease Risk Factor Surveillance

<insert country/site name>

Survey Information

Location and Date		Response	Code
1	Cluster/Centre/Village ID	⌊_⌋⌊_⌋⌊_⌋	I1
2	Cluster/Centre/Village name		I2
3	Interviewer ID	⌊_⌋⌊_⌋⌊_⌋	I3
4	Date of completion of the instrument	⌊_⌋⌊_⌋ ⌊_⌋⌊_⌋ ⌊_⌋⌊_⌋⌊_⌋⌊_⌋ dd mm year	I4

Participant Id Number ⌊_⌋⌊_⌋⌊_⌋ ⌊_⌋⌊_⌋⌊_⌋ ⌊_⌋⌊_⌋⌊_⌋

Consent, Interview Language and Name		Response	Code
5	Consent has been read and obtained	Yes 1 No 2 If NO, END	I5
6	Interview Language *[Insert Language]*	English 1 *[Add others]* 2 *[Add others]* 3 *[Add others]* 4	I6
7	Time of interview (24 hour clock)	⌊_⌋⌊_⌋ : ⌊_⌋⌊_⌋ hrs mins	I7
8	Family Surname		I8
9	First Name		I9
Additional Information that may be helpful			
10	Contact phone number where possible		I10

Record and file identification information (I5 to I10) separately from the completed questionnaire.

Participant Identification Number ⌊_⌋⌊_⌋⌊_⌋ ⌊_⌋⌊_⌋⌊_⌋ ⌊_⌋⌊_⌋⌊_⌋

Step 1 Demographic Information

CORE: Demographic Information

Question		Response	Code
11	Sex (*Record Male / Female as observed*)	Male 1 Female 2	C1
12	What is your date of birth? *Don't Know 77 77 7777*	⌊_⌋⌊_⌋ ⌊_⌋⌊_⌋ ⌊_⌋⌊_⌋⌊_⌋⌊_⌋ *If known, Go to C4* dd mm year	C2
13	How old are you?	Years ⌊_⌋⌊_⌋	C3
14	In total, how many years have you spent at school or in full-time study (excluding pre-school)?	Years ⌊_⌋⌊_⌋	C4

EXPANDED: Demographic Information

15	What is the **highest level of education** you have completed? *[INSERT COUNTRY-SPECIFIC CATEGORIES]*	No formal schooling 1 Less than primary school 2 Primary school completed 3 Secondary school completed 4 High school completed 5 College/University completed 6 Post graduate degree 7 Refused 88	C5
16	What is your *[insert relevant ethnic group / racial group / cultural subgroup / others]* **background**?	*[Locally defined]* 1 *[Locally defined]* 2 *[Locally defined]* 3 Refused 88	C6
17	What is your **marital status**?	Never married 1 Currently married 2 Separated 3 Divorced 4 Widowed 5 Cohabitating 6 Refused 88	C7
18	Which of the following best describes your **main work** status over the past 12 months? *[INSERT COUNTRY-SPECIFIC CATEGORIES]* *(USE SHOWCARD)*	Government employee 1 Non-government employee 2 Self-employed 3 Non-paid 4 Student 5 Homemaker 6 Retired 7 Unemployed (able to work) 8 Unemployed (unable to work) 9 Refused 88	C8
19	How many people older than 18 years, including yourself, live in your household?	Number of people ⌊_⌋⌊_⌋	C9

Participant Identification Number ⌊_⌋⌊_⌋⌊_⌋ ⌊_⌋⌊_⌋⌊_⌋ ⌊_⌋⌊_⌋⌊_⌋

EXPANDED: Demographic Information, Continued			
Question		**Response**	**Code**
20	Taking **the past year**, can you tell me what the average earnings of the household have been? *(RECORD ONLY ONE, NOT ALL 3)*	Per week ⌊_⌋⌊_⌋⌊_⌋⌊_⌋⌊_⌋⌊_⌋⌊_⌋ *Go to T1*	C10a
		OR per month ⌊_⌋⌊_⌋⌊_⌋⌊_⌋⌊_⌋⌊_⌋⌊_⌋ *Go to T1*	C10b
		OR per year ⌊_⌋⌊_⌋⌊_⌋⌊_⌋⌊_⌋⌊_⌋⌊_⌋ *Go to T1*	C10c
		Refused 88	C10d
21	If you don't know the amount, can you give an **estimate** of the annual household income if I read some options to you? Is it *[INSERT QUINTILE VALUES IN LOCAL CURRENCY]* *(READ OPTIONS)*	≤ Quintile (Q) 1 1 More than Q 1, ≤ Q 2 2 More than Q 2, ≤ Q 3 3 More than Q 3, ≤ Q 4 4 More than Q 4 5 Don't Know 77 Refused 88	C11

Step 1 Behavioural Measurements

CORE: Tobacco Use			
Now I am going to ask you some questions about various health behaviours. This includes things like smoking, drinking alcohol, eating fruits and vegetables and physical activity. Let's start with tobacco.			
Question		**Response**	**Code**
22	Do you currently smoke any **tobacco products**, such as cigarettes, cigars or pipes? *(USE SHOWCARD)*	Yes 1 No 2 *If No, go to T6*	T1
23	Do you currently smoke tobacco products **daily**?	Yes 1 No 2 *If No, go to T6*	T2
24	How old were you when you **first started** smoking daily?	Age (years) Don't know 77 ⌊_⌋⌊_⌋ *If Known, go to T5a*	T3
25	Do you remember how long ago it was? *(RECORD ONLY 1, NOT ALL 3)* *Don't know 77*	In Years ⌊_⌋⌊_⌋ *If Known, go to T5a*	T4a
		OR in Months ⌊_⌋⌊_⌋ *If Known, go to T5a*	T4b
		OR in Weeks ⌊_⌋⌊_⌋	T4c
26	On average, **how many** of the following do you smoke each day? *(RECORD FOR EACH TYPE, USE SHOWCARD)* *Don't Know 77*	Manufactured cigarettes ⌊_⌋⌊_⌋	T5a
		Hand-rolled cigarettes ⌊_⌋⌊_⌋	T5b
		Pipes full of tobacco ⌊_⌋⌊_⌋	T5c
		Cigars, cheroots, cigarillos ⌊_⌋⌊_⌋	T5d
		Other ⌊_⌋⌊_⌋ *If Other, go to T5other, else go to T9*	T5e
		Other (please specify): ⌊_⌋⌊_⌋⌊_⌋⌊_⌋⌊_⌋⌊_⌋⌊_⌋⌊_⌋ *Go to T9*	T5other

Participant Identification Number ⌊_⌋⌊_⌋⌊_⌋ ⌊_⌋⌊_⌋⌊_⌋ ⌊_⌋⌊_⌋⌊_⌋

EXPANDED: Tobacco Use			
Question		**Response**	**Code**
27	In the past, did you **ever** smoke **daily**?	Yes 1 No 2 *If No, go to T9*	T6
28	How old were you when you **stopped** smoking **daily**?	Age (years) ⌊_⌋⌊_⌋ Don't Know 77 *If Known, go to T9*	T7
29	How **long ago** did you stop smoking daily? *(RECORD ONLY 1, NOT ALL 3)* *Don't Know 77*	Years ago ⌊_⌋⌊_⌋ *If Known, go to T9* OR Months ago ⌊_⌋⌊_⌋ *If Known, go to T9* OR Weeks ago ⌊_⌋⌊_⌋	T8a T8b T8c
30	Do you **currently use** any **smokeless tobacco** such as *(snuff, chewing tobacco, betel)? (USE SHOWCARD)*	Yes 1 No 2 *If No, go to T12*	T9
31	Do you **currently use smokeless tobacco** products **daily?**	Yes 1 No 2 *If No, go to T12*	T10
32	On average, how many **times a day** do you use .... *(RECORD FOR EACH TYPE, USE SHOWCARD)* *Don't Know 77*	Snuff, by mouth ⌊_⌋⌊_⌋	T11a
		Snuff, by nose ⌊_⌋⌊_⌋	T11b
		Chewing tobacco ⌊_⌋⌊_⌋	T11c
		Betel, quid ⌊_⌋⌊_⌋	T11d
		Other ⌊_⌋⌊_⌋ *If Other, go to T11other, else go to T13*	T11e
		Other (specify) ⌊_⌋⌊_⌋⌊_⌋⌊_⌋⌊_⌋⌊_⌋⌊_⌋⌊_⌋⌊_⌋⌊_⌋ *Go to T13*	T11other
33	In the **past**, did you **ever use** smokeless tobacco such as *(snuff, chewing tobacco, or betel)* **daily**?	Yes 1 No 2	T12
34	During the past 7 days, on how many days did someone **in your home** smoke when you were present?	Number of days Don't know 77 ⌊_⌋⌊_⌋	T13
35	During the past 7 days, on how many days did someone smoke in closed areas **in your workplace** (in the building, in a work area or a specific office) when you were present?	Number of days Don't know or don't work in a closed area 77 ⌊_⌋⌊_⌋	T14

Participant Identification Number ⌊_⌋⌊_⌋⌊_⌋ ⌊_⌋⌊_⌋⌊_⌋ ⌊_⌋⌊_⌋⌊_⌋

CORE: Alcohol Consumption

The next questions ask about the consumption of alcohol.

	Question	Response	Code
36	Have you **ever** consumed an alcoholic drink such as beer, wine, spirits, fermented cider or *[add other local examples]*? *(USE SHOWCARD OR SHOW EXAMPLES)*	Yes 1 No 2 *If No, go to D1*	A1a
37	Have you consumed an alcoholic drink within the **past 12 months**?	Yes 1 No 2 *If No, go to D1*	A1b
38	During the past 12 months, **how frequently** have you had at least one alcoholic drink? *(READ RESPONSES, USE SHOWCARD)*	Daily 1 5-6 days per week 2 1-4 days per week 3 1-3 days per month 4 Less than once a month 5	A2
39	Have you consumed an alcoholic drink within the **past 30 days**?	Yes 1 No 2 *If No, go to D1*	A3
40	During the past 30 days, on how many **occasions** did you have at least one alcoholic drink?	Number ⌊_⌋⌊_⌋ Don't know 77	A4
41	During the past 30 days, when you drank alcohol, **on average**, how many **standard alcoholic drinks** did you have during one drinking occasion? *(USE SHOWCARD)*	Number ⌊_⌋⌊_⌋ Don't know 77	A5
42	During the past 30 days, what was the **largest number** of standard alcoholic drinks you had on a single occasion, counting all types of alcoholic drinks together?	Largest number ⌊_⌋⌊_⌋ Don't Know 77	A6
43	During the past 30 days, how many times did you have for **men: five or more** for **women: four or more** standard alcoholic drinks in a single drinking occasion?	Number of times ⌊_⌋⌊_⌋ Don't Know 77	A7

EXPANDED: Alcohol Consumption

44	During the past 30 days, when you consumed an alcoholic drink, how often was it with meals? Please do not count snacks.	Usually with meals 1 Sometimes with meals 2 Rarely with meals 3 Never with meals 4	A8
45	During each of the **past 7 days**, how many standard alcoholic drinks did you have each day? *(USE SHOWCARD)* *Don't Know 77*	Monday ⌊_⌋⌊_⌋	A9a
		Tuesday ⌊_⌋⌊_⌋	A9b
		Wednesday ⌊_⌋⌊_⌋	A9c
		Thursday ⌊_⌋⌊_⌋	A9d
		Friday ⌊_⌋⌊_⌋	A9e
		Saturday ⌊_⌋⌊_⌋	A9f
		Sunday ⌊_⌋⌊_⌋	A9g

Participant Identification Number ⌊_⌋⌊_⌋⌊_⌋ ⌊_⌋⌊_⌋⌊_⌋ ⌊_⌋⌊_⌋⌊_⌋

CORE: Diet

The next questions ask about the fruits and vegetables that you usually eat. I have a nutrition card here that shows you some examples of local fruits and vegetables. Each picture represents the size of a serving. As you answer these questions please think of a typical week in the last year.

	Question	Response	Code
46	In a typical week, on how many days do you **eat fruit**? *(USE SHOWCARD)*	Number of days ⌊_⌋⌊_⌋ Don't Know 77 *If Zero days, go to D3*	D1
47	How many **servings** of fruit do you eat on **one** of those days? *(USE SHOWCARD)*	Number of servings ⌊_⌋⌊_⌋ Don't Know 77	D2
48	In a typical week, on how many days do you **eat vegetables**? *(USE SHOWCARD)*	Number of days ⌊_⌋⌊_⌋ Don't Know 77 *If Zero days, go to D5*	D3
49	How many **servings** of vegetables do you eat on one of those days? *(USE SHOWCARD)*	Number of servings ⌊_⌋⌊_⌋ Don't know 77	D4

EXPANDED: Diet

50	What type of **oil or fat is most often** used for meal preparation in your household? *(USE SHOWCARD)* *(SELECT ONLY ONE)*	Vegetable oil 1 Lard or suet 2 Butter or ghee 3 Margarine 4 Other 5 *If Other, go to D5 other* None in particular 6 None used 7 Don't know 77	D5
		Other ⌊_⌋⌊_⌋⌊_⌋⌊_⌋⌊_⌋⌊_⌋⌊_⌋⌊_⌋⌊_⌋⌊_⌋	D5other
51	On average, how many meals per week do you eat that were not prepared at a home? By meal, I mean breakfast, lunch and dinner.	Number ⌊_⌋⌊_⌋ Don't know 77	D6

Participant Identification Number ⌊_⌋⌊_⌋⌊_⌋ ⌊_⌋⌊_⌋⌊_⌋ ⌊_⌋⌊_⌋⌊_⌋

CORE: Physical Activity

Next I am going to ask you about the time you spend doing different types of physical activity in a typical week. Please answer these questions even if you do not consider yourself to be a physically active person.
Think first about the time you spend doing work. Think of work as the things that you have to do such as paid or unpaid work, study/training, household chores, harvesting food/crops, fishing or hunting for food, seeking employment. *[Insert other examples if needed].* In answering the following questions 'vigorous-intensity activities' are activities that require hard physical effort and cause large increases in breathing or heart rate, 'moderate-intensity activities' are activities that require moderate physical effort and cause small increases in breathing or heart rate.

	Question	Response	Code
Work			
52	Does your work involve vigorous-intensity activity that causes large increases in breathing or heart rate like *[carrying or lifting heavy loads, digging or construction work]* for at least 10 minutes continuously? *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If No, go to P 4*	P1
53	In a typical week, on how many days do you do vigorous-intensity activities as part of your work?	Number of days ⌊_⌋	P2
54	How much time do you spend doing vigorous-intensity activities at work on a typical day?	Hours : minutes ⌊_⌋⌊_⌋ : ⌊_⌋⌊_⌋ hrs mins	P3 (a-b)
55	Does your work involve moderate-intensity activity, that causes small increases in breathing or heart rate such as brisk walking *[or carrying light loads]* for at least 10 minutes continuously? *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If No, go to P 7*	P4
56	In a typical week, on how many days do you do moderate-intensity activities as part of your work?	Number of days ⌊_⌋	P5
57	How much time do you spend doing moderate-intensity activities at work on a typical day?	Hours : minutes ⌊_⌋⌊_⌋ : ⌊_⌋⌊_⌋ hrs mins	P6 (a-b)
Travel to and from places			
The next questions exclude the physical activities at work that you have already mentioned. Now I would like to ask you about the usual way you travel to and from places. For example to work, for shopping, to market, to place of worship. *[Insert other examples if needed]*			
58	Do you walk or use a bicycle *(pedal cycle)* for at least 10 minutes continuously to get to and from places?	Yes 1 No 2 *If No, go to P 10*	P7
59	In a typical week, on how many days do you walk or bicycle for at least 10 minutes continuously to get to and from places?	Number of days ⌊_⌋	P8
60	How much time do you spend walking or bicycling for travel on a typical day?	Hours : minutes ⌊_⌋⌊_⌋ : ⌊_⌋⌊_⌋ hrs mins	P9 (a-b)

Participant Identification Number ⌊_⌋⌊_⌋⌊_⌋ ⌊_⌋⌊_⌋⌊_⌋ ⌊_⌋⌊_⌋⌊_⌋

CORE: Physical Activity, Continued			
Question		**Response**	**Code**
Recreational activities			
The next questions exclude the work and transport activities that you have already mentioned. Now I would like to ask you about sports, fitness and recreational activities (leisure), *[Insert relevant terms]*.			
61	Do you do any vigorous-intensity sports, fitness or recreational *(leisure)* activities that cause large increases in breathing or heart rate like *[running or football]* for at least 10 minutes continuously? *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If No, go to P 13*	P10
62	In a typical week, on how many days do you do vigorous-intensity sports, fitness or recreational *(leisure)* activities?	Number of days ⌊_⌋	P11
63	How much time do you spend doing vigorous-intensity sports, fitness or recreational activities on a typical day?	Hours : minutes ⌊_⌋⌊_⌋ : ⌊_⌋⌊_⌋ (hrs : mins)	P12 (a-b)
64	Do you do any moderate-intensity sports, fitness or recreational *(leisure)* activities that cause a small increase in breathing or heart rate such as brisk walking, *[cycling, swimming, volleyball]* for at least 10 minutes continuously? *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If No, go to P16*	P13
65	In a typical week, on how many days do you do moderate-intensity sports, fitness or recreational *(leisure)* activities?	Number of days ⌊_⌋	P14
66	How much time do you spend doing moderate-intensity sports, fitness or recreational *(leisure)* activities on a typical day?	Hours : minutes ⌊_⌋⌊_⌋ : ⌊_⌋⌊_⌋ (hrs : mins)	P15 (a-b)

EXPANDED: Physical Activity			
Sedentary behaviour			
The following question is about sitting or reclining at work, at home, getting to and from places, or with friends including time spent sitting at a desk, sitting with friends, traveling in car, bus, train, reading, playing cards or watching television, but do not include time spent sleeping. *[INSERT EXAMPLES] (USE SHOWCARD)*			
67	How much time do you usually spend sitting or reclining on a typical day?	Hours : minutes ⌊_⌋⌊_⌋ : ⌊_⌋⌊_⌋ (hrs : mins)	P16 (a-b)

Participant Identification Number ⌊_⌋⌊_⌋⌊_⌋ ⌊_⌋⌊_⌋⌊_⌋ ⌊_⌋⌊_⌋⌊_⌋

CORE: History of Raised Blood Pressure			
Question		**Response**	**Code**
68	Have you ever had your blood pressure measured by a doctor or other health worker?	Yes 1 No 2 *If No, go to H6*	H1
69	Have you ever been told by a doctor or other health worker that you have raised blood pressure or hypertension?	Yes 1 No 2 *If No, go to H6*	H2a
70	Have you been told in the past 12 months?	Yes 1 No 2	H2b

EXPANDED: History of Raised Blood Pressure			
71	Are you currently receiving any of the following treatments/advice for high blood pressure prescribed by a doctor or other health worker?		
	Drugs (medication) that you have taken in the past two weeks	Yes 1 No 2	H3a
	Advice to reduce salt intake	Yes 1 No 2	H3b
	Advice or treatment to lose weight	Yes 1 No 2	H3c
	Advice or treatment to stop smoking	Yes 1 No 2	H3d
	Advice to start or do more exercise	Yes 1 No 2	H3e
72	Have you ever seen a traditional healer for raised blood pressure or hypertension?	Yes 1 No 2	H4
73	Are you currently taking any herbal or traditional remedy for your raised blood pressure?	Yes 1 No 2	H5

Participant Identification Number ⌊_⌋⌊_⌋⌊_⌋ ⌊_⌋⌊_⌋⌊_⌋ ⌊_⌋⌊_⌋⌊_⌋

CORE: History of Diabetes			
Question		**Response**	**Code**
74	Have you ever had your blood sugar measured by a doctor or other health worker?	Yes 1 No 2 *If No, go to M1*	H6
75	Have you ever been told by a doctor or other health worker that you have raised blood sugar or diabetes?	Yes 1 No 2 *If No, go to M1*	H7a
76	Have you been told in the past 12 months?	Yes 1 No 2	H7b

EXPANDED: History of Diabetes			
77	Are you currently receiving any of the following treatments/advice for diabetes prescribed by a doctor or other health worker?		
	Insulin	Yes 1 No 2	H8a
	Drugs (medication) that you have taken in the past two weeks	Yes 1 No 2	H8b
	Special prescribed diet	Yes 1 No 2	H8c
	Advice or treatment to lose weight	Yes 1 No 2	H8d
	Advice or treatment to stop smoking	Yes 1 No 2	H8e
	Advice to start or do more exercise	Yes 1 No 2	H8f
78	Have you ever seen a traditional healer for diabetes or raised blood sugar?	Yes 1 No 2	H9
79	Are you currently taking any herbal or traditional remedy for your diabetes?	Yes 1 No 2	H10

Participant Identification Number |_|_|_| |_|_|_| |_|_|_|

Step 2 Physical Measurements

CORE: Height and Weight			
Question		**Response**	**Code**
80	Interviewer ID	|_|_|_|	M1
81	Device IDs for height and weight	Height |_|_| Weight |_|_|	M2a M2b
82	Height	in Centimetres (cm) |_|_|_|.|_|	M3
83	Weight *If too large for scale 666.6*	in Kilograms (kg) |_|_|_|.|_|	M4
84	**For women:** Are you pregnant?	Yes 1 *If Yes, go to M 8* No 2	M5
CORE: Waist			
85	Device ID for waist	|_|_|	M6
86	Waist circumference	in Centimetres (cm) |_|_|_|.|_|	M7
CORE: Blood Pressure			
87	Interviewer ID	|_|_|_|	M8
88	Device ID for blood pressure	|_|_|	M9
89	Cuff size used	Small 1 Medium 2 Large 3	M10
90	Reading 1	Systolic (mmHg) |_|_|_|	M11a
		Diastolic (mmHg) |_|_|_|	M11b
91	Reading 2	Systolic (mmHg) |_|_|_|	M12a
		Diastolic (mmHg) |_|_|_|	M12b
92	Reading 3	Systolic (mmHg) |_|_|_|	M13a
		Diastolic (mmHg) |_|_|_|	M13b
93	During the past two weeks, have you been treated for raised blood pressure with drugs (medication) prescribed by a doctor or other health worker?	Yes 1 No 2	M14

EXPANDED: Hip Circumference and Heart Rate			
94	Hip circumference	in Centimeters (cm) |_|_|_|.|_|	M15
95	Heart Rate		
	Reading 1	Beats per minute |_|_|_|	M16a
	Reading 2	Beats per minute |_|_|_|	M16b
	Reading 3	Beats per minute |_|_|_|	M16c

Participant Identification Number |_|_|_| |_|_|_| |_|_|_|

Step 3 Biochemical Measurements

CORE: Blood Glucose			
Question		**Response**	**Code**
96	During the past 12 hours have you had anything to eat or drink, other than water?	Yes 1 No 2	B1
97	Technician ID	|_|_|_|	B2
98	Device ID	|_|_|	B3
99	Time of day blood specimen taken (24 hour clock)	Hours : minutes |_|_| : |_|_| hrs mins	B4
100	Fasting blood glucose *Choose accordingly: mmol/l or mg/dl*	mmol/l |_|_|.|_|_| mg/dl |_|_|_|.|_|	B5
101	Today, have you taken insulin or other drugs (medication) that have been prescribed by a doctor or other health worker for raised blood glucose?	Yes 1 No 2	B6
CORE: Blood Lipids			
102	Device ID	|_|_|	B7
103	Total cholesterol *Choose accordingly: mmol/l or mg/dl*	mmol/l |_|_|.|_|_| mg/dl |_|_|_|.|_|	B8
104	During the past two weeks, have you been treated for raised cholesterol with drugs (medication) prescribed by a doctor or other health worker?	Yes 1 No 2	B9

EXPANDED: Triglycerides and HDL Cholesterol			
105	Triglycerides *Choose accordingly: mmol/l or mg/dl*	mmol/l |_|_|.|_|_| mg/dl |_|_|_|.|_|	B10
106	HDL Cholesterol *Choose accordingly: mmol/l or mg/dl*	mmol/l |_|.|_|_| mg/dl |_|_|_|.|_|	B11

World Health Organization

Appendix N: Sedentary Behaviour Questionnaire

SEDENTARY BEHAVIOR: Weekday									
On a typical WEEKDAY, how much time do you spend (from when you wake up until you go to bed) doing the following?									
	None	15 min. or less	30 min.	1 hr	2 hrs	3 hrs	4 hrs	5 hrs	6 hrs or more
1. Watching television (including videos on VCR/DVD).	○	○	○	○	○	○	○	○	○
2. Playing computer or video games.	○	○	○	○	○	○	○	○	○
3. Sitting listening to music on the radio, tapes, or CDs.	○	○	○	○	○	○	○	○	○
4. Sitting and talking on the phone.	○	○	○	○	○	○	○	○	○
5. Doing paperwork or computer work (office work, emails, paying bills, etc.)	○	○	○	○	○	○	○	○	○
6. Sitting reading a book or magazine.	○	○	○	○	○	○	○	○	○
7. Playing a musical instrument.	○	○	○	○	○	○	○	○	○
8. Doing artwork or crafts.	○	○	○	○	○	○	○	○	○
9. Sitting and driving in a car, bus, or train.	○	○	○	○	○	○	○	○	○

SEDENTARY BEHAVIOR: Weekend Day									
On a typical WEEKEND DAY, how much time do you spend (from when you wake up until you go to bed) doing the following?									
	None	15 min. or less	30 min	1 hr	2 hrs	3 hrs	4 hrs	5 hrs	6 hrs or more
1. Watching television (including videos on VCR/DVD).	○	○	○	○	○	○	○	○	○
2. Playing computer or video games.	○	○	○	○	○	○	○	○	○
3. Sitting listening to music on the radio, tapes, or CDs.	○	○	○	○	○	○	○	○	○
4. Sitting and talking on the phone.	○	○	○	○	○	○	○	○	○
5. Doing paperwork or computer work (office work, emails, paying bills, etc.)	○	○	○	○	○	○	○	○	○
6. Sitting reading a book or magazine.	○	○	○	○	○	○	○	○	○
7. Playing a musical instrument.	○	○	○	○	○	○	○	○	○
8. Doing artwork or crafts.	○	○	○	○	○	○	○	○	○
9. Sitting and driving in a car, bus, or train.	○	○	○	○	○	○	○	○	○

Appendix O: Asset Index

Which of the following do you have in your household at the present time?

	YES	NO
1. Electricity		
2. Television		
3. Radio		
4. Motor vehicle		
5. Fridge		
6. Stove		
7. Oven		
8. Washing machine		
9. Telephone		
10. Video machine		
11. Microwave		
12. Computer/Laptop		
13. Cellular telephone		
14. DSTV		

Appendix P: DXA Participant Information Letter

WINELANDS RADIOLOGY
DIAGNOSTIC RADIOLOGISTS

Registration No.: 1994/005900/21
Vat No.: 4690 145 935
PR No.: 3805336

Dear Participants

Below you will find information about what you can expect when undergoing the Dual-energy X-ray Absorptiometry scan (or DXA scan as it is more commonly known).

The purpose of the study is to acquire precision measurements of your body composition e.g. the amount of fat-free mass and fat mass.

Bone densitometry uses a very small dose of ionizing radiation to produce pictures of the inside of your body. The amount of radiation used during a DXA scan varies depending on the area of the body being examined. Due to DXA using low dose radiation than standard X-ray examinations the radiographer (Ms Carene Valentine (HPCSA Practice No: DR0104922) can stay in the scanning room with you during the scan.

DXA and Pregnancy:
During pregnancy many imaging tests (e.g. DXA) are not performed for safety reasons i.e. not to expose the fetus to any amount of radiation, even if it is a low dose as in the case of DXA. Therefore, as a participant you will be required to undergo a urine pregnancy test on the day of the DXA scan to rule out any possibility of being pregnant. Please be aware that it is your responsibility to inform the student researchers (Ms Kasha Dickie and Ms Sharné Nieuwoudt) and radiographer (Ms Carene Valentine) if there is the possibility that you are pregnant.

On the day of examination:
This exam requires little to no special preparation.
You may be asked to remove some or all of your clothes and to wear a gown during the exam. A private change room facility will be made used of.
Your weight and height will be taken as this is information that is required to the results.
You will be in structured by the Radiographer to lie on the padded table while the X-ray detector passes slowly over the body's area, generating images on a computer monitor controlled and visible to the Radiographer.
To assess your spine, your legs will be supported on a padded box (i.e. foam cube) to flatten your pelvis and lumbar spine.

Drs. Van Wageningen & Partners Incorporated trading as Winelands Radiology www.winelandsradiology.co.za
Directors: Dr. G. van Wageningen, Dr. P.D. Berndt, Dr. C. Gebers, Dr. R.V.P. de Villiers, Dr. N.R. Kruger, Dr. E.F. Malan, Dr. S. Kruger, Dr. C. Hobson, Dr. S. Scheepers.
Assisted by: Dr. B. Stockland, Dr. J Bröcker

Mediclinic Vergelegen
Main Road,
Somerset West, 7130
Tel: 021 851 5545
Fax: 021 852 2697

Mediclinic Stellenbosch
C/O Saffraan & Rokewood Avenue,
Die Boord, Stellenbosch, 7600
Tel: 021 887 4640
Fax: 021 886 6379

Arun Place
Building 3D, Harley Street,
Somerset West, 7130
Tel: 021 851 7370
Fax: 021 851 0516

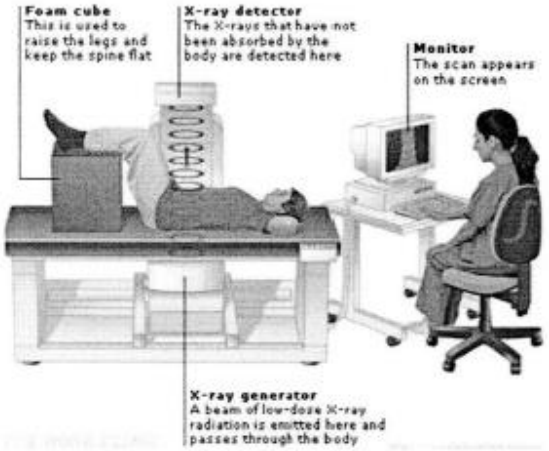
Sports Science Radiology
Boundary Road,
Newlands, 7700
Tel: 021 685 5144
Fax: 021 686 3482

Stelkor
34 Piet Retief Street,
Stellenbosch, 7600
Tel: 021 887 0305

Coetzenburg
Coetzenburg on Campus,
Coetzenburg Road,
Stellenbosch, 7600
Tel: 021 882 9801
Fax: 021 882 8491

WINELANDS
RADIOLOGY
DIAGNOSTIC RADIOLOGISTS

Registration No.: 1994/005900/21
Vat No.: 4690 145 935
PR No.: 3805336



To assess your hip, your foot is placed in a brace that rotates the hip inward. With the Body Composition scan, your whole body will be scanned while the feet are held together by a rubber band, this process will take more or less 7-minutes depending on your height.

The most important consideration to be aware of is to remain extremely still under the direction of the Radiographer.

Once all the images have been taken and saved under your personal subject study code (e.g. 01-80), you will be free to get changed. The results will be handed over in the form of a printed hard copy to the student researchers after each participant examination. These will be placed in an arch lever file according to date and then locked in a safe in the data storage room of the Department of Sport Science, Stellenbosch University.

Carene Valentine
Coetzenburg Imaging Center

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Mediclinic Vergelegen
Main Road,
Somerset West, 7130
Tel: 021 851 5545
Fax: 021 852 2897

Mediclinic Stellenbosch
C/O Saffraan & Rokewood Avenue,
Die Boord, Stellenbosch, 7600
Tel: 021 887 4640
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34 Piet Retief Street,
Stellenbosch, 7600
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Coetzenburg
Coetzenburg on Campus,
Coetzenburg Road,
Stellenbosch, 7600
Tel: 021 882 9801
Fax: 021 882 8491

Appendix Q: ActiGraph Participant Instructions

Instruction sheet for hip-worn monitoring device:

Please wear this hip monitor for 7 days from when you leave Test Day 1. During this time, please carry on with all your normal activities.

Description:

The hip monitor is a movement sensor and should be removed when you go to bed and put back on when you get up. The hip monitor is not waterproof; please remove it when showering, bathing and swimming. Whenever you need to remove the sensor, please reattach it as soon as you can.

Placement:

Place the belt around your waist. Please, make sure that it is placed approximately on the centre of your right hip (see picture below).

Please, take care that the monitor sits snugly around your hip and that it is not too loose.

Return:

When you have completed your 7-day period of wearing the device, please be sure to bring it back with you for test day 2 and hand it back to Ms Kasha Dickie (Student investigator and registered Biokineticist).

Thank you! **Written personal record (hs:min:sec) of time taken off and put back on**

Appendix R: ActiGraph Participant Record Sheet

Participant Code: _____

Date and Time: _____

	TIME PUT ON	TIME TAKEN OFF
DAY 1		
DAY 2		
DAY 3		
DAY 4		
DAY 5		
DAY 6		
DAY 7		
DAY 8		