Foot morphology of urban and rural South African children and adolescents

by

Marise Carina Breet

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Supervisor: Prof. Ranel Venter

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ABSTRACT

Ill-fitting shoes could negatively impact the development of the pediatric foot, in a very direct manner. This could eventually lead to foot problems and pathologies, both during childhood and adulthood. A substantial number of children and adolescents in South Africa were reported to be habitually barefoot. Additionally, vast differences have been documented between the foot morphology of South African children and adolescents and their German counterparts. Regardless of these findings, shoe companies are still developing shoes on a universal constant. The information acquired of differences in foot morphology in this study could be used to develop well-fitting shoes and contribute to the unimpeded development of children's feet.

The first aim of the study was to investigate the foot morphology of South African children and adolescents in both rural and urban areas of the Western Cape. The second aim was to compare the possible differences between the acquired foot measurements of children and adolescents and that of new school shoe sizes, currently available in the South African retail market.

A cross-sectional, observational, descriptive study design was used to determine the static standing and sitting foot measurements of children and adolescents from both urban and rural schools. The feet of children and adolescents between the ages of six and sixteen years were measured on a once-off basis. Newly manufactured school shoes were then measured and compared to the foot measurements of the children. The testing equipment used included a specially constructed foot caliper and a sliding caliper. A mixed model ANOVA was used to compare foot dimensions between gender, age and right- or left-side of the participants.

A total of seven-hundred-and-thirty-one school children (N=731) participated in the study. Children and adolescents from urban (N=393) and rural areas (N=338) were measured. The results indicated that the rural children and adolescents had a statistically higher sitting static arch height index ($p=0.001$), than the urban children. There were no statistically significant differences in the standing foot length (FL), standing foot width (FW) and standing static arch height index (sAHI) between the feet of children and adolescents from rural and urban areas.

The most pronounced difference observed in this study resulted from comparing the foot measurements of the participants in the study to the shoe dimensions currently available in the South African retail market. Fifty-nine percent (59%) of the children wore shoes that were not the correct length. Regarding shoe width, ninety-eight percent (98%) of the participants wore shoes too narrow for their feet. The results of this study emphasized the fact that in many cases, school shoes currently available in the retail market are not adequately suited for the habitually barefoot population studied.

Geographical location did not play a role in the foot development and foot morphology of the children and adolescents who participated in the current study. It appears as if factors such as footwear habits and ethnicity could be investigated. It is recommended that the shoe manufacturing industry consider the shoe width of school shoes for South African children and adolescents, to avoid the long-term adverse effects of ill-fitting shoes on the pediatric foot, specifically in the case of habitually barefoot populations.

Keywords: foot morphology, children, shoe fit, barefoot, school shoes

OPSOMMING

Swakpassende skoene kan die ontwikkeling van 'n groeiende voet negatief, en ook direk, beïnvloed. Dit kan uiteindelik lei tot 'n verandering in die voet se morfologie en biomeganiese gedrag, en kan voetprobleme en -patologieë gedurende die kinderjare veroorsaak, sowel as in volwassenheid. Dit is aangetoon dat ’n wesenlike aantal Suid-Afrikaanse kinders gewoonlik kaalvoet loop. Groot verskille in voetmorfologie is ook aangeteken tussen Suid-Afrikaanse kinders en adolessente en hulle Duitse eweknieë. Ten spyte van hierdie bevindings word universele mates steeds deur skoenmaatskappye gebruik. Hierdie studie kan bydra tot kennis oor verskille in voetmorfologie, en dié inligting gebruik word om skoene te ontwerp wat goed pas en sodoende 'n bydrae lewer tot die ongehinderde ontwikkeling van kindervoete.

Die eerste doelstelling van die studie was om die voetmorfologie van Suid-Afrikaanse kinders en adolessente in plattelandse gebiede in die Wes-Kaap met dié van hul eweknieë uit die stad te vergelyk. Die tweede doelstelling was om moontlike verskille tussen die voetmates van kinders en adolessente wat verkry is, te vergelyk met die nuwe skoengroottes wat tans in winkels in Suid-Afrika beskikbaar is.

’n Dwarssnit-, waarnemende en beskrywende navorsingsontwerp is gebruik om die statiese staande en sittende voetmates van kinders en adolessente uit plattelandse en stadskole te bepaal. Die voete van kinders en adolessente tussen die ouderdomme van ses en sestien jaar is eenmalig gemeet. Daarna is nuutvervaardigde skoolskoene gemeet en met die voetmates van die kinders vergelyk. Die toetsapparaat het ’n spesiaal ontwerpte voetkaliper en glypasser ingesluit. ’n Gemengde model ANOVA is gebruik om die voetdimensies tussen geslagte, ouderdom en regter- of linkerkant van die deelnemers te vergelyk.

’n Totaal van sewehonderd-een-en-dertig skoolkinders (N=731) het aan die studie deelgeneem. Dié kinders en adolessente was afkomstig uit skole in die stad (N=393) en plattelandse gebiede (N=338). Die kinders en adolessente uit die platteland het ’n betekenisvolle, hoër gemiddelde sittende, statiese voetbrughoogte gehad (p=0.001), in vergelyking met die kinders en adolossente uit die stad. Daar was geen betekenisvolle verskille t.o.v. staande voetlengte, staande voetbreedte en staande statiese voetbrughoogte tussen die twee groepe nie.

Die belangrikste resultaat van die studie was die verskil tussen die voetgrootte van die deelnemers en die grootte van die skoolskoene wat tans in winkels in Suid-Afrika beskikbaar is. Nege-en-vyftig persent (59%) van die kinders dra skoene in lengte, wat nie goed pas nie. Agt-en-negentig persent (98%) van die deelnemers dra skoene wat te nou is vir hulle voete. Die resultate van die huidige studie beklemtoon dat in baie gevalle skoolskoene wat tans in die winkels in Suid-Afrika beskikbaar is, nie geskik is vir 'n populasie wat gewoonlik kaalvoet loop nie.

Geografiese ligging het nie 'n rol gespeel in die voetontwikkeling en -morfologie van die kinders en adolessente in die huidige studie nie. Dit wil voorkom asof faktore soos skoendra-gewoontes en etniese verskille ondersoek sou kon word. Dit word aanbeveel dat die skoenvervaardigingsindustrie aandag gee aan die breedte van die skoolskoene wat tans deur kinders en adolessente in Suid-Afrika gedra word, ten einde die langtermyn negatiewe invloed daarvan op die ontwikkeling van die voet, en spesifiek van die kaalvoetkind, te vermy.

Sleutelwoorde: voetmorfologie, kinders, swakpassende skoene, kaalvoet, skoolskoene

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

%	:	Percentage
±	:	Standard deviation
AHI	:	Arch height index
BMI	:	Body mass index
CCD	:	Charge-couple-device
cm	:	centimetre
d	:	Cohen's D
DH	:	Dorsum height
dAHI	:	Dynamic arch height index
FAS	:	Footwear Assessment Score
FL	:	Foot length
FW	:	Foot width
HTL	:	Heel-toe-length
ICC	:	Interclass correlation coefficient
IOTF	:	International Obesity Task Force
kg	:	kilogram
kg/m^2	:	kilogram/square meter
m	:	medium
mm	:	millimetre
MTH1	:	first metatarsal head
MTH5	:	fifth metatarsal head
N	:	Number
n	:	number

s	:	narrow
sAHI	:	Static arch height index
SD	:	Standard deviation
SL	:	Shoe length
SW	:	Shoe width
w	:	wide
WB	:	Weight-bearing

OVERVIEW

This thesis is presented in research article-format. Consequently, the referencing style used in Chapter Four will differ to that of the remaining chapters. The chapters and content from this research study are structured as follows:

Chapter One: Introduction

This chapter contains the introduction, problem statement, aims and objectives, research questions and hypotheses of the current study. It should be noted that the reference style of the American Psychological Association (APA), 7th Edition, is used in all the chapters, except Chapter Four.

Chapter Two: Theoretical context

This chapter contains a summary of the existing literature on the foot morphology of children and adolescents. This review focuses on basic foot anatomy, internal and external influences on foot development and morphology, shoe design and manufacturing, as well as foot and shoe measurement techniques.

Chapter Three: Methodology.

This chapter gives an overview of the specific research methods that were used in this study. It also provides information on the study design and research processes which include ethical considerations, participants, and data collection procedures. The chapter concludes with information on the statistical analysis of the data and the reliability assessment.

Chapter Four: Research article

Title of the research article is: *Habitually barefoot children are wearing ill-fitting school shoes*. The focus of the article was to investigate whether the dimensions of available prescribed school shoes that are currently available in the South African retail market fit the foot dimensions of habitually barefoot South African children and adolescents The guidelines of the Journal, ***Frontiers in***

Pediatrics (Children and Health) (Addendum F) and the Vancouver method of referencing are used in the research article.

Chapter Five: Discussion and conclusion

This chapter consists of the results of the study and a relevant discussion of these. This is followed by a discussion of the limitations and practical applications of the study. The chapter concludes with recommendations for future research in the field of shoe-wearing habits and ethnicity, and its effect on foot morphology and foot development.

CHAPTER ONE

INTRODUCTION

1.1 Overview of literature

It has often been noted that children's feet are different from those of adults. For example, a comparison between the external shape of children's feet and those of adults clearly shows that the pediatric foot needs to go through several developmental stages before reaching maturity (Barisch-Fritz et al., 2014; Mauch et al., 2008). During this period, the pediatric foot is vulnerable to external forces (Staheli, 1991).

Several internal and external factors could have an impact on the development of children's feet. Internal factors, for example, include age, gender, race, body weight and biological maturation of the child. External factors are climate, footwear habits, ethnic background, and the activity level of the child, amongst others. These internal and external factors could either contribute to the normal development of the foot or, on the other hand, impede the developmental processes and lead to pathologic deformities (Staheli, 1991).

The significant role environmental factors could play in the development of feet needs to be highlighted. Mauch et al. (2008), and Thompson and Zipfel (2005) agree that climate, home environment, lifestyle and emerging socio-economic factors could all influence whether children walk barefoot or shod. This finding is supported by other researchers who found significant differences in the different stages of foot development, concerning foot shape, motor skill development, movement patterns, pliability and pressure distribution when habitually barefoot populations were compared to shod populations (D'Août et al., 2009; Hollander et al., 2018; Wegener et al., 2011; Wolf et al., 2008; Zech et al., 2018).

In addition, footwear that fails to respect the natural shape and function of the foot will ultimately alter the foot's morphology and biomechanical behaviour. This could have a negative effect on the foot's development (D'Août et al., 2009; Staheli, 1991). Researchers, such as Gottschalk et al. (1980) and Thompson and Zipfel (2005), agree that most foot pathologies and abnormalities in adulthood may have been established in childhood. Footwear should, therefore, conform to the natural shape and dimensions of the foot, both in static and dynamic conditions, especially while the foot is still maturing (Cheng & Perng, 1999).

The results mentioned above leads to the conclusion that it is of utmost importance to identify the different variables in children's feet to develop appropriate footwear that properly facilitates these variables (Barisch-Fritz et al., 2014; Walther et al., 2008). Each change to a shoe size should be accompanied by the corresponding changes to all dimensions, throughout the shoe (Mauch et al., 2009). Unfortunately, shoe constructions are typically based on the mean values of an entire population. The fit of the shoe should instead be optimized by designing it to conform to the distinctive anatomical features of the foot in each stage of growth (Mauch et al., 2009). Presently, most shoe companies are changing the size of manufactured shoes only by increasing or decreasing the length of the shoe, even though most fit problems are reported in the width dimensions of the shoes (Witana et al., 2004).

In a study conducted in 2015 in the Western Cape (De Villiers, 2017), data was gathered on the foot metrics of South African children and adolescents. For this purpose, a barefoot questionnaire was used to determine how often South African children spend time either barefoot or shod. The results obtained from this study concluded that ninety-point-nine percent (90.9%) of the participants, between the ages of six and eighteen, indicated that they were habitually barefoot. Unfortunately, there is presently minimal information on the foot morphology of South African children and adolescents. There currently also exists little academic support for the development of shoes for this habitually barefoot population.

1.2 Problem statement and significance of the study

During the past ten years, researchers have mainly focused their attention on the foot's functions and development. For example, the advantages and disadvantages of barefoot locomotion, compared to shod walking or running, received attention in many studies (D'Août et al., 2009; Hollander et al., 2016a; Shu et al., 2015; Wolf et al., 2008). Inter-continental differences in foot structure and shape were also pointed out by Mauch et al. (2008). It has been emphasized that ill-fitting shoes could directly affect foot development and have detrimental consequences for the biomechanics of the body (Barisch-Fritz et al., 2014; Buldt & Menz, 2018; Mauch et al., 2008). Despite the renewed interest in the fields of foot development and shoe-fitting, limited research has been undertaken on the basics of the foot shape measurements of the habitually barefoot South African population, particularly the pediatric population.

South African children and adolescents have an inherent culture of walking barefoot, and a significant number of children are reported to be habitually barefoot (De Villiers, 2017). Differences in the foot morphology of South African children, compared to that of German children, were also revealed in a South African population study (Hollander et al., 2016b). According to this study, South African children have a higher medial longitudinal arch, longer foot length (FL), wider foot width (FW) and a difference in foot pliability. Thompson and Zipfel (2005) also found in their study that sixty-two percent (62%) of South African adult females had a forefoot length-to-girth greater than the standardized ratio.

Regardless of these findings, shoe companies are still developing shoes on a universal constant. Different shoe width (SW) options are not currently available in retail, which means that children with a narrow or wider foot have problems finding shoes that properly fit (Thompson & Zipfel, 2005; Walther et al., 2008). As a result of this, the South African pediatric population is at an increased risk of developing foot problems and pathologies and, consequently, the accurate fitting of shoes is becoming an issue of utmost importance. Shoe fit in school going children and adolescents has been measured in previous studies in Spain (González Elena & Córdoba-Fernández, 2019) and South Africa (De Villiers, 2017). However, these studies compared the feet measurements to the shoe dimensions of participants, after the shoes had been worn for some time. The applicable ages and conditions of the shoes were not documented in these studies.

The importance of the current study is, firstly, that it could increase the limited knowledge of foot morphology differences under South African children growing up in rural areas, compared to children growing up in urban areas. Secondly, the measurements of newly manufactured shoes, when comparing it with the size and shape of habitually barefoot children’s feet, could guide the manufacturing industry in South Africa in providing better-fitting school shoes for habitually barefoot children and adolescents. This improvement in the manufacturing chain could, in future, significantly contribute to normal foot development under children while also leading to fewer foot deformities and musculoskeletal injuries, caused by ill-fitting shoes.

1.3 Research questions, Aims, Objectives and Hypotheses

This study was guided by two research questions, aims, objectives and hypotheses. The first research question investigated the foot morphology of South African children and adolescents. The second research question compared the acquired measurements to school shoe sizes currently available in the South African retail market.

Research question one

Is the foot morphology of South African children and adolescents (aged six to sixteen) in rural areas different from those in urban areas?

Research aim one

The first aim of the study was to determine the differences in foot morphology (foot length, foot width, standing static arch height index, and sitting static arch height index) between children and adolescents (aged six to sixteen) from rural and urban areas, located in the Western Cape, South Africa.

Objectives

Objective 1: To measure the foot length, foot width, and standing static arch height index, as well as the sitting static arch height index of children and adolescents (aged six to sixteen) from four rural schools, located in four regional areas of the Western Cape, South Africa.

Objective 2: To measure the foot length, foot width, and standing static arch height index, as well as the sitting static arch height index, of children and adolescents (aged six to sixteen) from four urban schools, located in two regional areas of the Western Cape, South Africa.

Objective 3: To compare and interpret the acquired measurements of foot length, foot width, and standing static arch height index as well as sitting static arch height index between children and adolescents (aged six to sixteen) from urban and rural schools, located in the Western Cape, South Africa.

Hypothesis statement one

The first research hypothesis stated that the foot morphology of children and adolescents (aged six to sixteen) from rural areas differs from that of children and adolescents in urban areas of the Western Cape, with rural children presenting with longer and wider feet, as well as higher standing and sitting static arch height indexes than their urban counterparts.

The null hypothesis (H_0) for the initial research hypothesis stated that there would be no difference between the groups for any of the variables mentioned above (H_0: $\mu_1 = \mu_2$). The alternative hypothesis (H_1) states that the means are not all equal between the measurements of the children and adolescents from rural areas compared to children and adolescents from urban areas.

Research question two

Do the current school shoe sizes available in retail make provision for the foot morphology of habitually barefoot South African children?

Research aim two

The second aim of the study was to determine the differences between the obtained foot measurements of children and adolescents (aged six to sixteen) and school shoe sizes, currently available in the South African retail market.

Objectives

Objective 1: To compare the sizes of four brands of new school shoes currently available in the South African retail market for boys with the measured feet sizes of boys (aged six to sixteen).

Objective 2: To compare the sizes of four brands of new school shoes currently available in the South African retail market for girls with the measured feet sizes of girls (aged six to sixteen).

Hypothesis statement two

Research hypothesis two stated that the current brands of new school shoes, available in the South African retail market, adequately accommodate the foot sizes of school-going children and adolescents (aged six to sixteen).

The null hypothesis (H_0) for the preceding research hypothesis was that the brands of new school shoes, currently available in the South African retail market, do not adequately accommodate the foot sizes of school-going children and adolescents (aged six to sixteen). The alternative hypothesis (H_1) states that the means are equal between the measurements of the feet of the children and adolescents and the shoe sizes available.

1.4 Variables

Dependent variables: foot length (FL), foot width (FW), standing and sitting static arch height indexes (sAHI).

Independent variables: urban, rural, school shoes.

Categorical variables: age, gender.

1.5 Assumptions

It was assumed that the caliper used to measure the foot morphology of the children was valid and reliable. It was assumed that children wore their own shoes to school on the day of testing, for purposes of the researcher verifying the participant’s shoe size.

1.6 Delimitations

For the purposes of this study, data was collected from children and adolescents attending selected participating rural and urban schools located in one South African province (Western Cape). School shoe sizes could only be determined by children who wore school shoes on the day of testing. New school shoes from four popular school shoe brands were measured, with the specific exclusion of health-, orthopedic-, or specially designed shoes.

CHAPTER TWO

THEORETICAL CONTEXT

2.1 Introduction

This chapter provides a brief review of relevant and recent literature, intending to place the research topic in a broader context. It should be noted that some references may appear to be dated. This is due to the limited amount of research in the field of pediatric foot development and shoe fit, which necessitates the inclusion of some dated sources. Also, due to the scarcity of available published research, references to a few leading authors in this field occur regularly. The review focuses on basic foot anatomy, internal and external influences on foot development and morphology, shoe design and manufacturing, as well as foot and shoe measurement techniques.

2.2 The development of the human foot

Understanding the basic anatomy and development of the foot is essential, as it provides insight into how foot-development could be influenced by external factors, such as shoes; it also aids in understanding the specific foot measurements related to the current study. The human foot is a complex system and considered to be one of the most critical joints when focusing on stability, mobility and balance of the body (Brukner & Khan, 2007; Shultz et al., 2000). Without the normal functioning of the foot and the ankle hinge joint, the whole kinetic chain of the body will be under lower-extremity mechanical stress, ultimately resulting in injury (Prentice, 2004; Shultz et al., 2000). The foot’s anatomy consists out of a total of twenty-six bones, thirty-three joints and over a hundred ligaments, tendons, and intrinsic and extrinsic muscles (D’Août et al., 2009). As seen in figure 2.1, these structures could be divided in three moving parts: the hindfoot, midfoot and forefoot (Brukner & Khan, 2007; Shultz et al., 2000). The seven tarsal bones (calcaneus, talus, navicular, cuboid and three cuneiforms bones), five metatarsal bones and fourteen phalanges interlock to form the foot arches (Brukner & Khan, 2007).

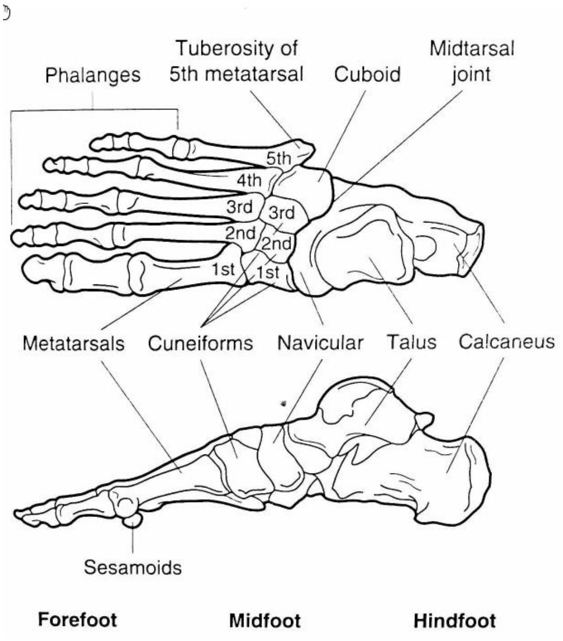

Figure 2-1: Basic anatomy of the foot osteology (Adapted from Shultz et al., 2000).

The ligaments and tendons of the foot maintain the medial and lateral longitudinal arches by tying the calcaneus to the distal portions of the metatarsal bones (Meiring et al., 1994). The medial plantar surface of the foot remains elevated while standing, sitting and walking to ensure free movement of the muscles, nerves and blood vessels and is maintained and supported by the muscles of the foot and the lower leg (Houglum, 2001; Meiring et al., 1994). The transverse arch can be found posteriorly to the metatarsal bones. This forms a rounding that transfers the weight of the body evenly to all parts of the foot (Meiring et al., 1994). Figure 2.2 and Figure 2.3 illustrate both the medial and lateral ligaments of the foot and ankle.

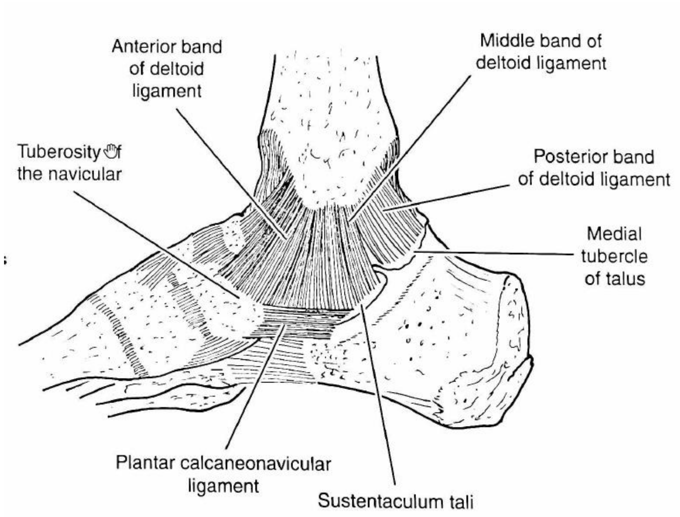

Figure 2-2: Medial ligaments of the foot and ankle (Adapted from Shultz et al., 2000).

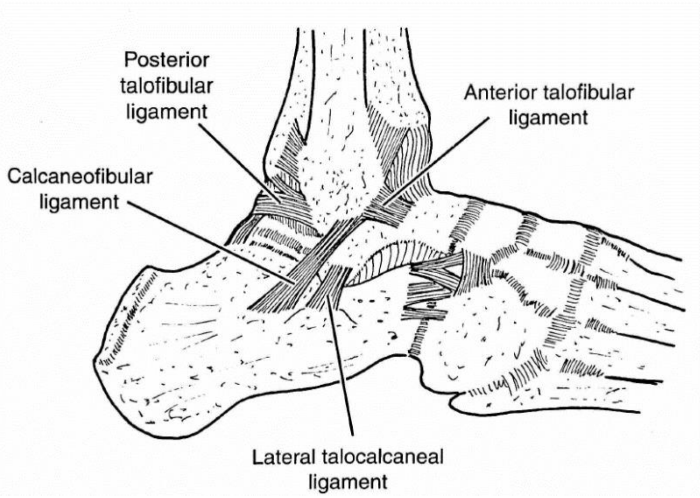

Figure 2-3: Lateral ligaments of the foot and ankle (Adapted from Shultz et al., 2000).

The elasticity of the longitudinal arch absorbs the shock during walking and weight loading. In the cases where the arches are unable to maintain their standard configuration, an imbalance will be created, leading to abnormal stresses, which could result in injuries to the foot and kinetic chain. (Houglum, 2001). The ankle and foot are responsible for producing a forceful movement, propelling the body forward, in both walking and running movements. Comparatively, the extrinsic muscles are responsible for ankle movements, with the contractions in the intrinsic foot muscles, to move the toes and for maintaining the longitudinal arch of the foot (Houglum, 2001; Martini, 2004).

A comparison between the external shape of children's feet and that of adults shows that the structural and functional characteristics of their feet are different, and maturation occurs over time, in the case of children. The child's foot goes through many structural changes before it reaches maturity (Barisch-Fritz et al., 2014; Mauch et al., 2008).

At birth, the infant's foot is mostly cartilaginous. Development of the foot starts with impacting forces like crawling, an upright posture and weight-bearing activities. During the first years of walking, numerous structural and functional changes occur in the foot (Bosch et al., 2010). For example, foot arches are generally present at birth, but might sometimes only develop fully at a later stage. A fat pad, called Spitzy's fat pad, which is situated underneath the midfoot, is present during the early stages of foot development (as cited in Bosch et al., 2009 and Walther et al., 2008). This might give the appearance of a pathological flatfoot. This fat pad assists in supporting and protecting the longitudinal arch during development but disappears around the age of six (Walther et al., 2008).

Pfeiffer et al. (2006) agreed that the occurrence of a “developmental” flatfoot decreased dramatically with an increase in age. The longitudinal arch develops at its own pace during the first six to eight years of life. Girls typically present with a higher arch height than boys, with both genders achieving values and characteristics compared to those of adults, by the age of six to seven years (Echarri & Forriol, 2003). The arch height index (AHI) is not believed to mature further after these years (Müller et al., 2012). Numerous studies have confirmed the drastic changes in foot size, motor skill development and mechanical stability of the foot tendons and ligaments during the first years of school (Müller et al., 2012; Walther et al., 2008).

During the first years of life, foot length (FL) usually increases at a fast-growing rate. Between the ages of four and twelve years, the FL in children can increase up to one-point-five centimetres (1.5cm) per year, after which it reaches a plateau (De Villiers, 2017; Müller et al., 2012). Generally, girls’ feet are believed to grow at a slower rate than those of boys (Walther et al., 2008). In a study conducted in Japan, Waseda et al. (2014) found that boys’ FL kept increasing up to the age of fifteen to sixteen years, whereas girls’ feet reached a plateau at approximately thirteen to fourteen years of age (Müller et al., 2012; Walther et al., 2008).

Conversely, foot width (FW) appeared to be wider in younger children than in adolescents. Müller et al. (2012) stated that this could be explained by the FL, increasing rapidly, and the FW/FL proportion changing accordingly. By the age of eight, children had similar FW/FL proportions to those of adults (Müller et al., 2012). Girls tend to have a slender midfoot, compared to the larger midfoot of boys (Walther et al., 2008).

While the anatomy of the foot has been studied for decades, the size, structure and shape characteristics of feet have been used as standardized comparisons.

2.3 Foot morphology

2.3.1 Defining foot morphology

The term "morphology" is derived from the Greek words "morphē" (form, shape or structure) and "logos" (study) (Stedman, 2001). The term "foot morphology" refers to the study of the size (both static and dynamic), structure and shape of the foot. The current study will focus on the variables of FL, FW and the static arch height index (sAHI) of the foot.

2.3.2 Foot length, foot width and arch height index

Foot length (FL) refers to the horizontal distance between the back of the heel to the front tip of the longest toe (Jurca et al., 2019; Müller et al., 2012; Waseda et al., 2014). This FL measurement is also referred to as heel-toe-length (HTL) or "maximum foot length," as used in González Elena and Córdoba-Fernández (2019). Some studies used the truncated FL, which refers to the horizontal distance between the heel and the first metatarsal head (MTH1). This is however, mostly used for statistical measurements as part of a formula (Hillstrom et al., 2013; Pohl & Farr, 2010). Maximum FL is used as the basic measurement in almost all shoe size systems and is universally regarded as the most important dimension to be accommodated by a shoe (Cheng & Perng, 1999). Foot length (FL) measured in a standing position will ensure the largest/longest measurement of the foot, as most foot extension are expected in this position (Barisch-Fritz et al., 2016). Foot length (FL) has also been a reliable prediction of standing height in a group of adolescents from Kosovo (Popovic et al., 2017). Foot length (FL) is, however, greatly influenced by gender, age and ethnicity (Jurca et al., 2019; Müller et al., 2012; Waseda et al., 2014).

Foot width (FW) refers to the maximum forefoot width and can be measured as the horizontal distance between the most medial point of the MTH1 and the most lateral point of the fifth metatarsal head (MTH5) (Barisch-Fritz et al., 2014; Müller et al., 2012). Literature has illustrated significant variances in FW measurements between children and adolescents and also between barefoot- and shod populations (Hollander et al., 2017; Mauch et al., 2008; Walther et al., 2008). Foot width (FW) can be measured in both sitting and standing positions. The splaying and elongation of the foot during weight-bearing is taken into account during measurements of standing FW (Barton et al., 2009). Foot width (FW) measurements are of great importance when considering shoe fit, since most studies have reported fit problems that are due to the width dimension of the shoe (Buldt & Menz, 2018; González

Elena & Córdoba-Fernández, 2019; Thompson & Zipfel, 2005; Walther et al., 2008; Witana et al., 2004).

Foot length (FL) and foot width (FW), however, are both horizontal measurements used to define foot morphology. Conversely, arch height index (AHI) refers to the vertical measurement of the foot dorsum height (DH), normalized to the FL (Hillstrom et al., 2013; Hollander et al., 2016b). A related weak relationship between arch stiffness and AHI was found with measurements in the standing position, which suggested that a higher AHI points towards a more rigid foot and a lower arch to a more flexible foot (Barnes et al., 2008). In contrast, Hollander et al. (2017) reported a higher sAHI in children and adolescents growing up barefoot, thus indicating a pliable foot, with lower incidences of flat feet (D'Aoȗt et al., 2009; Echarri & Forriol, 2003; Hollander et al., 2016b). The interpretation of AHI measurements is therefore contradictory and limited. Arch height index (AHI) measurements are mostly used to identify arch type extremes and to obtain information on how the foot makes contact with the ground during gait (Teyhen et al., 2009). The AHI could be measured in both static and dynamic positions with excellent reliability in both cases (Scholz et al., 2017).

2.3.3 Summary

There is at present limited information on the static and dynamic foot morphology of children and adolescents in South Africa. Guided by its aims, the focus of this study was on accumulating reliable data on the basic static morphology of the pediatric foot. This data could then be evaluated, compared to similar data and eventually distributed and applied by the shoe manufacturing industry to adjust and enhance their product offering, to the benefit of children and adolescents. Comparisons between the variables in FL, FW and sAHI were previously indicated as reliable, reproducible and popular, due to the simplicity of the procedures used. Based on the literature and the reasons mentioned above, measurements of FL, FW and sAHI could be compared accurately to the basic dimensions of South African shoes. As pointed out in literature, many variations in the measurements of each of these variables have been used. However, the current study needed to study the foot during maximum splaying and elongation; since these were the basic dimensions that should accommodated by the shoe.

The foot morphology variables indicated above can, however, not be considered in isolation, as they can be influenced by both internal and external factors. In more recent years these factors have sparked renewed interest among researchers and will be elaborated on further in the following section.

2.4 Factors influencing foot morphology

2.4.1 Internal influences on foot morphology

Vast differences in foot morphology between adults and children have been noted in research conducted internationally (Echarri & Forriol, 2003; Mauch et al., 2008). This could be due to factors having either a positive or negative effect on the development of the foot. Some of the internal influences affecting foot morphology include the age, gender, body mass index (BMI), and ethnicity of the child (Barisch-Fritz et al., 2014; De Villiers, 2017; Scholz et al., 2017).

Considerable differences exist in foot morphology of children at different ages and phases of development. Barisch-Fritz et al. (2014) described the feet of younger children as wider, more voluminous and higher, compared to those of adolescents. During the ages of ten to fourteen years, it was suggested that foot development might be influenced by hormonal changes, which might affect foot arch development (Hollander et al., 2017). Also, when younger boys were compared to older boys around fifteen years of age, De Villiers (2017) found significantly longer feet, with a higher dynamic arch height index (dAHI) in the older boys. Stavlas et al. (2005) reported significant changes in foot morphology during growth in five-thousand-eight-hundred-and-sixty-six (5866) children between the ages of six and seventeen years. The researchers concluded that, although it is believed that the most critical changes in foot morphology occur during the pre-school years, significant changes also occurred during the school ages until late adolescence. Age-related changes in foot morphology were also found in the one-thousand-one-hundred-and-five (1105) participants studied by Tomassoni et al. (2014). Although the participants in the mentioned study were between the ages of twenty and seventy-five years, it is still worth noting that age should be considered as an internal factor influencing foot morphology.

The gender of children also influenced the foot height, FW, foot girth normalized to FL, and the dAHI. Boys in particular had significantly wider and higher measurements than girls of the same age (Barisch-Fritz et al., 2014; Bosch et al., 2007; De Villiers, 2017; Echarri & Forriol, 2003). Stavlas et al. (2005, p.427) also found that the process of foot development differed between boys and girls and stated that the results from their study reflected a “different growth potential between the sexes.”

As mentioned previously, body weight affects the foot morphology of children and adults. Higher, wider and more voluminous feet were found in overweight participants (Barisch-Fritz et al., 2014;

Bosch et al., 2010), indicating that body weight in general and the BMI specifically, played a role in pediatric foot development. De Villiers (2017) confirmed this by finding significantly longer feet, with an increased midfoot width in overweight and obese children, compared to healthy or underweight children. Interestingly, a study done in South Africa on adult females reported that only one of the two study populations which was overweight, had an increase in FW and arch length. This could indicate the possibility of genetics contributions to the way the foot structure reacts under stress (Thompson & Zipfel, 2005).

Various researchers have indicated that ethnicity could contribute to differences in foot morphology due to different cultures and regional influences (Putti et al., 2010). In a study, it was suggested that ethnicity accounted for an increased risk for specific foot pathologies (Shu et al., 2015). Putti et al. (2010) also mentioned a more common occurrence of hallux valgus in Caucasians compared to other races, as well as differences in forefoot shape between Caucasian North Americans and Japanese / Koreans. With regard to ethnicity, white children and adolescents had significantly longer and wider feet than the brown children and adolescents of the same age. Also, the dAHI of white children and adolescents was significantly lower than that of brown children (De Villiers, 2017).

2.4.2 External influences on foot morphology

As in the case of the internal factors that influence foot morphology, there are many external factors that influence foot morphology, such as climate, footwear habits, and the fit of shoes. Significant differences in the foot morphology of children living on two different continents were found (Hollander et al., 2017; Mauch et al., 2008; Sacco et al., 2015). Mauch et al. (2008) explained further that in some countries with a distinctly warmer climate, open footwear or barefoot walking was part of the everyday lifestyle.

Noteworthy differences in foot morphology and foot function are reported between habitually barefoot and shod populations (D’Août et al., 2009). An increased sAHI, lower occurrences of flat feet, a longer FL, wider FW, and differences in foot pliability, were found in a study comparing habitually barefoot South African children and adolescents to their shod German counterparts (Hollander et al., 2017). Similar results were obtained in Congolese children and adults, who grew up habitually unshod in thong-type sandals and non-constrictive shoes (Echarri & Forriol, 2003). Echarri and Forriol (2003) attributed the difference in foot morphology to the influence of barefoot walking on the fascia, ligaments and muscles, by forcing these passive and active elements to work actively. Research indicated that consequently habitually barefooted subjects had stronger feet, with fewer deformities, when compared to those wearing shoes habitually. For example, native barefoot tribes presented with excellent mobility, especially in the forefoot, thickening on the plantar skin, flexibility in the midtarsal joints, alignment of the phalanges, variability in arch height, and the absence of static deformities (Staheli, 1991). Being habitually barefoot or shod influences not only the shape of the developing foot, but also motor skill development when performing balancing, jumping, and sprinting activities (Zech et al., 2018). Several studies agree that shoes have a substantial effect on the gait of children, especially on the motion patterns of the forefoot and foot strike patterns (Hollander et al., 2018; Wegener et al., 2011; Wolf et al., 2008). Shod females from the Welsh population presented with stiffer forefeet when compared to the pliability ratio in barefoot populations (Kadambande et al., 2006).

It must be emphasized that optimum foot development occurs when the natural shape and function of the foot is respected (D'Août et al., 2009; Staheli, 1991). Restrictive, ill-fitting shoes could contribute to many foot pathologies and cause many musculoskeletal conditions. It is, therefore, essential to consider the role of shoes on foot development and foot morphology, while focusing on a design specifically tailored for the pediatric population.

2.4.3 Summary

Vast differences in foot morphology of children and adults were observed, specifically due to age, gender, BMI and ethnicity. Although many previous studies examined the possible influences these internal factors could have on foot morphology, it needs to be emphasized that most of these factors are genetically predetermined. Accordingly, knowledge of and information on basic foot morphology were gathered during this study, whilst keeping the possible influence of age, gender, and BMI in mind.

Differences in the way children's feet respond to external forces have previously been linked to differences in ethnicity, but in view of the sensitivity and practicality of the topic, the influence of geographical positioning on foot morphology was assessed instead. Acquired measurements could subsequently be used to determine whether the shoe industry was designing school shoes to properly fit the feet of South Africa's habitually barefoot pediatric population.

2.5 Shoe fit, foot development and -morphology

Accurately fitting shoes are of utmost importance, and ill-fitting shoes could impede the normal development of the foot and cause foot problems and pathologies, both during childhood and adulthood (Cheng & Perng, 1999; Staheli, 1991; Thompson & Zipfel, 2005). Pathological deformities, such as hallux valgus, hammertoes or pes planus/flat feet, have been associated with the wearing of ill-fitting shoes. This is linked explicitly to shoes being too short or too narrow for the foot (Cheng & Perng, 1999; Shultz et al., 2000; Staheli, 1991). Eighty percent (80%) of South African adult females, who formed part of the study conducted by Thompson and Zipfel (2005), recalled wearing shoes during childhood, which caused pain, blisters, corns and callus. Foot pathologies, however, were not only limited to adult's feet but a significant relationship between wearing shoes in early childhood and the presence of flat feet (pes planus) in these children has been found (Mauch et al., 2008). A study done by Gottschalk et al. (1980) indicated that footwear *per se* is not an essential factor in the older individual, and underlying abnormality may be established at a much younger age or even during childhood.

Most researchers agree that well-fitting footwear mimics the shape and dimensions of feet, as well as protects feet against the environment (Mauch et al., 2009; Staheli, 1991; Walther et al., 2008; Witana et al., 2004). In addition, shoes for children and adolescents should ideally be comfortable, with soft and flexible materials, designed for maximum function and movement (Staheli, 1991; Walther et al., 2008). If, for instance, the sole of the shoe is too thick in the early years of development, it will have a negative growth impulse on the development of the upright foot position (Walther et al., 2008). On the other hand, if the shoe is too heavy, it could affect the gait and running patterns of the child (Staheli, 1991; Wegener et al., 2011). Data on the shock absorption, load distribution and elevation of a child's foot should be used as indicators for shoe modifications (Staheli, 1991).

2.6 Shoe design

Footwear manufacturers are currently not adjusting the dimensions of their shoe designs to accommodate intercontinental differences in foot morphology (Mauch et al., 2009). Furthermore, the child's shoe is mostly developed as a simple downsizing of an adult's shoe, even though detailed knowledge exists on the differences between anthropometrical data on children's feet when compared to those of adults. For example, the maximal forces and leverages of pediatric feet are different from those of adults, and the foot structures will only reach maturity at the age of about fifteen (Walther et al., 2008). Therefore, a shoe that provides cushioning and stability to adults might feel very hard for children. It is imperative to identify the influences of different variables on children's feet, in order to develop footwear that would account for these variables (Barisch-Fritz et al., 2014; Walther et al., 2008). Unfortunately, the market for children's shoes is not driven by sound orthopedic and biomechanical considerations but by consumer behaviour, fashion trends and sports idols. Shoe development and design have been based on trial-and-error by the last designers (Barisch-Fritz et al., 2014). Shoe manufacturers in South Africa are designing shoes according to the British shoe design system. Shoes are developed using length as a base-measurement and determining the standardized length-to-thread ratio, based on the Mondo Point System. Every length increase, therefore, corresponds with a standardized increase in foot girth (Cheng & Perng, 1999; Thompson & Zipfel, 2005).

Customizable and adjustable shoes should be considered, for example, for the adjustment of the broadening of the ball width where most variability of deformation occurs. This can be achieved by implementing more resilient, porous materials into the shoe and improving the lacings of the shoe (Barisch-Fritz et al., 2014; Staheli, 1991). Each increase in shoe size should be accompanied by a change in all the dimensions of the shoe. It is evident that feet of the same length could have vast individual differences and could vary in the position of the ball-of-foot, heel width and the instep height. All these measurements are essential features for a well-fitting shoe (Mauch et al., 2009).

Presently, most shoe companies are changing shoe size by increasing or decreasing only the length of the shoe, even though most fit problems are reported to be in the width dimension of the shoe. Specifying the correct fit for the width dimension will, therefore, ease the majority of footwear fit problems (Witana et al., 2004). The WMS is a quality seal mark from the German Shoe Institute-system and provides foot measuring devices which offer a combined shoe size, taking the FL and FW into account. This system respects the significant differences in foot shapes, and every product is sold in a different width dimension of narrow (s), medium (m) and wide (w) (Walther et al., 2008). Unfortunately, only a small number of manufacturers use the WMS-System, due to heightened logistics and the lack of investments into an industry that is not profitable. Most manufacturers produce a standard width, which means that children with wider/narrower feet will have problems finding shoes that fit (Thompson & Zipfel, 2005; Walther et al., 2008).

Variability in foot measurements was highlighted by a study conducted in Germany by Mauch et al. (2009). In this study, different dimensions of feet were assessed and divided into groups, using cluster analyses. The clustering procedure was primarily used to improve the static fit of the shoes. In contrast, detailed methods were used to assess deformation in defining areas of the feet (Barisch-Fritz et al., 2014).

Adding to the knowledge of foot morphology differences and using this information to develop well-fitting shoes to aid in the unimpaired development of children's feet, can be of significant value. In the long term, this could decrease medical costs for treating foot problems and other related musculoskeletal in childhood and adulthood, with the added benefit of increasing the quality of life and well-being of individuals.

2.7 Foot measurements

For several reasons, the measuring of feet of adults and children must be conducted in a research environment. Being mindful of the aims of the current study, the focus will remain on children's feet, as well as the reasons for measuring their feet, the equipment used, and the variables of interest.

Table 2.1 provides a summary of the most recent studies and methods used to measure children's feet.

Table 2-1: Overview of most recent measurement techniques used on children's feet

Authors of the study	**Sample**	**Aims of the study**	**Instruments used**	**Variables measured**
Barisch-Fritz, Schmeltzpfenning, Plank, Hein and Grau (2014)	Children Age: 6-16 years Country: Germany N=2554	To identify the effects of gender, age and BMI on the dynamic foot shape and foot deformation of children.	DynaScan 4D	Dynamic and static measurements of: - Foot length - Foot height - Foot width - Foot girth - Foot angles
González Elena and Córdoba-Fernández (2019)	Children Age: 3-12 years Country: Spain N=505	To compare the feet dimensions of schoolchildren to the inner length, width and height of their footwear.	Acetate sheet placed on a methacrylate base with a calibrated template imprinted to measure foot length, foot width and first metatarsal head height	Static FL, FW and height at the first metatarsal head
Hollander, De Villiers, Sehner,	Children Age: 6-18 years	To investigate the effect of being barefoot or shod on	Static foot measurement with foot calipers	Static FL, FW, foot DH Foot pliability

Wegscheider, Braumann, Venter and Zech (2017)	Country: Germany and South Africa N=810	foot development and foot arch morphology in children and adolescents.	Dynamic measurements with Emed-n50 pressure platform	dAHI
Hollander, De Villiers, Venter, Sehner, Wegscheider, Braumann and Zech (2018)	Children Age: 6-18 years Country: Germany and South Africa N= 678	To investigate the effect of habitual footwear usage on the foot strike patterns of children and adolescents.	Photoelectric and magnetic timing gates, with a wide-angle high-speed camera and video-based assessment	Foot strike patterns
Kerr, Stebbins, Theologis and Zavatsky (2015)	Children Age: 5-18 years Country: The United Kindom N=97	To investigate differences in lower limb posture between children with neutral or flat feet.	Observational classifications based on the "Oxford Foot Model Markers". Performed by a clinician Self-reported symptoms	Classifications of foot posture Foot angles Classification of symptoms
Müller, Carlsohn, Müller, Baur and Mayer (2012)	Children Age: 1-13 years Country: Germany N=7788	To investigate static and dynamic foot characteristics of infants and children.	Static measurement with a standardized foot measuring device	Static FL, and FW

			Dynamic measurements with Emed-n50 pressure platform	Dynamic foot contact area, foot peak pressure, foot force-time integral
Sacco, Onodera, Bosch and Rosenbaum (2015)	Children Age: 3-10 years Country: Germany and Brazil N= 485	To compare inter-continental anthropometric foot measurements of children.	Static footprints (Harris mat footprints) Chippaux-Smirak Index Staheli indices Index	Static forefoot width, midfoot width and rearfoot width
Scholz, Zech, Wegscheider, Lezius, Braumann, Sehner and Hollander (2017)	Children Age: 5-13 years Country: Germany N=88	To investigate the reliability of and correlation between static and dynamic foot arch measurements in the pediatric population	Static foot arch measurements with foot caliper Dynamic foot arch captured on a pedobarographic platform (Emed-n50 platform)	sAHI dAHI
Waseda, Suda, Inokuchi, Nishiwaki and Toyama (2014)	Children Age: 6-18 years Country: Japan N=10 155	To establish standard values for foot length and arch height in children and adolescence from Japan	INFOOT 3D foot measuring device with eight CCD cameras	Static FL, foot navicular height

From Table 2.1, it is evident that a variety of methods and types of equipment are used in a research setting to measure the shape and function of children's feet. These methods and procedures include indirect- or direct methods, field- or laboratory-based methods, and static- or dynamic measurements.

2.7.1 Indirect or direct methods

Indirect methods include the use of ink, static footprints, and photographic techniques, as seen in Sacco et al. (2015) and Hollander et al. (2018). Sacco et al. (2015) analyzed the footprints of four-hundred-and-eighty-five (485) children by measuring angles of the feet according to the Chippaux-Smirak Index and Staheli Index. Footprints and images are measured statistically (Echarri & Forriol, 2003; Redmond et al., 2006). There has been controversy regarding the use of footprints to measure foot structure and diagnose pathologies due to foot structure variations, which might influence the footprint, as well as difficulty in measuring certain angles of the foot (Cavanagh & Rodgers, 1987). Acquiring footprint measurements and analyzing the data could be time-consuming, although these measurements have shown a moderate to high correlation when compared to other measuring methods (Xiong et al., 2010).

Direct foot measurements include anthropometric methods, clinical assessment, ultrasonography quantification, and radiographic evaluations (Barisch-Fritz et al., 2014; De Villiers, 2017; González Elena & Córdoba-Fernández, 2019; Hollander et al., 2017; Kerr et al., 2015; Müller et al., 2012; Scholz et al., 2017; Waseda et al., 2014). Static anthropometric methods are time-consuming and measurements could be influenced by the time-of-day (Waseda et al., 2014). This method has, however, shown high reliability and correlation with dynamic measurements, as well as digital photographic methods (Pohl & Farr, 2010; Scholz et al., 2017).

2.7.2 Field- or laboratory-based methods

Clinical assessment methods, as seen in Kerr et al. (2015), involved using observational classifications based on the "Oxford Foot Model Markers." Although it might be the most suitable method used by clinicians to assess foot shape, the disadvantage of this method is that it can still be subjective (Stavlas et al., 2005). On the other hand, radiographic and ultrasonography evaluations are high in reliability, but these tests cannot be used outside the laboratory or institution. These tests are also expensive and expose the child to unnecessary health risks (Cavanagh & Rodgers, 1987; Stavlas et al., 2005).

Technological instruments were used to analyze foot structure and foot function directly in both static and dynamic conditions. They included the INFOOT 3D-foot measuring device with eight Charge-couple-device (CCD) cameras for static measurements (Waseda et al., 2014). In this study, laser projections from the top, bottom, left, and right was projected to the center of the device, where the foot was positioned. An image was taken with the CCD cameras to create a 3-Dimensional image of the foot. Static FL and navicular height were assessed via a computer programme. This device measured the foot in a static position.

The DynaScan 4D was used in a study performed in Germany (Barisch-Fritz et al., 2014). This scanner was used for static or dynamic measurements. The DynaScan 4D-scanner system captured objects with five scanner units situated on the left, right, and one at the bottom on the floor.

The EMED-n50 pressure platform was a popular device used for dynamic measurements (Hollander et al., 2017; Müller et al., 2012; Scholz et al., 2017). This pedobarographic platform was embedded in a walkway and used for measurements of AHI and foot pressure parameters. These technological instruments were time-efficient, excellent in reliability, and advanced knowledge of the foot in dynamic conditions (Scholz et al., 2017). However, dynamic measurements are affected by the individual's gait pattern and predefined walking velocity, which could be challenging to record, especially in the pediatric population, due to the difficulty of achieving a persistent, reproducible gait pattern (Müller et al., 2012; Scholz et al., 2017).

2.7.3 Static and dynamic measurements

Static caliper-based measurements in FL and FW have shown high reproducibility. Still, the correlation between static and dynamic measurements has been conflicting, with limited evidence concerning the pediatric population (Scholz et al., 2017). However, the relationship between the sAHI measurements and the dAHI has shown high reliability in adults, when normalized to half the FL, in double limb weight-bearing (Hollander et al., 2016a).

2.7.4 Summary

In the current study, the use of a static caliper was the preferred method of measurement due to its cost-effectiveness and the fact that it could be conducted efficiently anywhere. Static caliper measurements showed high reproducibility and have demonstrated high reliability in the past (Hollander et al., 2016b). One of the aims of the current study was to measure the feet of children and adolescents in urban and rural areas. Assessments of FL, FW and sAHI could be conducted efficiently in both urban areas and remote locations.

2.8 Shoe measurements

2.8.1 Methods to determine shoe dimensions

There currently exists limited knowledge of the objective measurements of shoe dimensions, in the pediatric population. Table 2.2 is a summary of the available methods used in recent studies.

Table 2-2: Overview techniques used to measure the dimensions of a shoe

Studies measuring footwear	**Sample**	**Aim of the study**	**Instruments used**	**Variables**
Barton, Bonanno and Menz (2009)	15 participants Age: not specified 2 x pairs of shoes each	To develop an efficient and reliable Footwear Assessment Tool for health professionals to assess footwear, in a range of populations	Health professionals used clinical experience to assess footwear characteristics Equipment used: Scale Palpation Brannock-style device Goniometer Steel ruler with millimetres	Footwear fit (length, width) Weight of shoe General structure of shoe (heel height, forefoot height, longitudinal profile, last shape) Motion control properties (number of laces, motion control scale) Cushioning (midsole durometer, heel sole durometer) Wear patterns
Burns, Leese and McMurdo (2002)	Elderly people Age: 64-93 years, mean age 82, in general rehabilitation ward Country: Scotland N=65	To investigate a proportion of older people in a rehabilitation ward, wearing incorrectly sized shoes and assessing the presence of complications	Measurement of internal dimensions of shoes with caliper Visual analogue pain scale	Shoe length (SL) Shoe width (SW) Foot pain

			Assessment of the foot by a health professional	
González Elena and Córdoba-Fernández (2019)	Children Age: 3-12 years old Country: Spain N=505	To compare the foot dimensions of schoolchildren to the inner length, width and height of their footwear.	Telescopic gauges with protractors were used to place an acetate transparent insole based on the dimensions of the child's foot inside the shoe	SL SW
Yurt , Sener and Yakut (2014)	Children Age: 4-6 years Country: Urban and rural areas in Turkey N=1000	To evaluate footwear suitability for Turkish preschool-aged children, comparing properties of outdoor and indoor footwear. The effect of age, gender, number of siblings, education and occupation of parents and the behaviour of the school management system on footwear selection.	Footwear Assessment Score (FAS) Measuring of inside materials in millimetres	Material of footwear Heel-to-ball length Width of footwear Room in the toe box Footwear slip Heel height Style of footwear Heel wear Length available for growth

However, gathering more information and knowledge on the foot morphology of children seemed pointless if these measurements could not be compared to the internal dimensions their shoes. As can be seen in Table 2.2, a variety of techniques are available to assess the characteristics of shoes and basic measurements for a good fit. Barton et al. (2009) and Yurt, Sener and Yakut (2014) conducted a detailed investigation of the shoe based on a Footwear Assessment Tool. This is, however, a time-consuming process, with subjective measurements. For example, testing to test the heel counter stiffness of the shoe, the tester had to apply pressure with "firm force" to the back of the shoe. The same process was followed to determine the lateral mid-sole hardness, which was subjectively categorized as either soft, firm, or hard (Barton et al., 2009).The force used by individual testers could vary considerably, subsequently giving different results.

The thumb-width measurement, used in Barton et al. (2009), to determine the distance between the front of the shoe and the longest toe, showed poor reliability. This was confirmed by Barisch-Fritz et al. (2016) in a study evaluating the rule-of-thumb commonly used by parents to determine adequate space in front of children's shoes. The results indicated that an average adult's thumb was bigger than the extra millimetres needed in SL to allow sufficient space for growth.

Other ways of measuring the SL and SW dimensions involved caliper-based measurements. These measurements are objective, cost-effective, reliable and easy to compare to foot measurements (Burns et al., 2002).

González Elena and Córdoba-Fernández (2019) evaluated the inside SW and SL using telescopic gauges, with protractors, based on the dimensions of the child's FL and FW. An extra five to fifteen millimetres (5-15mm) were added for toe-allowance and ten millimetres (10mm) for width fit-allowance. Using this method, the shoe could be classified as either too narrow/short, correctly fitting, or too wide/long. The disadvantage, though, was that actual SL and SW dimensions were not documented and, therefore, shoe manufacturers do not have data to adjust the shoes accordingly.

2.8.2 Summary

As indicated in the literature, determining correct shoe sizes, mainly SW, has been a challenging undertaking and is conducted in various ways. One of the aims of this study was to compare the fit of the school shoe with the basic dimensions of a child's foot, the objective being to aid shoe manufacturers in the future in producing well-fitting shoes. In the current study, a caliper-based measurement was used for shoe measurements. This was the preferred method, in the view of the fact that previous research pointed out that caliper-based measurements, as used in the studies of Barton et al. (2009) and Burns et al. (2002) were the best method of measuring SL and SW dimensions.

2.9 Conclusion

Understanding the basic anatomy and stages of development of the foot is of importance, as it provides insight into how both internal- and external forces can influence the development of the foot. Knowledge of foot size, -shape and -structure should form the basis of measurements used by shoe manufacturers to manufacture and provide well-fitting shoes to children. However, vast differences exist in foot morphology , due to many internal and external factors influencing the various stages of development.

Currently, the shoe manufacturing industry caters mainly for age- and gender-related foot morphology changes, due to the fact that shoe manufacturers in South Africa are designing shoes according to the British shoe design system. Shoes are developed using length as a base-measurement and determining the standardized length-to-thread ratio, based on the Mondo Point System. Every length increase, therefore, corresponds with a standardized increase in foot girth (Cheng & Perng, 1999), and different shoe sizes are available for males and females.

South Africa is in a unique position of having children from a variety of ethnic backgrounds, many of whom consider walking barefoot a cultural phenomenon. A significant majority of children between the ages of six and eighteen reported being habitually barefoot (De Villiers, 2017). Differences in foot morphology, such as an increased sAHI, lower occurrences of flat feet, a longer FL, wider FW, and differences in foot pliability, were found in a study comparing habitually barefoot South African children and adolescents to their shod German counterparts (Hollander et al., 2017). The question arises, therefore, whether the dimensions of South African shoes, based on the British shoe system, accommodates the foot structure, -shape and -size dimensions of a child or adolescent from South Africa adequately. South African children are required to wear school shoes as part of their prescribed school uniform.

A previous study in South Africa measured the school shoe fit of children and adolescents (De Villiers, 2017). Still, these shoe measurements were acquired using the used school shoes of each participant. The results of this study confirmed that sixty-seven percent (67%) of participants wore shoes that did not fit properly. The question remains if the participants simply did not possess the knowledge to select well-fitting shoes or if the shoes were, in fact, not initially developed for habitually barefoot individuals.

There is currently limited information available on the foot morphology of South African children. With the focus on shoes currently available in the retail market sector, it is vital to acquire more knowledge of foot measurements, and accurately address the foot fitment requirements of the diverse South African population (De Villiers, 2017; Thompson & Zipfel, 2005).

This study intended to gather more information on the foot morphology of the South African child and adolescent population. Whilst keeping the influence of internal factors, such as age, gender and BMI of participants, on foot morphology in mind, the study's focus was subsequently directed at the possible impact of geography on foot morphology. The newly acquired data was utilized to compare the FL and FW of participants to the shoe dimensions of school shoes, currently available in the retail market sector.

The next chapter will focus in more detail on the specific research design, methods and measurements that were used in the current study.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter gives an overview of the specific research methods that were used to fulfil the aims and objectives of this study. It provides information on the study design and research process that was followed, which included ethical considerations, participants, and data collection procedures. The chapter concludes with information on the statistical analysis and reliability assessment.

3.2 Study design

During the current study, the research was supported by two research questions which consistently guided the research design. This study followed a cross-sectional, observational, descriptive study design with no intervention. The feet of children and adolescents, between the ages of six and sixteen years, were measured during a once-off assessment. The variables tested included static standing foot length (FL), static standing foot width (FW), and static standing- and sitting foot dorsum height (DH), to determine the static arch height index (sAHI). The shoe length (SL) and shoe width (SW) of newly manufactured school shoes were measured and compared with the foot measurements of the children.

3.3 Ethical approval

Ethical approval for the study was obtained from the Research Ethics Committee of Stellenbosch University (REC-2018-7153) and the Health Research Ethics Committee of Stellenbosch University (Project ID 14419, Ref number S20/01/008) (Addendum A). The Western Cape Department of Education granted approval for the study to be conducted in the participating schools (Addendum B). The study was carried out in accordance with the Helsinki Declaration guidelines.

3.4 Participants

The Western Cape is divided into six areas, namely the City of Cape Town Metropolitan Municipality, and five district municipalities consisting of the West Coast, the Cape Winelands, Overberg, the Central Karoo and the Garden Route districts. A list of twenty primary and secondary schools located in these areas was compiled for this study. Based on the sample size calculations, four primary and four secondary schools from the areas of the City of Cape Town, the West Coast, the Cape Winelands and Overberg were contacted for participation in the study. The response rate was 100%, with all contacted schools interested and willing to participate. The furthest distance the researcher travelled from Stellenbosch, to conduct testing at designated schools, was approximately 200 kilometres. This occurred during visits to schools in the Montagu and Hopefield areas.

An *a priori* sample size power calculation was performed with $\alpha = 0.05$, $Power_{(1-\beta)} = 0.8$ (80%) and an effect size of zero-point-four (0.4), classified as a medium effect size. Based on the power calculations, one hundred (100) participants had to be measured from both rural and urban areas (100 participants per region).

Inclusion criteria stipulated the participation of both boys and girls between the ages of six and sixteen, who attended one of the designated schools in the Western Cape, South Africa, and who had submitted a completed and signed Informed Consent and Assent form. Data of participants were excluded if they had an acute foot injury at the time of testing or a severe foot deformity, in which case their feet could not be measured accurately. In cases of a foot deformity, the child’s feet would still be measured to avoid the humiliation of a child, but this data was not used.

After receiving approval for the study from the Western Cape Department of Education (Addendum B), the twenty selected schools were contacted via email by the principal researcher (Addendum C). Four primary and four secondary schools showed interest in participating in the study. The children and adolescents from the interested schools, as well as their parents or legal guardians, were informed about the study through a Written Project Information Sheet. A Consent/Assent Form for participation was attached to the Information Sheet and handed out two weeks before the commencement of testing (Addendum C). The dates and times for testing were coordinated with representatives from the participating schools.

3.5 Data collection procedure

Due to the large number of participants who responded to the invitation to be part of the study, the researcher decided to test as many children as possible within the allocated time.

The data collection procedure at the schools commenced with an information session addressing participants, after which a general questionnaire was completed. Anthropometric measurements, as well as static foot measurements, both on the left and right feet, were performed. Shoe measurements of newly manufactured school shoes were conducted on a different occasion, at specified retail market outlets. The flowchart in Figure 3.1 demonstrates the layout of the data collection procedure.

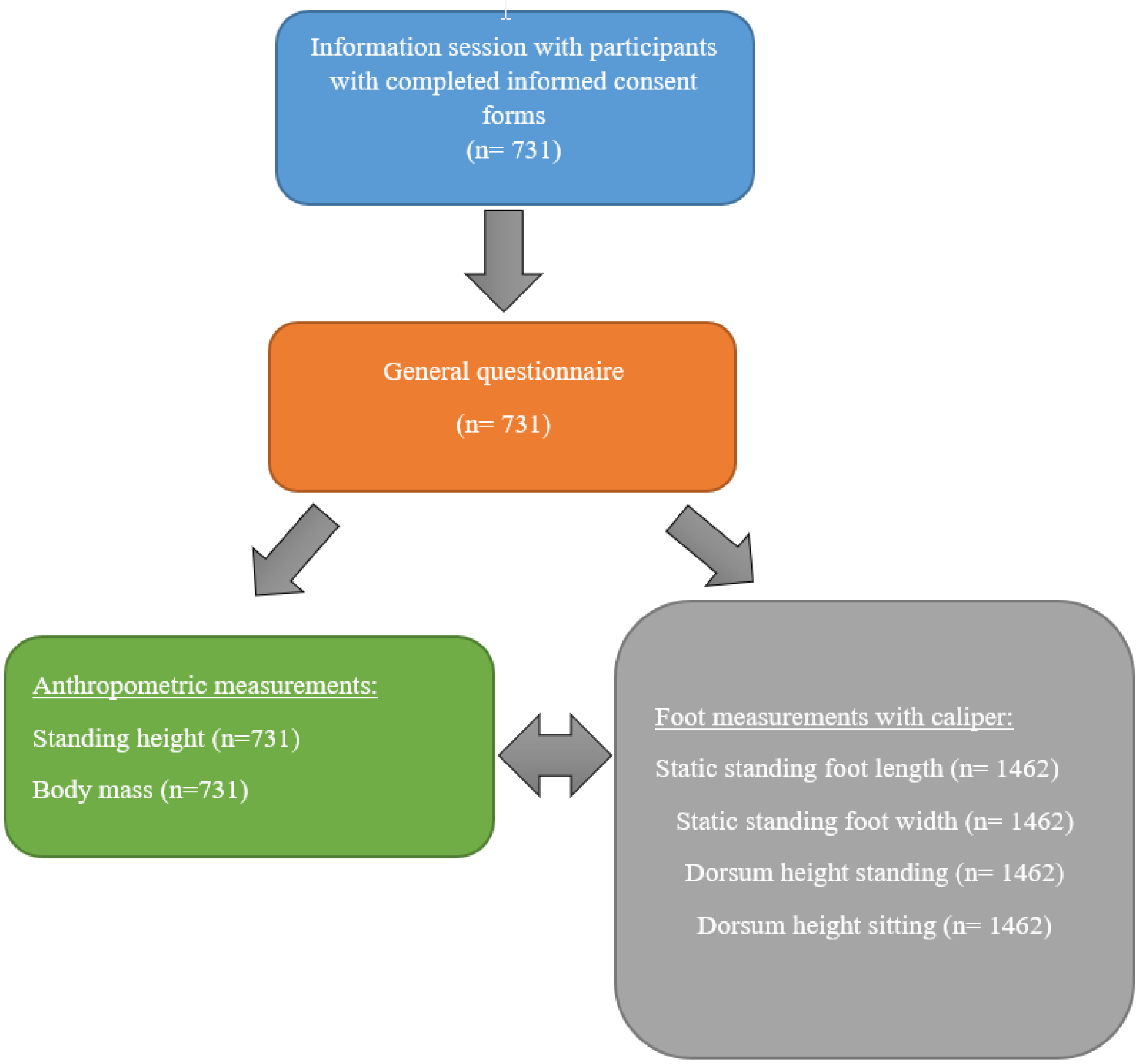

Figure 3-1: A flow chart of the data-collection procedure

3.5.1 Information sessions

An indoor assessment area was made available at each school. Participants attended the testing session in groups of ten to twenty participants at a time. The researcher collected the consent and assent forms and then explained the testing procedure. Participants had the opportunity to ask questions. Figure 3.2. shows a typical setting at a school during data collection.

Figure 3-2: Example of a typical set-up for testing at a school (Photograph Ranel Venter)

3.5.2 General questionnaire

A general questionnaire, consisting of the following questions and particulars, was completed by each participant (Addendum D):

- The age of the participant, at the time of testing
- The gender of the participant
- The current shoe size of the participant

Children or adolescents, who were unable to read or write at the time of testing, were assisted by a research assistant. Figure 3.3 shows a research assistant supporting a participant in need of assistance to complete the general questionnaire. Children were assured that it was acceptable to ask for assistance.

Figure 3-3: A research assistant completing a questionnaire with a participant (Photograph by Marise Breet)

3.6 Tests and measurements

The principal researcher conducted all foot and shoe measurements. At the same time, qualified research assistants (respectively holding BSc (Hons) (Sport Science) and MSc (Sport Science) degrees) conducted the anthropometric tests. Both the principal researcher and assistants were adequately trained in the use of the testing equipment and had experience in administering the tests. To complete all the required tests on each participant, took approximately ten (10) minutes.

All participants were tested on a once-off basis. None of the tests conducted were physically straining; therefore, fatigue did not influence the order of testing. It was suggested that the feet could have been exposed to physical load during the day and that this factor could influence the results of the DH measurements, and subsequently alter the sAHI outcomes for participants (Scholz et al., 2017). To avoid this, all the measurements for the current study were taken during school hours, in the morning**.**

3.6.1 Anthropometric measurements

The anthropometrical measurements that were taken included standing height and body mass measurements.

Standing height

Each participant's standing height was taken, using a portable stadiometer (Charder HM200P Portstad, Germany). The participant was positioned, barefoot, with his/her back against the stadiometer, heels shoulder-width apart. The participant's head was placed in the Frankfort plane while being asked to "stand tall," with his or her heels, buttocks, and upper back touching the stadiometer. The stadiometer headboard was lowered onto the participant's head, ensuring all hair was compressed. After the participant was instructed to breathe in, the reading was taken to the nearest zero-point-one centimetre (0.1cm) (Marfell-Jones et al., 2011).

Body mass

Each participant's body mass was determined with a self-calibrating electronic scale (A&D UC-321 health scale, Australia). The participant was required to stand, barefoot, in the centre of the scale with his or her weight distributed evenly between both legs while looking forward. The reading was recorded to the nearest zero-point-zero-five kilograms (0.05 kg).

Body mass index (BMI)

Based on the standing height and body mass readings, the body mass index of each participant was calculated with the following formula.

$$\text{BMI} = \frac{\text{Body weight (kg)}}{\text{Standing height (m)}^2}$$

The values used to categorize adults into different BMI categories, according to the International Obesity Task Force (IOTF), have been revised by Cole and Lobstein (2012), to be used for children (Addendum E). The categories were as follows: underweight < 18.5 kg/m^2, healthy weight 18.6 kg/m^2-24.9 kg/m^2, overweight 25 kg/m^2-29.9 kg/m^2, obese 30 kg/m^2 - 34.9 kg/m^2, and morbidly obese > 35 kg/m^2 (Cole & Lobstein, 2012). These revised categories were used to determine the BMI category for each participant in the current study.

3.6.2 Foot measurements

Static foot measurements were done with a specially constructed foot caliper. The caliper consisted of heel cups for proper positioning, and horizontal metal sliding indicators for accurate measurements, with a resolution of one millimetre (1mm) (Hollander et al., 2016b). The reliability of this static foot measurement was confirmed to be in the range of "good to excellent" for children and also demonstrated high reproducibility (Scholz et al., 2017).

Static standing foot length (FL) and static standing foot width (FW)

To determining the maximum FL, the heel-to-toe length (HTL) measurement was used. FL and FW of the participants were measured barefoot, with the participants standing with the back of the heels touching the heel cups, both knees extended, and weight distributed evenly between both feet, while looking straight ahead. In the standing position, the foot being measured was in an elongated position, with fifty percent (50%) of the body weight distributed over each foot. Measurement of the feet, using the caliper is shown in Figure 3.4.

Figure 3-4: An example of a standing HTL and standing FW measurement using the caliper (Photograph by Marise Breet)

Both the right and left feet of each participant was measured. HTL was defined as the distance, in millimetres, between the most posterior aspect of the foot and the most anterior part of the toes (Barisch-Fritz et al., 2014; Hollander et al., 2016b). FW was measured, in millimetres, between the most medial part of the first metatarsal head (MTH1) and the most lateral point of the fifth metatarsal head (MTH5) (Barisch-Fritz et al., 2014). All measurements were recorded to the nearest zero-point-zero-one millimetre (0.01mm).

Standing and sitting foot dorsum height (DH)

A portable caliper was used to measure the DH for each foot independently. Two separate measurements were taken of each foot. Firstly, the participant was asked to stand up straight, barefoot on the floor, double-limb stance, with fifty percent (50%) of his/her weight distributed over each foot. The measurement was taken from the floor to the top of the foot, at fifty percent (50%) of the HTL (Barisch-Fritz et al., 2014) (Figure 3.5).

Figure 3-5: The researcher measures the standing DH, at fifty percent (50%) of the HTL (Photograph by Jana de Wet)

Secondly, the participant was asked to sit on a chair with both feet on the floor. Chairs with age-appropriate seat heights were available for younger children, to enable them to have both feet on the floor. According to Hollander et al. (2016b), the seated position amounts to ten percent (10%) of body weight distributed over each foot. The DH was measured from the floor to the top of the foot, at fifty percent (50%) of the HTL of each foot.

Using the formula below, the sAHI was determined for each foot (Hollander et al., 2016b).

Table 3-1: The formula used to determine the standing and sitting sAHI for each foot

$$\text{Standing static arch height index} = \frac{\text{Standing DH}}{\text{HTL}}$$

$$\text{Sitting static arch height index} = \frac{\text{Sitting DH}}{\text{HTL}}$$

3.6.3 Shoe measurements

Shoe length

Measurements of SL and SW were performed on the right shoe of new school sizes currently available in the retail market sector. A flexible plastic straw was used to measure the inside length of the shoe according to the guidelines recommended by Barton et al. (2009). One end of the straw was placed in the toe area at the longest part of the shoe, with the other end of the straw, touching the heel cup, as illustrated in Figure 3.6. The straw was then bent at the heel and cut. The straw was measured to the nearest millimetre using a steel ruler.

Figure 3-6: The image shows a plastic straw cut to fit the length of the shoe (Photograph by Ranel Venter)

Shoe width

The width of the shoe was measured using a sliding caliper (Burns et al., 2002). The caliper was placed over the upper part of the shoe, and the measurement was taken on the most medial and lateral parts of the shoe (Figure 3.7). Specific care was taken not to compress the shoe during measurement.

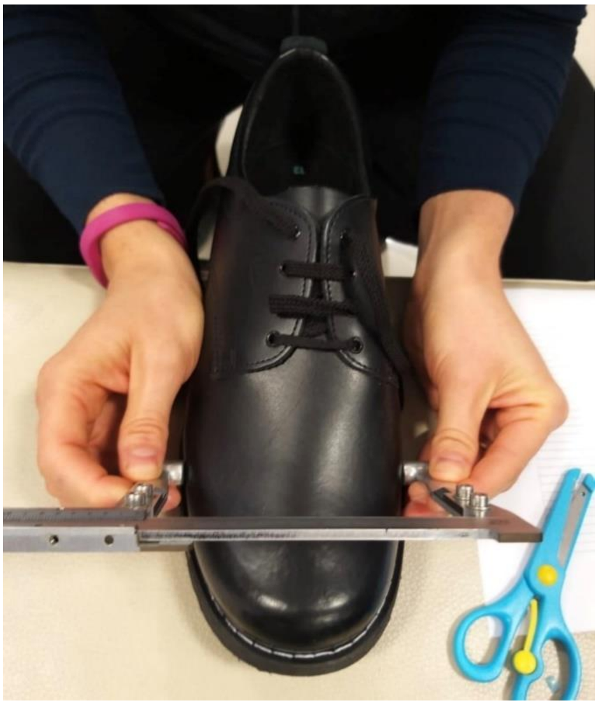

Figure 3-7: Shoe width measurement with a caliper (Photograph by Marise Breet)

3.7 Reliability assessment

The researchers completed a test-retest reliability assessment for intra- and inter-tester reliability for both feet and shoe measurements. During this assessment, the researchers did not have access to any previous measurements. Inter-rater reliability was calculated with an interval of one week. Inter-rater intraclass correlation coefficient (ICC) for foot measurements, was zero-point-nine-nine (0.99) for HTL Left, zero-point-nine-eight (0.98) for HTL Right, zero-point-nine-nine (0.99) for FW Left, and zero-point-nine-three (0.93) for FW Right. Inter-rater ICC was zero-point-nine-nine (0.99) for SL, and zero-point-nine-nine (0.99) for SW. According to Koo and Li (2016), ICC values less than 0.5, between 0.5 and 0.75, between 0.75 and 0.9, and greater than 0.90 are indicative of poor, moderate, good, and excellent reliability, respectively. The inter- and intra-tester reliability values are therefore excellent in the current study.

3.8 Statistical analysis

Participant information was based on descriptive statistics (mean and standard deviation). A mixed model Analysis of Variance (ANOVA) was used to compare foot dimensions between various groupings. This analysis accounted for the correlation between measurements on the left and right feet of the same participant. The participants were entered into the statistical model as a random effect. Gender, age and side (left or right) were treated as fixed effects. For post hoc testing, the Fisher Least Significant (LSD) difference testing was used.

Due to the number of children and feet measured, Cohen's effect size (ES) was also calculated. The values applied for Cohen's effect size were ≥ -0.15 and < 0.15 (negligible effect), ≥ 0.15 and < 0.40 (small effect), ≥ 0.40 and < 0.75 (medium effect), ≥ 0.75 and < 1.10 (large effect), ≥ 1.10 and < 1.45 (very large effect) and > 1.45 (huge effect) (Thalheimer & Cook, 2002).

CHAPTER FOUR

RESEARCH ARTICLE

Habitually barefoot children are wearing ill-fitting school shoes

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This article has been submitted to the journal ***Frontiers Pediatric–Children and Health****. This does not imply that the article has been accepted or will be accepted in the said journal. It is currently in the Journal's independent review process. The journal's guidelines for authors (Addendum F) are followed in this chapter. This implies, amongst others, that the Vancouver method of referencing is used here, which differs from that of the American Psychological Association (APA, 7th Edition) used in the other chapters.*

Table of Contents

Habitually barefoot children are wearing ill-fitting school shoes

Marise C. Breet [1], Ranel Venter [1]

[1]Movement Laboratory, Department of Sport Science, Faculty of Medicine and Health Sciences, Stellenbosch University, Stellenbosch, South Africa

***Correspondence**
Marise Breet
marise@mbio.co.za

Keywords: shoe fit, foot development, children, barefoot, school shoes.

Abstract

Background: Research shows that ill-fitting shoes can negatively impact the development of the pediatric foot, in a very direct manner. The primary aim of the study was to determine if the dimensions of available prescribed school shoes currently fit the foot dimensions of habitually barefoot South African children and adolescents.

Methods: A cross-sectional observational study was conducted where static standing foot measurements of children and adolescents from urban and rural schools in the Western Cape, South Africa, were obtained. The maximum foot length (HTL) and foot width (FW) with an added 10mm toe and width fit allowance to each participant, were compared to the corresponding school shoe length and width available in retail (N=77). Mixed model ANOVA was used to compare foot dimensions between gender, age and side.

Results: Six hundred and ninety-eight school children (N=698) (431 girls; 267 boys; average age 10.86 years, SD=2.55) were participants. Results show that comparing the shoe length and feet length of participants, as well as taking the 10 mm toe allowance into account, fifty-nine percent (59%) of children wore shoes that were not the correct length. With regards to the shoe width and the added 10 mm of width fit allowance, ninety-eight percent (98%) of the shoes worn by participants were too narrow for their feet. The results of this study emphasize that, in many cases, school shoes currently available in retail, are not suited for the habitually barefoot population studied.

Conclusions: It is recommended that the shoe manufacturing industry should consider the shoe width of school shoes for South African children and adolescents to avoid the long-term adverse effect on the pediatric foot, specifically in habitually barefoot populations.

Introduction

Foot morphology has been studied in various populations over the years. In recent years the function and development of the foot have sparked renewed interest (1). Areas on which studies have focused over the past ten years include the following: foot movement patterns (2–6), the advantages and disadvantages of barefoot locomotion compared to shod walking (6–11), shoe development, shoe characteristics, shoe fitting assessment methods (12–17), and inter-continental differences in foot morphology and foot function (1,7,17–19). A few recent studies have focused on the pediatric foot and specific footwear habits and foot development (2,7,14,20).

It has been pointed out that during childhood and the developmental years, the foot may have the same features as an adult foot but should not be treated as such. For example, ongoing development and specific needs, through different stages of growth, make the pediatric foot vulnerable (15). The soft tissues and foot bones are still maturing during these stages, and the full development of these structures is only achieved late in adolescence (21). Secondly, internal factors such as age, gender, and body mass index (BMI) also influence the development of the pediatric foot. Rapid changes in foot shape and function throughout the first fourteen years of life, coupled with high variability in static- and dynamic positions, have been reported (3,5,20,22). During standing and walking, increased body height and weight lead to more foot loading and peak pressure in different areas of the foot (3). A wider midfoot section and flatter foot arch were observed in boys throughout the first nine years of development (3). During the corresponding developmental stage, higher foot arches were observed in girls (23).

The development of the pediatric foot is also vulnerable to external influences, most notable climate, socio-economic status and shoe-wearing habits (18,19,22,24). For example, growing up barefoot, compared to growing up shod, influences pediatric foot arch morphology, foot pliability, the hallux valgus angle, rearfoot strike patterns and motor performance (6,7,25). Shoes have been identified as an external factor that could significantly influence foot development, as well as gait in children (9,11).

Forefoot movement patterns are also significantly influenced by shoes (9). Compared to barefoot walking, longer steps, increased knee and ankle range of motion, reduced foot movement, swing phase leg speed and shock absorption, as well as increased rearfoot strike patterns, were reported in children wearing shoes (11). Although shoes should primarily protect the foot from the external environment, they should still allow the foot to develop and function optimally (12,15,16,22,23). The impact of shoes on developing feet is also illustrated by the fact that shoes are often used to treat foot deformities and specific musculoskeletal injuries (12). Therefore, it is important that shoes are developed to fit feet properly, and not to interfere with the development of the pediatric foot.

Ill-fitting shoes can also cause injuries to the knees, hips, back and other musculoskeletal conditions. This is due to changes in the biomechanical alignment of the body and the impact of load transfer during walking (8,12,13). It has been recommended that the fitting of shoes, as well as shoe characteristics, should be considered by health professionals when treating patients with musculoskeletal injuries (12). Large portions of adults and children in Spain, Germany, the United Kingdom and South Africa are wearing ill-fitting shoes (10,13,14,18,21,26), with associated pain and foot pathology (16,27,28). Between forty-six to eighty-one percent (46-81%) of international study populations were wearing shoes that were too narrow for their feet (16). In this regard, it has been suggested that the shoe fit should resemble the barefoot position of the foot (8). Most comprehensive studies have been done on adult feet and adult shoe design (29) and not the pediatric population.

There are several possible reasons for the prevalence of ill-fitting shoes. An essential factor is that the development of children's shoes is often not predominantly influenced by orthopaedic and biomechanical considerations, but on fashion trends (10,15,21). Shoes currently available in retail tend to focus on the correct fit, according to toe allowance, but limited guidelines are given regarding the width of the shoe (10). South Africa's shoe manufacturers use a shoe design based on the British system, using foot length as the primary measurement. In this system, each increase in foot length will correspond with a standardized increase in foot girth, based on the Mondo Point System (28,30).

Thompson et al. (28) found that sixty-two percent (62%) of adult female participants in a study conducted in South Africa had a forefoot length-to-girth greater than the standardized length-to-girth ratio (10,15,21). Differences in inter-continental foot morphology should be considered when developing shoes for children. This should ensure the correct shoe fit according to the unique foot dimensions of the child, based on previously mentioned external factors (18,19). Unfortunately, a lack of available information on inter-continental foot morphology differences contributes to the current problems with child-friendly shoes (18). Researchers emphasize that the functional aspects of the shoe should cater for unhindered, normal development of the foot (13–15,31).

Mauch et al.(18) have stressed the importance of obtaining comprehensive information on the differences in foot morphology in children across different continents. South African children have an inherent culture of walking barefoot, with a significant majority of children between the ages of six and eighteen years reporting to be habitually barefoot (7). South African's warmer climate also allows children to be barefoot more often during most parts of the year. For example, differences between the foot morphology of South African and German children have drawn attention to on a higher medial longitudinal arch, longer foot length, wider foot width, and a difference in foot pliability in the South African study population (32). Unfortunately, there has been limited research on shoe fitting for South African children and adolescents. In South Africa, school shoes usually form part of the prescribed school uniform. This study aimed to collect data on the unique foot dimensions and foot shapes of South African children to equip the local shoe manufacturing companies to provide South African children with shoes that correctly fit and support their feet.

Material and methods

A cross-sectional observational study was conducted, with foot measurements taken of children and adolescents between the ages six and sixteen, from both urban (N=379) and rural (N=319) schools in the Western Cape, South Africa. After receiving approval from the Western Cape Department of Education, schools were randomly selected per stratum (representing a combination of regional and school models). These selected schools were contacted via email by the principal investigators.

All children and adolescents from each school, as well as their parents or legal guardians, were informed about the study through a Written Project Information Sheet, and consent forms were handed out two weeks prior to the commencement of testing. Inclusion criteria stipulated boys and girls between six and sixteen years of age, who attended one of the participating schools in the Western Cape, and who had submitted completed and signed Informed Consent and Assent forms. Participants were explicitly excluded if they had an acute foot injury at the time of testing or a severe foot deformity, in which case their feet could not be measured accurately. All participants were assessed for height and weight, and their current shoe size was documented. Additionally, participants provided their age and gender on a Personal Information Sheet. All participants were tested on a once-off basis during school hours. Before the study having been conducted, ethical approval was obtained from the Research Ethics Committee of Stellenbosch University (REC-2018-7153) and the Health Research Ethics Committee (Project ID 14419, Ref number S20/01/008). The study was carried out in accordance with the Helsinki Declaration guidelines.

Foot measurements

Static foot measurements were done using a specially constructed foot caliper. The caliper consisted of heel cups for proper positioning and horizontal metal sliding indicators for accurate measurement, with a resolution of 1 mm (24) (Fig. 1). The reliability of this static foot measurement was proved to be in the range of "good to excellent" for children and demonstrated high potential for reproducibility (33).

Figure 1: Heel-to-toe-length and foot width measured with a specially constructed caliper.

The foot length/heel-to-toe length (HTL) and foot width (FW) were measured barefoot with the participant standing with his or her back of the heels touching the heel cups, with both knees extended, and weight distributed evenly between both feet and looking straight ahead. In the standing position, the foot being measured is in an elongated position, with fifty percent (50%) of the body weight distributed over each foot. These are the basic foot dimensions that should be accommodated by shoes (12,22). Both the right and left feet were measured. Measurements of the longest and widest feet were used for statistical analysis, with a coin flipped to determine the use of the measurements when both feet were of equal length or width (14). Heel-to-toe length (HTL) was defined as the distance, in millimetres, between the most posterior aspect of the foot and the most anterior part of the toes (22,24). Foot width (FW) was measured, in millimetres, between the most medial part of the first metatarsal head (MTH1) and the most lateral point of the fifth metatarsal head (MTH5) (22). All measurements were recorded to the nearest 0.01millimetre.

Literature has recommended a toe allowance of 5 to 20 mm (12,14); however, muscle contraction of the medial longitudinal arch in the foot can be responsible for a smaller foot length (15). In the current study, the researcher performed standing static foot length measurements, and measured the foot during maximal extension. Subsequently, the researchers have decided on a toe allowance of 10 mm to determine the shoe length fit.

Shoe measurements

Measurements of shoe length and width were performed on the right shoe of new school sizes available in the retail sector. A flexible plastic straw was used to measure the inside length of the shoe according to the guidelines recommend by Barton et al. (12)(Fig. 2). One end of the straw was placed in the toe area at the longest part of the shoe, with the other end, touching the heel cup. The straw was then bent at the heel and cut (12). The straw was measured to the nearest millimetre using a steel ruler. An additional 5 to 20 mm toe allowance (TA) to the heel-to-toe (HTL) measurement (12,14,15) is suggested for the splaying and elongation during movement of the developing foot (12). This is to ensure a proper fit of the foot in the length of the shoe.

Figure 2: Measurement of the inside length of a new school shoe (boys) with the use of a cut plastic straw.

The width of the shoe was measured using a sliding caliper (34). The caliper was placed over the upper part of the shoe, and the measurement was taken on the most medial and lateral parts of the shoe. Specific care was taken not to compress the shoe during measurement (Fig. 3). A shoe width allowance of 10 mm has been suggested to ensure a proper fit (14).

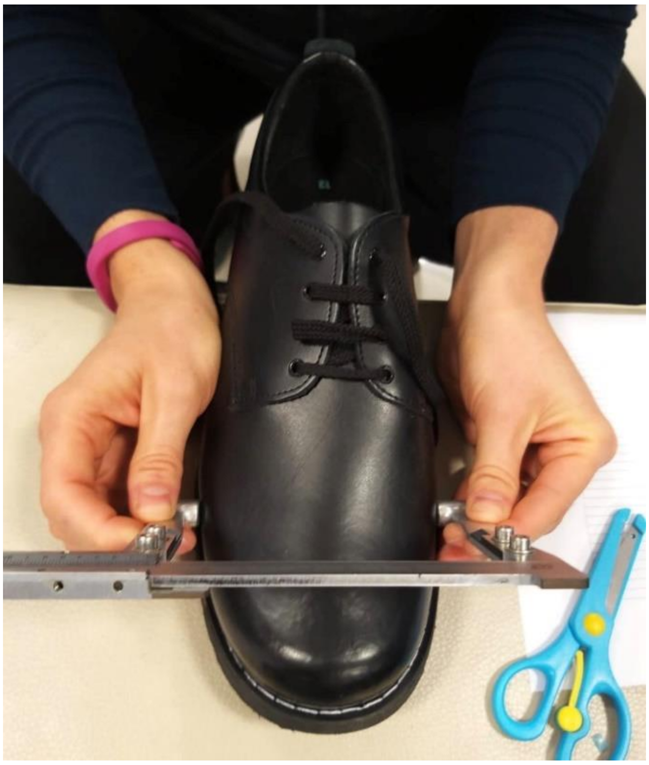

Figure 3: Measurement of the outside shoe width of a new school shoe (boys) with a caliper.

Reliability of foot and shoe measurements

The researchers completed a test-retest reliability assessment for both intra- and inter-tester reliability. During this assessment, the researchers' prior results were completely obscured from their views. Inter-rater reliability was calculated with an interval of one week. Inter-rater intraclass correlation coefficient (ICC) with confidence levels of ninety-five percent (95%) (Cronbach's α) for foot measurements, was 0.99 for FL Left, 0.98 for FL Right, 0.99 for FW Left, 0.93, and for FW Right, 0.93. Inter-rater ICC was 0.99 for shoe length (SL), and 0.99 for shoe width (SW).

Statistical analysis

A mixed model analysis of variance (ANOVA) was used to compare foot dimensions between various groupings. This analysis accounted for the correlation between measurements on the left and right feet of the same participant. The participants were entered into the statistical model as a random effect. Gender, age and side (left or right) were treated as fixed effects. For post hoc testing, Fisher least Significant (LSD) difference testing was used.

Results

Foot measurements of six hundred and ninety-eight school children (N=698) schoolchildren (431 girls; 267 boys) between the ages of six and sixteen years were taken. The average age of the participants was 10.86 (SD=2.55). Table 1 shows the number of children per age group, as well as the number of boys and girls, tested in each age group.

Table 1: Number of children and gender in each age group tested

Age (years)	N	Gender
6	18	F:12; M:6
7	88	F:51; M:37
8	61	F:28; M:33
9	44	F:27; M:17
10	70	F:40; M:30
11	77	F:43; M:34
12	150	F:101; M:49
13	87	F:56; M:31
14	62	F:43; M:19
15	33	F:26; M:7
16	8	F:4; M:4
6 - 16	698	F:431; M:267

N=number of participants, F=female participants, M=male participants

In the total group of children, boys had significantly longer feet than the girls ($p < 0.01$). Looking at age-specific differences, no significant differences in feet length existed between boys and girls, until the participant reached the age of twelve years. Between the ages of twelve and sixteen, significant differences ($p<0.01$) in feet length were found between boys and girls. For the whole group, the participant's right feet were significantly longer than the left ($p<0.01$), and this applied equally so for boys and girls (non-significant interaction, $p=0.86$).

The boys in the group overall had significantly wider feet than the girls ($p < 0.01$). Considering age-specific differences, there was a consistent trend for boys having wider feet, up till the age of 10, after which larger (and significant, $p<0.01$) differences were observed from ages eleven to sixteen years. Between ages eleven and fourteen, significant differences in feet width were observed between boys and girls ($p<0.01$). Similar to feet length, the right feet of participants from the whole group were significantly wider ($p<0.01$) than the left feet, and this applied equally so for boys and girls (non-significant interaction, $p=0.37$). The difference in width between the left and right feet could be observed from the age of seven years in both genders.

The number of children who wore shoes that were either too short or too narrow, according to guidelines for shoe fit in children, are shown in Table 2.

Table 2: Shoe fit based on comparisons between length and width of feet and school shoes. Values are shown as a percentage of the whole sample.

Shoe fit (length) compared to foot length		Shoe fit (width) compared to foot width	
Shoe too short	22% (N=154)	Shoe too narrow	98% (N=682)
Shoe within limits	41% (N=286)	Shoe within limits	2% (N=15)
Shoe too long	37% (N=258)	Shoe too wide	0% (N=1)

N=number of participants

Comparing the length of the shoes worn, and taking into account the toe allowance of 10 mm, twenty-two percent (22%) (N=154) of the children tested wore shoes too short for their feet, forty-one percent (41%) (N=286) wore shoes well-fitting in length and thirty-seven percent (37%) (N=258) wore shoes that were too long for their feet. Concerning the shoe width, with an added fit allowance of 10 mm, the results showed that ninety-eight percent (98%) (N=682) of the shoes were too narrow for the feet, two percent (2%) (N=15) were of the correct width, and zero percent (0%) (N=1) were too wide for the feet.

Discussion

The current study aimed to determine if the dimensions of the currently available prescribed school shoes accommodate the dimensions (length and width) of a sample of habitually barefoot South African children and adolescents. The first important finding was that for ninety-eight percent (98%) of the participants, school shoes were too narrow for their feet. This finding supports previous research, which indicated that sixty-six-point seven percent (66.7%) of participants from Spain wore shoes that were too narrow (14). The difference in results between the Spanish and the current South African study could be ascribed to the footwear habits (habitually barefoot) of South African children and adolescents (14). South Africa is regarded as a country with a warm climate, and children are barefoot more often than in other countries with colder weather, which trend possibly also influences the shape and development of the foot (18). Researchers agree that habitually barefoot populations displayed an increased or above-average forefoot width, compared to habitually shod populations (7,8,23,26,28). In the current study, shoe width was measured with a sliding caliper to measure the widest part on the outside of the shoe. In contrast, previous studies measured the inner shoe-width with specialized telescopic gauges containing protractors (14). González Elena and Córdoba-Fernández, as well as the current study determined shoe width fit with an added 10 mm for width fit allowance. Measuring on the outside of the shoe has the limitation of the shoe material, adding to the width of the shoes. This would, however, mean that the added width of the shoe, due to the shoe material, still supports the finding that the currently available shoes are not wide enough for the children’s feet.

In the current study, fifty-nine percent (59%) of children wore shoes that were not the correct length. Considering a recent study on shoe fit on 505 school-going children in Spain, also taking into account a toe allowance of 5-15 mm, seventy-two point five percent (72.5%) of school-going children were wearing ill-fitting shoes (14). These findings correlate with a previous study conducted in South Africa, which reported sixty-seven percent (67%) of South African children (26) wearing ill-fitting shoes. A possible reason for the differences between the current study and the previous studies is that previous studies measured the shoe after the participants had worn it. This poses the question of whether, at the time the previous research was conducted, the shoes were in good condition or not, and if that factor could have contributed to the percentage of ill-fittings discovered. The current study investigated the shoe measurements using a newly manufactured shoe. It is, therefore, challenging to compare the results obtained from using a newly manufactured shoe to that of one that has been worn for a period. Some arguments could be made that the percentage of ill-fitting shoes in the previous studies might have been either lower or higher had the shoe been measured before it was worn for some time.

Upon further inspection of the school shoes currently available in the South African retail market, it was found that a good range and variety of school shoe lengths are available. The reason for ill-fitting shoes, when considering foot length, might be the quality of information available on footwear fit, which can, at times, be scare and not scientifically based (13). Other reasons for ill-fitting shoes in foot length might be the rapid increase in foot length in children between the ages of six and fourteen years of age. Between these ages, foot length in children can increase up to 1.5 cm per year, after which it reaches a plateau (5,20,26). Therefore, the shoe fit needs to be checked regularly while keeping the appropriate toe allowance in mind. Accurate feedback on the shoe fit, concerning toe allowance, cannot be obtained from the child; therefore, parents need to be educated appropriately to select the appropriate shoe size (15). Even though a toe allowance of 10 mm has been added to the foot length results, the current study still reports thirty-seven percent (37%) of shoes being too long for the foot. This correlates with the findings of Barisch-Fritz et al. that toe allowance should be smaller than assumed. The recommended 90th percentile for toe allowance for females is 9.8 mm and for males 11.5 mm (15). Another possible reason for shoes not corresponding with the foot length might be the decision to change the shoe length in an attempt to accommodate the width of the foot for more comfort, as South African footwear does not offer a width adjustment option.

The current study supports the findings of Mauch et al.(18) that intercontinental differences in foot dimensions are common. The reasons behind the differences might require more research. The shoe industry to familiarize itself with these research-based differences and adapt footwear accordingly to ensure better-fitting shoes. Upon investigation, it appears that shoe companies are not currently catering for inter-continental feet differences. Previous studies, which investigated foot shapes and morphological differences between habitually barefoot children and habitually shod children, reported longer feet in the barefoot population (7), This finding is supported by Shu et al. (35), who reported significantly larger feet in barefoot females. These results, however, do not align with the finding of a study on German habitually shod children, which reported significantly longer feet than their Australian, habitually barefoot, counterparts. This difference was, however, only present in younger children, and no significant difference was recorded for older subjects (18).

While the adult foot has been researched extensively, the pediatric foot is still a much-understudied field (29). Even when looking at the external foot shape of a child, when compared to an adult, the structural and functional characteristics are different (22). Anthropometrical data on the pediatric foot is essential when considering footwear design and shoe construction (21,29,36,37). The maximal forces and leverages of children's feet are vastly different from those of adults. Subsequently, a shoe that provides cushioning and stability to most adults may feel hard and uncomfortable for children (21).

The market for children's shoes is not currently driven by orthopaedic and biomechanical considerations, but by consumer behaviour and trends. Children's shoes are mostly developed as downsizing of an adult shoe (21). According to previous studies, manufacturers are not taking the 3D shape of the foot into account and are unable to produce a variability to cater for the differences in foot morphology (22,29).

Shoe designs for children in habitually barefoot populations should, therefore, produce a shoe to fit the foot correctly and mimic the shape and dimensions of the bare foot. Optimum foot development occurs when the natural shape and function of the foot is respected (8,21,29,36,37). However, one of the most challenging tasks that remain in shoe manufacturing is the ability to access useful data to build a standard shape from available measurements (30). In most current designs, shoe length is used as a basic measurement, without considering the other dimensions (30).

The current study advances and elaborate on existing views on this highly relevant issue, as it places the onus on shoe manufacturing companies to enhance and improve on the basic dimensions of available shoes for habitually barefoot populations. Dynamic measurements will add another dimension to the development of the South African pediatric shoe. Future research to investigate the foot dimensions of habitually barefoot children and adolescents, focusing on shoe development, under dynamic conditions, is indicated. Future research should also investigate whether currently available shoes respect the foot development of the habitually barefoot population, with a specific focus on foot pliability and arch height index.

This is not a new problem and, already at the start of the previous century, Hoffman (38) stated that "because of the tightness of the "modern" shoe, the habitually wide shape of the forefoot, with lots of space between the toes necessary for grasping functions, is lost."

Ill-fitting shoes can have a lasting effect on the gait patterns and development of the foot, causing foot abnormalities such as a hammer-, clawed- and retracted toes (30,39). Associated pain and pathology, due to ill-fitting footwear, are widely reported (11,13,16,28). Previously, eighty percent (80%) of South African adult females reported wearing shoes, which caused pain, blisters and callouses (28). Common foot deformities like hallux valgus are significantly induced and influenced by shoe fit being too narrow or too short (30,39). Shoes, which are too narrow for the foot, will restrict the slay of the forefoot, leading to biomechanical deviations and restriction in movement of the foot (10). Hallux valgus are believed to be avoided and corrected by selecting and wearing shoes that provide sufficient space for the toes (30). Given the width dimensions of shoes available in the present study, the majority of children in South Africa will not have the option of a school shoe with a wider forefoot, as this is not available. Current shoe design practices in South Africa are also based on a Mondo Point System (30), which might not be the correct system for habitually barefoot populations.

These results should assist the school shoe manufacturing industry, and all shoe manufacturing industries, to provide well-fitting shoes for habitually barefoot populations. For the immediate future, it can assist with normal foot development in children, in the long run, to minimize foot deformities, pain and musculoskeletal injuries in adulthood.

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CHAPTER FIVE

DISCUSSION AND CONCLUSION

5.1 Introduction

During the past few years, research on foot morphology and function has received an increasing amount of attention. Many of the studies in this field have focused on the advantages and disadvantages of barefoot locomotion, compared to shod walking and running. For example, a study was conducted by De Villiers (2017) in the Western Cape, South Africa, which reported that ninety-point-nine percent (90.9%) of the participants between the ages of six and eighteen years, were classified as being habitually barefoot. In studies where habitually barefoot populations were compared with their shod counterparts, researchers found significant differences in the various stages of foot development, relating to foot shape, motor skill development, movement patterns, pliability and pressure distribution (D'Août et al., 2009; Hollander et al., 2017; Wegener et al., 2011; Wolf et al., 2008; Zech et al., 2018). In addition, to shoe-wearing habits and the environment, as well as certain internal factors, such as age, gender and body mass index (BMI), have been indicated as factors influencing foot morphology and function (Barisch-Fritz et al., 2014; De Villiers, 2017; Scholz et al., 2017).

Existing data confirms that South African children and adolescents' feet differ from their German counterparts. An increased static arch height index (sAHI), with lower occurrences of flat feet, a longer foot length (FL), wider foot width (FW), and differences in foot pliability have been reported in South African children (Hollander et al., 2017). Even though studies have confirmed intercontinental differences in the foot morphology of children, there is still a shortage of published research on the foot morphology and stages of foot development of South African children and adolescents. The first aim of the current study was to determine the differences in foot morphology (FL, FW, standing sAHI, and sitting sAHI) between children and adolescents (aged six to sixteen) from rural and urban areas, located in the Western Cape, South Africa.

The adverse effects of ill-fitting footwear, specifically during childhood, while the foot is still developing, have been linked to pathologies and abnormalities in adulthood (Gottschalk et al., 1980; Thompson & Zipfel, 2005). Currently, South African shoe manufacturers are designing shoes according to the British shoe design system, with standardized length-width-ratios (Cheng & Perng, 1999). European shoe-wearing habits differ from those in South Africa, due to differences in climate. The second aim of the study was, therefore to determine the differences between the acquired foot measurements of children and adolescents (aged six to sixteen) and the school shoe sizes, currently available in the South African retail market.

It is believed that an important contribution can be made to improve foot development health in children by adding to the currently limited data on foot morphology differences under South African children who are located in different areas, and by making this information available to the shoe manufacturing industry. The implementation of the research findings by the shoe manufacturing industry could also lead to fewer foot deformities and other musculoskeletal injuries later in life.

Although South African children are regarded as habitually barefoot, as stated in the study of De Villiers (2017), it should be noted that children and adolescents are required to wear prescribed school shoes as part of their school uniform. From the age of thirteen years, when children typically start attending secondary school, school rules specifically stipulate that the wearing of school shoes is compulsory during school hours. The focus of the study was, therefore, to compare the acquired foot measurements of children and adolescents with the dimensions of currently available school shoes from the retail market sector.

The principal findings of the study will be discussed in the following section, focussing on the stated hypotheses. It should be noted that the discussion section of the current thesis will contain more detail on results than a typical discussion chapter. This is due to the article-format of the thesis, without a chapter allocated to the results of the study. This is deemed necessary for the context of the discussed content. More detailed results are presented in Addendum G. The novelty of the current study presented a challenge in comparing the findings with other related published research.

5.2 Discussion

In the following section, the results of the current study will be reported on and discussed in relation to the stated hypotheses of the study.

Descriptive statistics of participants

A total of seven-hundred-and-thirty-one school children (N=731) (450 girls, 281 boys, with an average age of ten-point-eight-six (10.86) (±2.55)) years participated in the study. Children and adolescents from urban (N=393) and rural areas (N=338) were measured. The total number of feet measured during data collection was one-thousand-four-hundred-and-sixty-two (1 462). The urban children and adolescents had a mean age of ten-point-two (10.2) (±2.5) years, while the rural children and adolescents were on average eleven-point-six (11.6) (± 2.4) years old. Demographics of participants are available in Addendum G.

The participants were divided into BMI categories, as suggested by Cole and Lobstein (2012). Sixty-five percent (65%) of urban participants and sixty-one percent (61%) of rural participants had a healthy BMI. Of the participants located in the urban areas, thirty-one percent (31%) formed part of the overweight-, obese- or morbidly obese categories. In the rural areas, thirty-three percent (33%) of the participants, formed part of similar categories. A table, with detailed information relating to the BMI of the participants is available in Addendum G.

Hypothesis One

The first research hypothesis stated that the foot morphology of children and adolescents (aged six to sixteen) from rural areas differs from that of children and adolescents in urban areas of the Western Cape, with rural children presenting with longer and wider feet, as well as higher sitting and standing static arch height indexes than their urban counterparts.

The null hypothesis (H_0) for the initial research hypothesis stated that there would be no difference between the groups for any of the variables mentioned above (H_0: μ1= μ2). The alternative hypothesis (H_1) stated that the means were not all equal between the measurements of the children and adolescents from rural areas compared to those from urban areas.

Results from the current study indicated that there was no statistically significant difference between the standing FL of children and adolescents from rural and urban areas however, a small practical significant difference (d = 0.39) was found, indicating that the feet of children from urban areas were longer than the feet of children living in rural areas.

Previous studies indicated that FL continuously increased, at a fast-growing rate between the ages of four and twelve years, and that FL can increase up to one-point-five centimetres (1.5cm) per year, after which it reaches a plateau (De Villiers, 2017; Müller et al., 2012). In the current study, the mean age of participants in rural areas was eleven-point-six (11.6) (±2.4) years, and that of the urban participants ten-point-two (10.2) (±2.5) years. Applying the outcomes of the previous research mentioned above to this specific study, it would be expected that the children and adolescents from rural areas would have longer feet than their urban counterparts, based on age. However, this finding was not confirmed by the results of the current study, as the children and adolescents from the urban areas were found to have longer feet.

The percentage of girls tested in the urban group was sixty-seven percent (67%), compared to fifty-five percent (55%) in the rural group. Contrarily, a larger percentage of boys from the rural group were tested (45%), compared to thirty-two percent (32%) of boys originating from urban areas. (See detailed demographics of participants in Addendum G). Focusing on the possible influence of gender on FL development, Waseda et al. (2014) found that boys' foot length kept increasing up to the age of sixteen years, compared to that of girls', who are believed to grow at a slower rate than boys. Boys had significantly wider and higher feet measurements than girls of the same age (Barisch-Fritz et al., 2014; Bosch et al., 2009; De Villiers, 2017; Echarri & Forriol, 2003). The results of the current study do not correlate with these findings, as the number of boys from rural areas who were tested, exceeded those from urban areas, who were tested. Likewise, most girl participants were from urban areas, with a smaller number of girl participants originating from rural areas. One would have expected that the average FL of participants originating from the rural areas would have been longer, but this was not found to be the case.

The body mass index (BMI) of children and adolescents has been proven to play a role in the development of the pediatric foot, with overweight adults and children presenting with significantly longer and wider feet, compared to those in the healthy and underweight BMI categories (Barisch-

Fritz et al., 2014; Bosch et al., 2010; De Villiers, 2017). In the current study, thirty-one percent (31%) of participants falling in the overweight-, obese- or morbidly obese categories resided in urban areas, whereas thirty-three percent (33%) resided in rural areas. As in the case of age and gender, the children from rural areas should have presented with longer feet than the participants from urban areas, due to an increased BMI accounting for longer feet.

A possible explanation for these results could be the genetics or ethnicity of the participants, with previous research pointing out that ethnicity could play a role in the foot morphology of children, adolescents and adults (De Villiers, 2017; Golightly et al., 2012; Shu et al., 2015). However, due to the sensitivity of this topic, the current study did not report on the influence of these factors on the foot morphology of children.

Regarding FW, no statistically significant difference was found between children and adolescents from rural and urban areas however, a medium practical significant difference ($d = 0.42$) was found with the feet of the rural children being wider, compared to those of urban children. Similarly, no statistically significant difference in standing sAHI was found between children and adolescents from rural and urban areas, and only a negligible practical significant difference ($d = 0.05$) was found, with the rural children presenting with a higher sAHI index. However, a statistically significant difference ($p<0.01$) was found in sitting sAHI between children and adolescents from rural and urban areas, even though the practical significant difference ($d = 0.11$) was negligible, with the rural children presenting with a higher sitting sAHI.

The recorded results on FW and standing and sitting sAHI could be explained by a possible difference in footwear habits between the children and adolescents located in urban areas, compared to those living in rural areas. Barefoot populations, when compared to shod populations, have previously been associated with an increase in standing and sitting sAHI, with a wider FW (Echarri & Forriol, 2003; Hollander et al., 2017). It had been expected that the children and adolescents from rural areas would spend more time being barefoot than their counterparts in urban areas and, by comparing the measurements in foot morphology, this trend could have been shown. However, this was not the case, and possible explanations might indicate the need for further investigation in the shoe wearing habits of children and adolescents.

It seems as if the current study is the first attempt to determine whether there are differences in foot morphology between children and adolescents, located in rural and urban areas. Slight differences in foot morphology between children and adolescents located in urban and rural areas would be a clear indication to investigate other factors influencing the foot morphology of these groups. Conflicting findings in previous research relating to FL would also indicate the need for further investigation of these factors. An investigation and comparison of the foot morphology and footwear habits between children attending primary and secondary schools could be informative, as the wearing of prescribed shoes is compulsory from secondary school onwards.

Although a study conducted in 2015 reported that ninety-point-nine percent (90.9%) of South African children and adolescents were habitually barefoot (De Villiers, 2017), it needs to be kept in mind that this previous study, as well as the current one, only included participants from one of the nominated schools in the Western Cape. This means that the participants in these studies had already been wearing school shoes regularly, as part of their school uniform. Although fit of school shoes will be discussed in more detail during the second research question, it needs to be considered that the participants, who took part in the study, might have been exposed to ill-fitting shoes for some time already. As the pediatric foot is exceptionally vulnerable to external influences, the normal foot development of these participants might have been altered to some extent already.

After a statistical analysis of the data acquired, the null hypothesis (H_0) is rejected. The feet of children located in rural areas had a higher sitting sAHI than children located in urban areas.

It is interesting that further analyses of the children's feet in the current study indicated that the sizes of the measured feet (FL and FW) were significantly different when the left and right feet of children are compared, from both urban and rural areas. For all children, the right foot was significantly ($p<0.01$) longer and wider than their left foot when measured in standing and seated positions. This applied equally to both boys and girls (non-significant interaction, $p=0.86$). Furthermore, the static standing and seated DH were significantly more for the right foot than for the left foot. The standing and seated sAHI was also higher for the right foot in both rural and urban children.

Other studies which confirmed differences between the right and left feet indicated anterior foot pressure as significantly higher in the right foot than the left, in seven-hundred-and-sixty-four (764) preschool children, aged three-point-five to six-point-five (3.5-6.5) years (Matsuda & Demura, 2013). These findings are in contrast with a recent study performed on Spanish school children, where seventy-two-point-six percent (72.6%) of participants had a longer left than right foot (González Elena & Córdoba-Fernández, 2019). Current research on this topic is minimal and inconclusive. It could be hypothesized that these findings might be related to foot dominance, but the current study did not take this into account, and can, therefore not confirm this hypothesis.

Hypothesis two

Research hypothesis two stated that the current brands of new school shoes, available in the South African retail market, adequately accommodate the foot sizes of school-going children and adolescents (aged six to sixteen).

The null hypothesis (H_0) for the preceding research hypothesis was that the brands of new school shoes, currently available in the South African retail market, do not adequately accommodate the foot sizes of school-going children and adolescents (aged six to sixteen). The alternative hypothesis (H_1) states that the means are equal between the measurements of the feet of the children and adolescents and the available shoe sizes.

Results indicated that, comparing the SL with the FL of participants, while taking a ten-millimetre (10mm) toe-allowance into account, fifty-nine percent (59%) of children wore shoes that were not the correct length. Referring to the shoe width and the added ten-millimetre (10mm) of width fit-allowance, it was concluded that ninety-eight percent (98%) of shoes worn by participants were too narrow for their feet. The results of the current study emphasize the fact that in the cases of most school shoes currently available in retail, the available shoes are not suitable for the habitually barefoot population studied. The null hypothesis (H_0) is accepted.

Article one (Chapter Four) contains the discussion related to hypothesis two and will not be repeated in this section.

5.3 Summary of main findings

As a conclusion to the study, Table 5.1 provides an overview of the hypotheses covered in the study, as well as their outcomes.

Table 5-1: Hypotheses and outcomes

Hypotheses	**Variable**	**Outcomes**
1.The null hypothesis (H_0) stated that there would be no difference between the foot morphology of the children and adolescents (aged six to sixteen) from the rural areas when compared to their counterparts from urban areas of the Western Cape	**Rejected**	
	Standing FL	No statistically significant difference. Only small practical significant difference (d = 0.39) with the feet of urban children longer
	Standing FW	No statistically significant difference. Medium practical significant difference (d = 0.42) with the feet of rural children wider
	Standing sAHI	No statistically significant difference. Negligible practical significant difference (d = 0.05), with rural children having a higher standing sAHI

	Sitting sAHI	A statistically significant difference ($p<0.01$). Negligible practical significant difference ($d = 0.11$) with rural children having a higher sitting sAHI
2. The null hypothesis (H_0) stated that the brands of new school shoes, currently available in the South African retail market do not adequately accommodate the foot sizes of school-going children and adolescents (aged six to sixteen), in the Western Cape.	**Accepted** SL compared to FL SW compared to FW	 Fifty-nine percent (59%) of the children wore shoes that were either too long or too short for their feet Ninety-eight percent (98%) of the participants wore shoes that were too narrow for their feet

5.4 Practical applications

The results of the current study could contribute in the following ways:

- The data acquired during this study, as well as the findings and conclusions of this study, could be added to a database. This could contribute significantly to the knowledge, understanding and study of habitually barefoot populations, as well as that of the South African pediatric foot morphology.
- The broader understanding of the foot morphology of South African children and adolescents could help in early screening for foot pathologies or deviations from the norm.
- The newly acquired data could be used to guide the shoe manufacturing industry to adjust the basic dimensions of manufactured school shoes, in order to accommodate the FL and FW dimensions of South African children better.

- Parents, as well as school children and adolescents, should be educated about the importance of wearing well-fitting shoes. Current information on toe- and fit-allowance should be readily available, to ensure the purchase, as well as fitting of the correct size shoe.

5.5 Study limitations

Certain limitations were experienced during the study, including the following:

- One of the study's limitations related to the fact that the different ethnical groups amongst the participants were not recorded and reported on due to ethical sensitivity. As ethnicity forms part of one of the internal factors influencing foot morphology and the way the foot reacts to external influences, some foot morphology differences in the current study groups could not be explained. Additionally, there is no certainty that there existed an equal representation of all ethnical groups for data purposes.
- A further study limitation was the attempted involvement of a larger number of older participants between fifteen and sixteen (15-16) years of age, who could not participate in the study, due to academic responsibilities. Having had these students participate in the study could have influenced the eventual results, as the shoe-wearing habits of these students might have had a more significant influence on the results of the study. The reason for this is the fact that, from secondary school onwards, shoes become a compulsory part of the school uniform.

5.6 Recommendations for future studies

Based on the results of this study, the following recommendations are suggested:

- A questionnaire on the shoe-wearing habits of students of both urban and rural schools should be conducted, specifically focusing on the distinct differences in these habits between students attending primary and secondary schools. The proposed study could investigate changes in foot morphology, when the child reaches secondary school, and the wearing of school shoes becomes compulsory.
- An accurate shoe-fit consists of more than just the static dimensions of the shoe. An investigation of the foot under dynamic conditions, with the accompanying assessment of the foot pliability could equip shoe manufacturers with more information to develop better-fitting shoes for South African children.

- Further research which utilizes a longitudinal study to gain information on the foot development of the habitually barefoot child and adolescent in South Africa, is recommended.

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ADDENDA

ADDENDUM A: ETHICAL APPROVAL

Approval from REC 2018

NOTICE OF APPROVAL

REC Humanities New Application Form

29 September 2018

Project number: 7153

Project Title: Foot morphology of urban and rural South African children and adolescents

Dear Prof Rachel Venter

Your response to stipulations submitted on 20 August 2018 was reviewed and approved by the REC: Humanities.

Please note the following for your approved submission:

Ethics approval period:

Protocol approval date (Humanities)	Protocol expiration date (Humanities)
16 August 2018	15 August 2019

GENERAL COMMENTS:

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 (7153) 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)

Included Documents:

Document Type	File Name	Date	Version
Default	Scoring sheet for assessments	02/05/2018	1
Non-disclosure agreement	Confidentiality agreement	22/05/2018	1
Parental consent form	English consent Parents	13/06/2018	1
Parental consent form	Vrywaringsvorm - ouers	13/06/2018	1
Assent form	Consent form - High school students	13/06/2018	1
Assent form	Vrywaringsvorm - hoërskoolkinders	13/06/2018	1
Assent form	Informasie en vrywaringsvorm – kinders	13/06/2018	1
Assent form	Information leaflet and assent form - children	13/06/2018	1
Informed Consent Form	Informasie en vrywaringsvorm - kinders	13/06/2018	1
Informed Consent Form	Information leaflet and assent form - children	13/06/2018	1
Informed Consent Form	Consent form - High school students	13/06/2018	1
Informed Consent Form	Vrywaringsvorm - hoërskoolkinders	13/06/2018	1

Data collection tool	Kaalvoetvraelys	13/06/2018	1
Data collection tool	Barefoot habits questionnaire	13/06/2018	1
Data collection tool	Tests and measurements	13/06/2018	1
Proof of permission	Western Cape Education Department Research approval letter	13/06/2018	1
Informed Consent Form	Consent form - Parents 2	18/07/2018	2
Informed Consent Form	Vrywaringsvorm - ouers 2	18/07/2018	2
Informed Consent Form	Vrywaringsvorm - hoërskoolkinders 2	18/07/2018	2
Informed Consent Form	Consent form – High school students 2	18/07/2018	2
Informed Consent Form	Informasie en vrywaringsvorm – kinders 2	18/07/2018	2
Informed Consent Form	Information leaflet and assent form - children 2	18/07/2018	2
Research Protocol/Proposal	Proposal 2	18/07/2018	2
Default	Modifications required for REC	18/07/2018	1
Default	REC-2018-7153 Feedback to REC	14/08/2018	2
Default	REC-2018-7153 Feedback to REC 20 August 2018	20/08/2018	3

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.*

Approval from HREC 2020

Approval Notice

New Application

07/05/2020

Project ID :14419

HREC Reference No: S20/01/008

Project Title: Foot morphology of urban and rural South African children and adolescents

Dear Mrs Marise Breet

We refer to your response received on 20/03/2020. Please be advised that your submission was reviewed and **approved** by members of **Health Research Ethics Committee** via **expedited** review procedures on 07/05/2020.

Please note the following information about your approved research protocol:

Protocol Approval Date: 07 May 2020

Protocol Expiry Date: 06 May 2020

COVID19 Proviso

1. Kindly note that although the study has been granted ethics approval, the study may not proceed during the current national lockdown as an embargo has been placed on studies that require face-to- face interaction with research participants and/or put participants in harm's way in the time of COVID-19 – either potentially or in reality.
2. HREC will publish on the HREC website a date when the said embargo is to be lifted taking into consideration the best interest of participants and national interests around COVID-19.
3. If you wish to continue with the study, please consult with the Health Research Ethics Office staff to explore requirements and possibilities.

Please remember to use your Project ID 14419 and Ethics Reference Number S20/01/008 on any documents or correspondence with the HREC concerning your research protocol.

Please note that the HREC 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.

After Ethical Review

Translation of the informed consent document(s) to the language(s) applicable to your study participants should now be submitted to the HREC.

Please note you can submit your progress report through the online ethics application process, available at: Links Application Form Direct Link and the application should be submitted to the HREC before the year has expired. Please see *Forms and Instructions* on our HREC website (www.sun.ac.za/healthresearchethics) for guidance on how to submit a progress report.

The HREC will then consider the continuation of the project for a further year (if necessary). Annually a number of projects may be selected randomly for an external audit.

Provincial and City of Cape Town Approval

Please note that for research at a primary or secondary healthcare facility, permission must still be obtained from the relevant authorities (Western Cape Departement of Health and/or City Health) to conduct the research as stated in the protocol. Please consult the Western Cape Government website for access to the online Health Research Approval Process, see: https://www.westerncape.gov.za/general-publication/health-research-approval-process. Research that will be conducted at any tertiary academic institution requires approval from the relevant hospital manager. Ethics approval is required BEFORE approval can be obtained from these health authorities.

We wish you the best as you conduct your research.

For standard HREC forms and instructions, please visit: Forms and Instructions on our HREC website https://applyethics.sun.ac.za/ProjectView/Index/14419

If you have any questions or need further assistance, please contact the HREC office at 021 938 9677.

Yours sincerely,

Mrs. Melody Shana

Coordinator

HREC1

National Health Research Ethics Council (NHREC) Registration Number:

REC-130408-012 (HREC1)•REC-230208-010 (HREC2)

Federal Wide Assurance Number: 00001372
Office of Human Research Protections (OHRP) Institutional Review Board (IRB) Number:
IRB0005240 (HREC1)•IRB0005239 (HREC2)

The Health Research Ethics Committee (HREC) complies with the SA National Health Act No. 61 of 2003 as it pertains to health research. The HREC abides by the ethical norms and principles for research, established by the World Medical Association (2013). Declaration of Helsinki: Ethical Principles for Medical Research Involving Human Subjects; the South African Department of Health (2006). Guidelines for Good Practice in the Conduct of Clinical Trials with Human Participants in South Africa (2nd edition); as well as the Department of Health (2015). Ethics in Health Research: Principles, Processes and Structures (2nd edition).

The Health Research Ethics Committee reviews research involving human subjects conducted or supported by the Department of Health and Human Services, or other federal departments or agencies that apply the Federal Policy for the Protection of Human Subjects to such research (United States Code of Federal Regulations Title 45 Part 46); and/or clinical investigations regulated by the Food and Drug Administration (FDA) of the Department of Health and Human Services.

ADDENDUM B: LETTERS OF APPROVAL FROM THE WESTERN CAPE DEPARTMENT OF EDUCATION

Letter of approval from the Western Cape Department of Education 2018

Audrey.wyngaard@westerncape.gov.za

tel: +27 021 467 9272

Fax: 0865902282

Private Bag x9114, Cape Town, 8000

wced.wcape.gov.za

REFERENCE: 20180425–1590

ENQUIRIES: Dr A T Wyngaard

Mrs Marise Breet
34 Hebron Street
Eversdal
Durbanville
7550

Dear Mrs Marise Breet

RESEARCH PROPOSAL: **FOOT POSTURE OF URBAN AND RURAL SOUTH AFRICAN CHILDREN AND ADOLESCENTS**

Your application to conduct the above-mentioned research in schools in the Western Cape has been approved subject to the following conditions:

1. Principals, educators and learners are under no obligation to assist you in your investigation.
2. Principals, educators, learners and schools should not be identifiable in any way from the results of the investigation.
3. You make all the arrangements concerning your investigation.
4. Educators' programmes are not to be interrupted.
5. The Study is to be conducted from **02 May 2018 till 27 February 2019**
6. No research can be conducted during the fourth term as schools are preparing and finalizing syllabi for examinations (October to December).

7. Should you wish to extend the period of your survey, please contact Dr A.T Wyngaard at the contact numbers above quoting the reference number?
8. A photocopy of this letter is submitted to the principal where the intended research is to be conducted.
9. Your research will be limited to the list of schools as forwarded to the Western Cape Education Department.
10. A brief summary of the content, findings and recommendations is provided to the Director: Research Services.
11. The Department receives a copy of the completed report/dissertation/thesis addressed to:

The Director: Research Services

Western Cape Education Department
Private Bag X9114
CAPE TOWN
8000

We wish you success in your research.

Kind regards.
Signed: Dr Audrey T Wyngaard
Directorate: Research
DATE: 25 April 2018

Letter of approval from the Western Cape Department of Education 2019

Audrey.wyngaard@westerncape.gov.za

Tel: +27 021 467 9272

Fax: 0865902282

Private Bag x9114, Cape Town, 8000

wced.wcape.gov.za

REFERENCE: 20180425–1590

ENQUIRIES: Dr A T Wyngaard

Mrs Marise Breet
34 Hebron Street
Eversdal
Durbanville
7550

Dear Mrs Marise Breet

RESEARCH PROPOSAL: FOOT POSTURE OF URBAN AND RURAL SOUTH AFRICAN CHILDREN AND ADOLESCENTS

Your application to conduct the above-mentioned research in schools in the Western Cape has been approved subject to the following conditions:

1. Principals, educators and learners are under no obligation to assist you in your investigation.
2. Principals, educators, learners and schools should not be identifiable in any way from the results of the investigation.
3. You make all the arrangements concerning your investigation.
4. Educators' programmes are not to be interrupted.
5. The Study is to be conducted from **20 January 2020 till 20 March 2020**
6. No research can be conducted during the fourth term as schools are preparing and finalizing syllabi for examinations (October to December).
7. Should you wish to extend the period of your survey, please contact Dr A.T Wyngaard at the contact numbers above quoting the reference number?

8. A photocopy of this letter is submitted to the principal where the intended research is to be conducted.
9. Your research will be limited to the list of schools as forwarded to the Western Cape Education Department.
10. A brief summary of the content, findings and recommendations is provided to the Director: Research Services.
11. The Department receives a copy of the completed report/dissertation/thesis addressed to:

The Director: Research Services
Western Cape Education Department
Private Bag X9114
CAPE TOWN
8000

We wish you success in your research.

Kind regards.
Signed: Dr Audrey T Wyngaard
Directorate: Research
DATE: 06 November 2019

ADDENDUM C: INFORMED CONSENT FORMS

Letter to headmaster – Information about study

(Datum)

Beste Mnr/Mev ……….

RE: Navorsing oor voetmorfologie van Suid-Afrikaanse kinders en adolessente in die stad en plattelandse gebiede

Ek is Marise Breet, 'n biokinetikus en MSc student van die Departement van Sportwetenskap aan die Universiteit van Stellenbosch. Ek is deel van 'n navorsingsprojek wat handel oor die ontwikkeling van kinders en adolessente se voete, onder leiding van Prof Ranel Venter. Daar is tot op hede baie min informasie oor Suid-Afrikaanse kinders en adolessente se voete. Ons het 20 skole in die Wes-Kaap geidentifiseer en ek wil graag u skool uitnooi om deel te neem aan ons navorsingstudie. Ons het reeds toestemming by die Departement van Onderwys van die Wes-Kaap gekry om u te kontak. U skool is vir moontlike deelname aan die studie gekies op grond van die area waar u skool geleë is, asook die ouderdomme van die kinders in u skool.

- **DOEL VAN DIE STUDIE**

Die hoofdoel van die studie is om te bepaal hoe die voetgroottes en voetvorms van Suid-Afikaanse kinders en adolessente verskil. Hierdie informasie gaan ons help om die huidige skoengroottes en die effek wat skoene op die ontwikkelende voet het, te evalueer.

- **PROSEDURES**

Indien u instem dat u skool kan deelneem aan hierdie studie, sal die deelnemende leerders op ‘n bepaalde dag, eenmaal die volgende toetse en metings ondergaan:

  - *Invul van 'n vraelys oor kaalvoetgewoontes*: Hiermee wil ons agterkom hoe gereeld die leerders kaalvoet is.
  - *Antropometriese meting*: Die leerders se lengte en gewig sal gemeet word.
  - *Voetvorm:* Die leerders sal gevra word om kaalvoet op 'n voetmetingsapparaat te staan waar hulle voetlengte en -breedte sowel as die hoogte van sy/haar voetbrug bepaal sal word.

- **MOONTLIKE RISIKO'S EN ONGEMAK**

Hierdie is almal eenvoudige toetse. Alhoewel dit dalk onbekend sal wees vir die leerders behoort dit nie die leerders buitengewoon moeg te maak of ongemak te veroorsaak nie.

- **MOONTLIK VOORDELE VIR DIE STUDIEDEELNEMERS EN/OF SAMELEWING**

U skool sal geen direkte voordeel uit die studie trek nie. In die groter prentjie hou die studie wel voordele in vir:

- Die kennis op die gebied van sportwetenskap
- Data oor die ontwikkeling van kindervoete
- Informasie kan moontlik 'n meer akkurate en opgedateerde gids wees vir Suid-Afrikaanse skoenvervaardigers
- Uitskakeling van toekomstige biomeganiese probleme in kinders en volwassenes se voete, knieë, heupe en werwelkolom.

- **VERGOEDING VIR DEELNAME**

U leerders of skool sal nie vir deelname aan die studie betaal word nie.

- **VERTROULIKHEID**

Ons wil bepaal hoe kinders en adolessente se voete groei, ontwikkel en verander oor tyd, soos hulle ouer word. Dit sal ons help om die karaktereienskappe van Suid-Afrikaanse kinders en adolessente te identifiseer, wat skoenvervaardinging in Suid-Afrika kan beinvloed.
Vertroulikheid sal gehandhaaf word deur die data en harde kopieë veilig in 'n geslote kamer te bêre. Die resultate sal gestoor word op 'n persoonlike rekenaar met 'n wagwoord.
Alle data sal ten alle tye anoniem hanteer word. Wanneer u leerders se data met ander kinders sin vergelyk word, sal hulle identiteit nie verklap word nie. U mag op enige stadium toestemming terugtrek en ons vra om die dokumente te vernietig.
Enige informasie in konneksie met die studie, wat u leerders se identiteit kan verklap sal vertroulik hanteer word en sal slegs met u toestemming of ingevolge wetsvereistes bekend gemaak word. Slegs die navorser en die studieleier sal na die data kyk. Indien die navorsing gepubliseer word, sal die data in die algemeen maw vir die groep in die geheel bespreek word.

- **DEELNAME EN ONTTREKKING**

U kan kies of u leerders aan hierdie studie mag deelneem of nie. So ook sal elke leerder en sy ouers ‘n vrywaringsvorm moet teken om in te stem vir deelname. Die kind/ouer kan steeds in enige stadium onttrek. Nie-deelname sal geen negatiewe gevolge vir u leerders inhou nie. Die navorser kan ook besluit om u kind aan die studie te onttrek indien omstandighede vereis

- **BESONDERHEDE VAN NAVORSERS**

Indien u enige vrae oor die navorsing het of as enige iets u pla, kontak ons gerus:
Marise Breet (selfoon: 083-533-0580 of per e-pos: marise@mbio.co.za)
Prof Ranel Venter (selfoon: 083-309-2894 of per e-pos: rev@sun.ac.za)

- **REGTE VAN NAVORSINGSDEELNEMERS**

Vir enige vrae oor u leerders se regte as studiedeelnemers, skakel asb vir:
Ms Marlene Fouche by die Universiteit van Stellenbosch se Afdeling Navorsingsontwikkeling (Werk: 021-808-4622 of per e-pos mfouche@sun.ac.za).

Indien u inwillig dat leerders in u skool gekontak kan word vir deelname en dat die toetsings in u skool mag plaasvind, sal ek dit waardeer indien u terugvoer aan my kan gee by marise@mbio.co.za in terme van die verdere prosesse en prosedures wat u vereis. Ek sal u in die week van 18 November telefonies kontak indien ek nie per e-pos terugvoer ontvang het nie.

By voorbaat dankie

Groete
Marise Breet

Written Project Information Sheet and Informed consent for parents (English)

STELLENBOSCH UNIVERSITY

CONSENT TO PARTICIPATE IN RESEARCH

PARENTS

Foot morphology of urban and rural South African children and adolescents

I am Marise Breet, MSc student from the Department of Sport Science, Stellenbosch University. We are busy with a research project in which we are investigating how South-African children and adolescent's feet are developing over time and how the foot functions in standing and moving positions (foot posture). This study is led by Prof. Ranel Venter. I would like to invite your child to participate in the research study. The results of this study will be used in my thesis for my Master's degree in Sport Science. Your child has been chosen as a possible participant in the study because he/she are in one of the participating schools and are of the right age. I will be performing the tests at the school, at an allocated time during school hours.

- **PURPOSE OF THE STUDY**

The main purpose of this study is to determine the differences in foot sizes, foot shapes and foot functions (collectively explained as foot posture) of South African children and adolescents. This information could assist us to evaluate the current shoe sizes children have access to and to provide information on footwear use for growing feet.

- **PROCEDURES**

If you agree that your child take part in this study, your child will have to undergo the following tests and measurements on a once-off basis:

- Barefoot questionnaire: This written questionnaire will be done to determine how often your child is barefoot.
- Anthropometric measurements: Your child's height and weight will be measured.
- Foot shape: Your child will be asked to stand/sit without shoes with both legs on a foot measuring calliper. A calliper is an instrument to measure foot length, foot width and arch height.

- **POTENTIAL RISKS AND DISCOMFORT**

There are no risks involved in participation. These are simple tests and they should not make your child tired or cause any discomfort.

- **POTENTIAL BENEFITS FOR STUDY PARTICIPANTS AND/OR SOCIETY**

Your child will not gain any direct benefit from participating in the study. In the bigger picture however, the study holds benefits for the knowledge in the field of Sport Science as well as data in the development of your child's foot. This information could possibly be a more accurate and updated guide to South African shoe manufacturers. It has been shown that children's feet are more sensitive to external factors, like shoes, and therefore it is of utmost importance that the shoes fit the diameters of our children's feet in walking and standing.

- **REMUNERATION FOR PARTICIPATION**

Your child will not be paid to participate in the study.

- **CONFIDENTIALITY**

We want to determine how children's feet develop and grow over time as they get older. This will help us to identify characteristics of the feet of habitually barefoot South African children and adolescents, which could influence shoe development in South Africa.

While we keep the data, hard copies with their information will be safely protected in a locked room, while results will be saved on a password protected computer. When we compare your child's data with other children, their identity will not be known. You may withdraw consent and ask us to destroy unused identifiable documents and data at any time.

Any information that is obtained in connection with this study and that could reveal your child's identity will remain confidential and will only be revealed with your consent or if required by law. Only the researcher and supervisor will be able to look at the data. If the research should be published, the data will be discussed in general and group data will be reported. Your child will not be identifiable.

- **PARTICIPATION AND WITHDRAWAL**

You can decide whether your child could participate in this study, or not. Non-participation or withdrawal at any stage will not hold any negative consequences for you or your child. The researcher could also decide to remove your child from the study should circumstances require this. Your child will not waive any legal claims or rights by taking part of this research study.

- **DETAILS OF RESEARCHERS**

If you should have any questions or concerns, please feel free to contact us:

Marise Breet (mobile: 083-533-0580 or by email: marise@mbio.co.za)

Prof Ranel Venter (mobile: 083-309-2894 or by email: rev@sun.ac.za)

- **RIGHTS OF RESEARCH PARTICIPANTS**

For any questions about your child's rights as a study participant please contact:

Ms Marlene Fouche at the University of Stellenbosch, Division for Research Development

(Work: 021-808-4622 or by email mfouche@sun.ac.za).

SIGNATURE OF PARENT

I was given a copy of the letter with information.

I, (name) ____ consent that

my child (name) ____ in grade ______ may participate in this study.

Date of birth of child: ___________________

____

Name of parent

____ _________________

Signature of parent **Date**

Written Project Information Sheet and Informed consent for parents (Afrikaans)

UNIVERSITEIT VAN STELLENBOSCH
VRYWARINGSVORM VIR OUERS

Voetmorfologie van Suid-Afrikaanse kinders en adolessente in die stad en plattelandse gebiede

Ek is Marise Breet, 'n biokinetikus en MSc student van die Departement van Sportwetenskap aan die Universiteit van Stellenbosch. Ek is deel van 'n navorsingsprojek wat handel oor die ontwikkeling en funksie van Suid-Afrikaanse kinders en adolessente se voete (voetpostuur), onder leiding van Prof Ranel Venter. Ek wil u kind graag uitnooi om deel te neem aan ons navorsingstudie. Die resultate van hierdie studie sal gebruik word in my tesis vir my Meestersgraad in Sportwetenskap. Hy/sy is as 'n moontlike studiedeelnemer gekies omdat hy/sy in een van die deelnemerskole is en ook die regte ouderdom is.

- **DOEL VAN DIE STUDIE**

Die hoofdoel van die studie is om te bepaal hoe die voetgroottes, voetvorms en voetfunksies (gesamentlik beskryf as voetpostuur) van Suid-Afikaanse kinders en adolessente verskil. Hierdie informasie gaan ons help om die huidige skoengroottes en die effek wat skoene op die ontwikkelende voet het, te evalueer.

- **PROSEDURES**

Indien u instem dat u kind kan deelneem aan hierdie studie, sal u kind eenmaal die volgende toetse en metings ondergaan:

- *Invul van 'n vraelys oor kaalvoetgewoontes*: Hiermee wil ons agterkom hoe gereeld jou kind kaalvoet is.
- *Antropometriese meting*: Jou kind se lengte en gewig sal gemeet word.
- *Voetvorm:* U kind sal gevra word om kaalvoet op 'n voetmetingsapparaat te staan waar u kind se voetlengte en -breedte sowel as die hoogte van sy/haar voetbrug bepaal sal word.

- **MOONTLIKE RISIKO'S EN ONGEMAK**

Hierdie is almal eenvoudige toetse. Alhoewel dit dalk onbekend vir u kind kan wees behoort dit nie u kind buitengewoon moeg te maak of ongemak te veroorsaak nie.

- **MOONTLIK VOORDELE VIR DIE STUDIEDEELNEMERS EN/OF SAMELEWING**

U kind sal geen direkte voordeel uit die studie trek nie. In die groter prentjie hou die studie wel voordele in vir die kennis op die gebied van sportwetenskap sowel as vir die data oor die ontwikkeling van kindervoete. Hierdie informasie kan moontlik 'n meer akkurate en opgedateerde gids wees vir Suid-Afrikaanse skoenvervaardigers. Dit is bewys dat kinders se voete baie meer sensitief is vir eksterne faktore, soos skoene, en dit is dus van groot belang dat kinders se skoene pas by die afmetings van kinders se voete.

- **VERGOEDING VIR DEELNAME**

U kind sal nie vir deelname aan die studie betaal word nie.

- **VERTROULIKHEID**

Ons wil bepaal hoe kinders se voete groei, ontwikkel en verander oor tyd, soos hulle ouer word. Dit sal ons help om die karaktereienskappe van Suid-Afrikaanse kinders en adolessente te identifiseer, wat skoenvervaardinging in Suid-Afrika kan beinvloed.
Vertroulikheid sal gehandhaaf word deur die data en harde kopieë veilig in 'n geslote kamer te bêre. Die resultate sal gestoor word op 'n persoonlike rekenaar met 'n wagwoord.
Alle data sal ten alle tye so hanteer word dat net ek en my studieleier jou kind se naam sal sien. Niemand anders sal die lyste met die data en hul naam sien nie. Wanneer u kind se data met ander kinders sin vergelyk word, sal hulle identiteit nie verklap word nie. U mag op enige stadium toestemming terugtrek en ons vra om die dokumente te vernietig.
Enige informasie in konneksie met die studie, wat u kind se identiteit kan verklap sal vertroulik hanteer word en sal slegs met u toestemming of ingevolge wetsvereistes bekend gemaak word. Slegs die navorser en die studieleier sal na die data kyk. Indien die navorsing gepubliseer word, sal die data in die algemeen maw vir die groep in die geheel bespreek word.

- **DEELNAME EN ONTTREKKING**

U kan kies of u kind aan hierdie studie mag deelneem of nie. Indien u aanbied dat u kind kan deelneem, kan u hom/haar steeds in enige stadium onttrek. Nie-deelname sal geen negatiewe gevolge vir u kind inhou nie. Die navorser kan ook besluit om u kind aan die studie te onttrek indien omstandighede vereis

- **BESONDERHEDE VAN NAVORSERS**

Indien u enige vrae oor die navorsing het of as enige iets u pla, kontak ons gerus:
Marise Breet (selfoon: 083-533-0580 of per e-pos: marise@mbio.co.za)

Prof Ranel Venter (selfoon: 083-309-2894 of per e-pos: rev@sun.ac.za)

- **REGTE VAN NAVORSINGSDEELNEMERS**

Vir enige vrae oor u kind se regte as studiedeelnemer, skakel asb vir:

Ms Marlene Fouche by die Universiteit van Stellenbosch se Afdeling Navorsingsontwikkeling (Werk: 021-808-4622 of per e-pos mfouche@sun.ac.za).

HANDTEKENING VAN OUER

Ek het 'n afskrif van die vorm ontvang.

Ek, (naam) ____ stem in dat

my kind (naam) ____ in graad ______ aan hierdie studie kan deelneem.

Geboortedatum van kind: _______________________

____

Naam van ouer/voog

_______________________________________ ________________

Handtekening van ouer/voog **Datum**

Written Project Information Sheet and Informed consent for high school participants (English)

STELLENBOSCH UNIVERSITY

CONSENT TO PARTICIPATE IN RESEARCH

HIGH SCHOOL STUDENTS

Foot morphology of urban and rural South African children and adolescents

I am Marise Breet, MSc student from the Department of Sport Science, Stellenbosch University. We are busy with a research project in which we are investigating how South-African children's and adolescent's feet are developing over time and how the foot functions in standing and moving positions (foot posture). This study is led by prof. Ranel Venter. I would like to invite you to participate in the research study. The results of this study will be used in my thesis for my Master's degree in Sport Science. You have been chosen as a possible participant in the study because you are in one of the participating schools and are of the right age. I will be performing the tests at the school, at an allocated time during school hours.

- **PURPOSE OF THE STUDY**

The main purpose of this study is to determine the differences in foot sizes, foot shapes and foot functions (collectively explained as foot posture) of South African children and adolescents. This information could assist us to evaluate the current shoe sizes children have access to and to provide information on footwear use for growing feet.

- **PROCEDURES**

If you agree to take part in this study, you will have to undergo the following tests and measurements on a once-off basis:

- Barefoot questionnaire: This written questionnaire will be done to determine how often you are barefoot.
- Anthropometric measurements: Your height and weight will be measured.
- Foot shape: You will be asked to stand/sit without shoes with both legs on a foot measuring caliper. A caliper is an instrument to measure your foot length, foot width and arch height.

- **POTENTIAL RISKS AND DISCOMFORT**

There are no risks involved in participation. These are simple tests and they should not make you tired or cause any discomfort

- **POTENTIAL BENEFITS FOR STUDY PARTICIPANTS AND/OR SOCIETY**

You will not gain any direct benefit from participating in the study. In the bigger picture however, the study holds benefits for the knowledge in the field of Sport Science as well as data in the development of children's feet. This information could possibly be a more accurate and updated guide to South African shoe manufacturers. It has been shown that children's feet are more sensitive to external factors, like shoes, and therefore it is of utmost importance that the shoes fit the diameters of our children's feet in walking and standing.

- **REMUNERATION FOR PARTICIPATION**

You will not be paid to participate in the study.

- **CONFIDENTIALITY**

We want to determine how children's feet develop and grow over time as they get older. This will help us to identify characteristics of the feet of habitually barefoot South African children and adolescents, which could influence shoe development in South Africa.

While we keep the data, hard copies with your information will be safely protected in a locked room, while results will be saved on a password protected computer. Only my study leader and I will see the data with you name on. Other people will not see the lists with your name on. When we compare your data with other children, your identity will not be known. You may withdraw consent and ask us to destroy unused identifiable documents and data at any time.

Any information that is obtained in connection with this study and that could reveal your identity will remain confidential and will only be revealed with your consent or if required by law. Only the researcher and supervisor will be able to look at the data. If the research should be published, the data will be discussed in general and group data will be reported. You will not be identifiable.

- **PARTICIPATION AND WITHDRAWAL**

You can decide whether you participate in this study, or not. Non-participation or withdrawal at any stage will not hold any negative consequences for you. The researcher could also decide to remove you from the study should circumstances require this. You will not waive any legal claims or rights by taking part of this research study.

- **DETAILS OF RESEARCHERS**

If you should have any questions or concerns, please feel free to contact us:

Marise Breet (mobile: 083-533-0580 or by email: marise@mbio.co.za)

Prof Ranel Venter (mobile: 083-309-2894 or by email: rev@sun.ac.za)

- **RIGHTS OF RESEARCH PARTICIPANTS**

For any questions about you rights as a study participant please contact:

Ms Marlene Fouche at the University of Stellenbosch, Division for Research Development (Work: 021-808-4622 or by email mfouche@sun.ac.za).

SIGNATURE OF PARTICIPANT

I was given a copy of the letter with information.

I, (name) ____ consent that I will participate in this study.

____

Name of participant

_______________________________________ ________________

Signature of participant **Date**

Written Project Information Sheet and Informed consent for high school participants (Afrikaans)

UNIVERSITEIT VAN STELLENBOSCH

VRYWARINGSVORM VIR HOëRSKOOLKINDERS

Voetmorfologie van Suid-Afrikaanse kinders en adolessente in die stad en plattelandse gebiede

Ek is Marise Breet, 'n biokinetikus en MSc student van die Departement van Sportwetenskap aan die Universiteit van Stellenbosch. Ek is deel van 'n navorsingsprojek wat handel oor die ontwikkeling en funksie van Suid-Afrikaanse kinders en adolessente se voete (voetpostuur), onder leiding van Prof Ranel Venter. Ek wil jou graag uitnooi om deel te neem aan ons navorsingstudie. Die resultate van hierdie studie sal gebruik word in my tesis vir my Meestersgraad in Sportwetenskap. Jy is as 'n moontlike studiedeelnemer gekies omdat jy in een van die deelnemerskole is en ook die regte ouderdom is. Ek sal jou voete by die skool kom toets, op ‘n sekere tyd gedurende skoolure.

- **DOEL VAN DIE STUDIE**

Die hoofdoel van die studie is om te bepaal hoe die voetgroottes, voetvorms en voetfunksies (gesamentlik beskryf as voetpostuur) van Suid-Afikaanse kinders en adolessente verskil. Hierdie informasie gaan ons help om die huidige skoengroottes en die effek wat skoene op die ontwikkelende voet het, te evalueer.

- **PROSEDURES**

Indien jy instem om deel te neem aan hierdie studie, sal jy eenmaal die volgende toetse en metings ondergaan:

- *Invul van 'n vraelys oor kaalvoetgewoontes*: Hiermee wil ons agterkom hoe gereeld jy kaalvoet is.
- *Antropometriese meting*: Jou lengte en gewig sal gemeet word.
- *Voetvorm:* Jy sal gevra word om kaalvoet op 'n voetmetingsapparaat te staan waar jou voetlengte en -breedte sowel as die hoogte van jou voetbrug bepaal sal word.

- **MOONTLIKE RISIKO'S EN ONGEMAK**

Hierdie is almal eenvoudige toetse. Alhoewel dit dalk onbekend vir jou kan wees behoort dit jou nie buitengewoon moeg te maak of ongemak te veroorsaak nie.

- **MOONTLIK VOORDELE VIR DIE STUDIEDEELNEMERS EN/OF SAMELEWING**

Jy sal geen direkte voordeel uit die studie trek nie. In die groter prentjie hou die studie wel voordele in vir die kennis op die gebied van sportwetenskap sowel as vir die data oor die ontwikkeling van kindervoete. Hierdie informasie kan moontlik 'n meer akkurate en opgedateerde gids wees vir Suid-Afrikaanse skoenvervaardigers. Dit is bewys dat kinders se voete baie meer sensitief is vir eksterne faktore, soos skoene, en dit is dus van groot belang dat kinders se skoene pas by die afmetings van kinders se voete.

- **VERGOEDING VIR DEELNAME**

Jy sal nie vir deelname aan die studie betaal word nie.

- **VERTROULIKHEID**

Ons wil bepaal hoe kinders se voete groei, ontwikkel en verander oor tyd, soos hulle ouer word. Dit sal ons help om die karaktereienskappe van Suid-Afrikaanse kinders en adolessente te identifiseer, wat skoenvervaardinging in Suid-Afrika kan beinvloed.

Vertroulikheid sal gehandhaaf word deur die data en harde kopieë veilig in 'n geslote kamer te bêre. Die resultate sal gestoor word op 'n persoonlike rekenaar met 'n wagwoord.

Alle data sal ten alle tye so hanteer word dat net ek en my studieleier jou naam sal sien. Niemand anders sal die lyste met die data en jou naam sien nie. Wanneer jou data met ander kinders sin vergelyk word, sal jou identiteit nie verklap word nie. Jy mag op enige stadium toestemming terugtrek en ons vra om die dokumente te vernietig.

Enige informasie in konneksie met die studie, wat jou identiteit kan verklap sal vertroulik hanteer word en sal slegs met jou toestemming of ingevolge wetsvereistes bekend gemaak word. Slegs die navorser en die studieleier sal na die data kyk. Indien die navorsing gepubliseer word, sal die data in die algemeen maw vir die groep in die geheel bespreek word.

- **DEELNAME EN ONTTREKKING**

Jy kan kies of jy aan hierdie studie wil deelneem of nie. Indien jy belangstel om deel te neem, kan jy steeds in enige stadium onttrek. Nie-deelname sal geen negatiewe gevolge vir jou inhou nie. Die navorser kan ook besluit om jou aan die studie te onttrek indien omstandighede vereis

- **BESONDERHEDE VAN NAVORSERS**

Indien jy enige vrae oor die navorsing het of as enige iets jou pla, kontak ons gerus:

Marise Breet (selfoon: 083-533-0580 of per e-pos: marise@mbio.co.za)

Prof Ranel Venter (selfoon: 083-309-2894 of per e-pos: rev@sun.ac.za)

- **REGTE VAN NAVORSINGSDEELNEMERS**

Vir enige vrae oor jou regte as studiedeelnemer, skakel asb vir:

Ms Marlene Fouche by die Universiteit van Stellenbosch se Afdeling Navorsingsontwikkeling (Werk: 021-808-4622 of per e-pos mfouche@sun.ac.za).

HANDTEKENING VAN DEELNEMER

Ek het 'n afskrif van die vorm ontvang.

Ek, (naam) ____ stem in om aan hierdie studie deel te neem.

____

Naam van deelnemer

____ ________________

Handtekening van deelnemer **Datum**

Participant information leaflet and assent form for primary school participants (English)

STELLENBOSCH UNIVERSITY

PARTICIPATION INFORMATION LEAFLET AND ASSENT FORM

Foot morphology of urban and rural South African children and adolescents

RESEARCHER'S NAME: Marise Breet

ADDRESS: Department of Sport Science, Stellenbosch University

CONTACT NUMBER: 021 808 4735/ 021 808 4735

What is RESEARCH?

Research is something we do to find NEW KNOWLEDGE about the way things (and people) work. We use research projects and studies to help us find out more about children and teenagers and the things that affect their lives, their schools, their families and their health. We do this to try and make the world a better place!

What is this research project all about?

During this project we want to see what effect your everyday shoes and if you live inside/outside a city have on:

The way you walk

The shape of your feet

Why have I been invited to take part in this research project?

You are invited because you are a pupil in one of the schools that was chosen for the study. You are healthy, do not have a foot injury and you are the right age.

Who is doing the research?

My name is Marise Breet. I am a Biokineticist working in my own practice in Durbanville. My job is to help people get better after an injury, an accident or if they were very ill. We help them by doing specific exercises.

What will happen to me in this study?

During the study we will do a few tests.

First of all we will measure your height and weight.

We will take measurements of your foot while you are standing and sitting.

Can anything bad happen to me?

Nothing bad can happen to you during the study. The only thing that might happen is that your muscles might feel uncomfortable. We will show you how to do everything.

Will anyone know I am in the study?

Nobody have to know that you are part of the study. Your specific results will only be known to Marise.

Who can I talk to about the study?

If you have questions or want to speak to someone about the study you can contact:

Marise Breet (cell phone: 083 533 0580; email: marise@mbio.co.za) or Prof Ranel Venter (cell phone: 083 309 2894; email: rev@sun.ac.za)

What if I do not want to do this?

No one can force you to be part of the study. If you do not want to do this, you do not have to. Even if your parents allowed you and signed the form, you still do not have to do it.

If you said that you want to be part of the study and decide later on that you do not want to do it any more, nothing will happen to you and you can stop being part of it.

Do you understand this research study and are willing to take part in it?

YES NO

Has the researcher answered all your questions?

YES NO

Do you understand that you can STOP being part in the study at any time?

YES NO

________________________ ________________

Signature of child **Date**

Participant information leaflet and assent form for primary school participants (Afrikaans)

STELLENBOSCH UNIVERSITEIT

INFORMASIE EN VRYWARINGSVORM VIR KINDERS

Voetmorfologie van Suid-Afrikaanse kinders en adolessente in die stad en plattelandse gebiede

NAVORSER SE NAAM: Marise Breet

ADRES: Departement Sportwetenskap, Universiteit van Stellenbosch

KONTAKNOMMER: 021 808 4735/ 083 533 0580

Wat is NAVORSING?

Navorsing is iets wat ons doen om MEER TE LEER oor hoe dinge (en mense) werk. Ons gebruik navorsingsprojekte of -ondersoeke om meer uit te vind oor kinders en tieners en die dinge wat hulle lewe beïnvloed, soos hulle skool, hulle gesin en hulle gesondheid. Ons doen dit omdat ons die wêreld ’n beter plek probeer maak.

Waaroor gaan hierdie navorsingsprojek?

Met hierdie navorsings wil ons kyk of die skoene wat jy dra, en of jy binne of buite die stad bly, die volgende doen:

Die manier waarop jy loop verander

Die vorm van jou voet

Hoekom vra julle my om aan hierdie navorsingsprojek deel te neem?

Ons wil graag hê dat jy moet deelneem aan die projek, omdat jy in die skool is wat ons gekies het om deel te wees, jy gesond is, jy nie enige beserings het nie, en jy die regte ouderdom is.

Wie doen die navorsing?

My naam is Marise Breet en ek is ’n Biokinetikus. Ek gebruik oefening om mense sterker te maak nadat hulle seergekry het of as hulle baie siek was.

Wat sal ek moet doen as ek aan die studie wil deelneem?

As ons na jou skool toe kom om toetse te doen gaan ons:

Eers kyk hoe lank en swaar jy is.

Ons gaan dan jou voet meet terwyl jy sit en staan.

Is daar enigiets wat verkeerd kan gaan?

Niks kan jou seermaak in die studie nie. Ons sal vir jou mooi wys hoe om alles te doen.

Sal ander mense weet ek neem aan die projek deel?

Niemand hoef te weet dat jy aan die studie deelneem nie en niemand anders, behalwe Marise, sal jou metings sien nie.

Met wie kan ek oor die projek gesels?

As jy enige vrae het oor die projek of as jy met iemand wil gesels oor die projek kan jy vir:

Marise Breet (selfoon: 083 533 0580; e-pos: marise@mbio.co.za) of Prof Ranel Venter (selfoon: 083 309 2894; e-pos: rev@sun.ac.za) kontak.

Wat gebeur as ek nie wil deelneem nie?

Jy hoef net deel te neem aan die projek as jy wil. Jy gaan nie gedwing word nie en dit maak nie saak as jou ouers gesê het jy mag nie, en as jy nie wil nie, hoef jy nie.

As jy wel gesê het jy wil deelneem en jy sien later jy is nie lus nie, kan jy enige tyd vir my sê en dan kan jy ophou deelneem aan die projek.

Verstaan jy waaroor hierdie navorsing gaan, en sal jy aan die projek deelneem?

JA NEE

Het die navorser al jou vrae beantwoord?

JA NEE

Verstaan jy dat jy kan OPHOU deelneem net wanneer jy wil?

JA NEE

______________________________ ______________

Kind se handtekening **Datum**

ADDENDUM D: TESTING SHEETS

General questionnaire and scoring sheet

SCORING SHEET

Foot morphology of urban and rural South African children and adolescents

EVALUATION CODE: ________

General Information

Name and surname: ________________________________

Age: _____ Date of birth: __________________ Gender: ☐ Male ☐ Female

Size shoe: __________ Informed consent: ☐ Yes Barefoot questionnaire: ☐ Yes

TESTING STATION 1:

Height STANDING	cm
Weight	kg

TESTING STATION 2:

	LEFT FOOT	RIGHT FOOT
Foot **length**: STANDING	cm *Mark half of foot	cm *Mark half of foot
Foot **width**: STANDING	cm	cm
Foot **length**: SITTING	cm	cm
Foot **width**: SITTING	cm	cm
Dorsum height STANDING	cm	cm
Dorsum height SITTING	cm	cm

ADDENDUM E: BMI ACCORDING TO AGE

Age (years)	Boys						Girls					
	BMI 16*	BMI 17*	BMI 18.5*	BMI 25*	BMI 30*	BMI 35*	BMI 16*	BMI 17*	BMI 18.5*	BMI 25*	BMI 30*	BMI 35*
5.0	12.80	13.40	14.26	17.39	19.27	20.79	12.59	13.18	14.04	17.23	19.20	20.85
5.5	12.66	13.27	14.15	17.42	19.46	21.15	12.46	13.06	13.93	17.25	19.36	21.16
6.0	12.54	13.16	14.06	17.52	19.76	21.69	12.34	12.96	13.85	17.33	19.62	21.61
6.5	12.44	13.07	14.00	17.67	20.15	22.35	12.26	12.89	13.81	17.48	19.96	22.19
7.0	12.39	13.04	14.00	17.88	20.59	23.08	12.23	12.87	13.83	17.69	20.39	22.88
7.5	12.39	13.06	14.05	18.12	21.06	23.83	12.25	12.91	13.90	17.96	20.89	23.65
8.0	12.43	13.11	14.13	18.41	21.56	24.61	12.30	12.98	14.00	18.28	21.44	24.50
8.5	12.48	13.19	14.24	18.73	22.11	25.45	12.37	13.07	14.13	18.63	22.04	25.42
9.0	12.54	13.27	14.36	19.07	22.71	26.40	12.44	13.16	14.26	18.99	22.66	26.39
9.5	12.61	13.36	14.49	19.43	23.34	27.39	12.52	13.27	14.40	19.38	23.31	27.38
10.0	12.70	13.47	14.63	19.80	23.96	28.35	12.63	13.40	14.58	19.78	23.97	28.36
10.5	12.80	13.59	14.79	20.15	24.54	29.22	12.77	13.57	14.78	20.21	24.62	29.28
11.0	12.91	13.73	14.96	20.51	25.07	29.97	12.94	13.77	15.03	20.66	25.25	30.14
11.5	13.05	13.89	15.15	20.85	25.56	30.63	13.15	14.00	15.30	21.12	25.87	30.93
12.0	13.22	14.07	15.36	21.20	26.02	31.21	13.38	14.26	15.59	21.59	26.47	31.66
12.5	13.40	14.27	15.59	21.54	26.45	31.73	13.64	14.54	15.91	22.05	27.04	32.33
13.0	13.61	14.50	15.84	21.89	26.87	32.19	13.92	14.84	16.23	22.49	27.57	32.91
13.5	13.84	14.74	16.11	22.25	27.26	32.61	14.20	15.13	16.55	22.90	28.03	33.39
14.0	14.09	15.01	16.39	22.60	27.64	32.98	14.47	15.43	16.86	23.27	28.42	33.78
14.5	14.35	15.28	16.69	22.95	28.00	33.29	14.74	15.71	17.16	23.60	28.74	34.07
15.0	14.61	15.55	16.98	23.28	28.32	33.56	15.00	15.97	17.43	23.89	29.01	34.28
15.5	14.87	15.82	17.26	23.59	28.61	33.78	15.24	16.21	17.68	24.13	29.22	34.43
16.0	15.12	16.08	17.53	23.89	28.88	33.98	15.45	16.42	17.90	24.34	29.40	34.55
16.5	15.36	16.33	17.79	24.18	29.15	34.19	15.63	16.61	18.08	24.53	29.55	34.64
17.0	15.59	16.57	18.04	24.46	29.43	34.43	15.78	16.76	18.24	24.70	29.70	34.75
17.5	15.80	16.79	18.28	24.73	29.71	34.71	15.90	16.89	18.38	24.85	29.85	34.87
18.0	16	17	18.5	25	30	35	16	17	18.5	25	30	35

ADDENDUM F: FRONTIERS AUTHOR GUIDELINES

Manuscript Formatting Guidelines

1. General standards

1.1. Article Type

1.2. Templates

1.3. Manuscript Length

1.4. Language Editing

1.5. Language Style

1.6. Search Engine Optimization (SEO)

1.7. CrossMark Policy

1.8. Title

1.9. Authors and Affiliations

1.10. Consortium/Group and Collaborative Authors

1.11. Abstract

1.12. Keywords

1.13. Text

1.14. Nomenclature

1.15. Sections

1.16. Acknowledgments

1.17. Contribution to the Field Statement

2. Figure and Table Guidelines

2.1. CC-BY Licence

2.2. Figure Requirements and Style Guidelines

2.2.1. Captions

2.2.2. Image Size and Resolution Requirements

1. General standards

1.1. Article Type

Frontiers requires authors to carefully select the appropriate article type for their manuscript and to comply with the article type descriptions defined in the journal's "Article Types" page, which can be seen from the "For Authors" menu on any Frontiers journal page. Please pay close attention to the word count limits.

1.2. Templates

If working with Word please use our Frontiers Word templates. If you wish to submit your article as LaTeX, we recommend our Frontiers LaTeX templates.

For LaTeX files, please ensure all relevant manuscript files are uploaded: .tex file, PDF, and .bib file (if the bibliography is not already included in the .tex file).

During the Interactive Review, authors are encouraged to upload versions using "Track Changes." Editors and reviewers can only download the PDF file of the submitted manuscript.

1.3. Manuscript Length

Frontiers encourages the authors to closely follow the article word count lengths given in the "Article Types" page of the journals. The manuscript length includes only the main body of the text, footnotes, and all citations within it, and excludes the abstract, section titles, figure and table captions, funding statement, acknowledgments, and references in the bibliography. Please indicate the number of words and the number of figures and tables included in your manuscript on the first page.

1.4. Language Editing

Frontiers requires manuscripts submitted to meet international English language standards to be considered for publication.

For authors who would like their manuscript to receive language editing or proofreading to improve the clarity of the manuscript and help highlight their research, Frontiers recommends the language-editing services provided by the following external partners:

Editage

Frontiers is pleased to recommend the language-editing service provided by our external partner Editage to authors who believe their manuscripts would benefit from professional editing. These services may be particularly useful for researchers for whom English is not the primary language. They can help to improve the grammar, syntax, and flow of your manuscript prior to submission. Frontiers authors will receive a 10% discount by visiting the following link: https://editage.com/frontiers/.

The Charlesworth Group

Frontiers recommends the Charlesworth Group's author services, who has a long-standing track record in language editing and proofreading. This is a third-party service for which Frontiers authors will receive a 10% discount by visiting the following link: https://www.cwauthors.com/frontiers/.

Note that sending your manuscript for language editing does not imply or guarantee that it will be accepted for publication by a Frontiers journal. Editorial decisions on the scientific content of a manuscript are independent of whether it has received language editing or proofreading by the partner services, or other services.

1.5. Language Style

The default language style at Frontiers is American English. If you prefer your article to be formatted in British English, please specify this on the first page of your manuscript. For any questions regarding style, Frontiers recommends authors to consult the Chicago Manual of Style.

1.6. Search Engine Optimization (SEO)

There are a few simple ways to maximize your article's discoverability. Follow the steps below to improve search results of your article:

- include a few of your article's keywords in the title of the article;
- do not use long article titles;
- pick 5 to 8 keywords using a mix of generic and more specific terms on the article subject(s);
- use the maximum amount of keywords in the first 2 sentences of the abstract;
- use some of the keywords in level 1 headings.

1.7. CrossMark Policy

CrossMark is a multi-publisher initiative to provide a standard way for readers to locate the current version of a piece of content. By applying the CrossMark logo Frontiers is committed to maintaining the content it publishes and to alerting readers to changes if and when they occur. Clicking on the CrossMark logo will tell you the current status of a document and may also give you additional publication record information about the document.

1.8. Title

The title should be concise, omitting terms that are implicit and, where possible, be a statement of the main result or conclusion presented in the manuscript. Abbreviations should be avoided within the title.

Witty or creative titles are welcome, but only if relevant and within measure. Consider if a title meant to be thought-provoking might be misinterpreted as offensive or alarming. In extreme cases, the editorial office may veto a title and propose an alternative.

Authors should try to avoid, if possible:

- titles that are a mere question without giving the answer;
- unambitious titles, for example starting with "Towards," "A description of," "A characterization of," "Preliminary study on;"

- vague titles, for example starting with "Role of…," "Link between…," "Effect of..." that do not specify the role, link, or effect;
- include terms that are out of place, for example the taxonomic affiliation apart from species name.

For Corrigenda, Book Reviews, General Commentaries, and Editorials, the title of your manuscript should have the following format:

- "Corrigendum: Title of Original Article"
- "Book Review: Title of Book"
- General Commentaries
  - "Commentary: Title of Original Article"
  - "Response: Commentary: Title of Original Article"
- "Editorial: Title of Research Topic"

The running title should be a maximum of 5 words in length.

1.9. Authors and Affiliations

All names are listed together and separated by commas. Provide exact and correct author names as these will be indexed in official archives. Affiliations should be keyed to the author's name with superscript numbers and be listed as follows: Laboratory, Institute, Department, Organization, City, State abbreviation (only for United States, Canada, and Australia), and Country (without detailed address information such as city zip codes or street names).

Example: Max Maximus [1]

[1] Department of Excellence, International University of Science, New York, NY, United States.

The Corresponding Author(s) should be marked with an asterisk in the author list. Provide the exact contact email address of the corresponding author(s) in a separate section.

Correspondence:

Max Maximus

maximus@iuscience.edu

If any authors wish to include a change of address, list the present address(es) below the correspondence details using a unique superscript symbol keyed to the author(s) in the author list.

1.10. Consortium/Group and Collaborative Authors

Consortium/group authorship should be listed in the manuscript with the other author(s).

In cases where authorship is retained by the consortium/group, the consortium/group should be listed as an author separated by "," or "and,". The consortium/group name will appear in the author list, in the citation, and in the copyright. If provided, the consortium/group members will be listed in a separate section at the end of the article.

For the collaborators of the consortium/group to be indexed in PubMed, they do not have to be inserted in the Frontiers submission system individually. However, in the manuscript itself, provide a section with the name of the consortium/group as the heading followed by the list of collaborators, so they can be tagged accordingly and indexed properly.

Example: John Smith, Barbara Smith and The Collaborative Working Group.

In cases where work is presented by the author(s) on behalf of a consortium/group, it should be included in the author list separated with the wording "for" or "on behalf of." The consortium/group will not retain authorship and will only appear in the author list.

Example: John Smith and Barbara Smith on behalf of The Collaborative Working Group.

1.11. Abstract

As a primary goal, the abstract should render the general significance and conceptual advance of the work clearly accessible to a broad readership. In the abstract, minimize the use of abbreviations and do not cite references, figures or tables.

For Clinical Trial articles, please include the Unique Identifier and the URL of the publicly accessible website on which the trial is registered.

1.12. Keywords

All article types require a minimum of 5 and a maximum of 8 keywords.

1.13. Text

The entire document should be single-spaced and must contain page and line numbers in order to facilitate the review process. The manuscript should be written using either Word or LaTeX. For templates, see 1.2. Templates.

1.14. Nomenclature

- The use of abbreviations should be kept to a minimum. Non-standard abbreviations should be avoided unless they appear at least four times, and defined upon first use in the main text. Consider also giving a list of non-standard abbreviations at the end, immediately before the Acknowledgments.
- Equations should be inserted in editable format from the equation editor.
- Italicize gene symbols and use the approved gene nomenclature where it is available. For human genes, please refer to the HUGO Gene Nomenclature Committee (HGNC). New gene symbols should be submitted here. Common alternative gene aliases may also be reported, but should not be used alone in place of the HGNC symbol. Nomenclature committees for other species are listed here. Protein products are not italicized.
- We encourage the use of Standard International Units in all manuscripts.
- Chemical compounds and biomolecules should be referred to using systematic nomenclature, preferably using the recommendations by IUPAC.
- Astronomical objects should be referred to using the nomenclature given by the International Astronomical Union provided here.
- Life Science Identifiers (LSIDs) for ZOOBANK registered names or nomenclatural acts should be listed in the manuscript before the keywords. An LSID is represented as a uniform resource name (URN) with the following format: urn:lsid:<Authority>:<Namespace>:<ObjectID>[:<Version>]

For more information on LSIDs please see the Code section.

1.15. Sections

The manuscript is organized by headings and subheadings. The section headings should be those appropriate for your field and the research itself. You may insert up to 5 heading levels into your manuscript (i.e.,: 3.2.2.1.2 Heading Title).

For Original Research articles, it is recommended to organize your manuscript in the following sections or their equivalents for your field:

INTRODUCTION

Succinct, with no subheadings.

MATERIALS AND METHODS

This section may be divided by subheadings and should contain sufficient detail so that when read in conjunction with cited references, all procedures can be repeated. For experiments reporting results on animal or human subject research, an ethics approval statement should be included in this section (for further information, see the Bioethics section.)

RESULTS

This section may be divided by subheadings. Footnotes should not be used and must be transferred to the main text.

DISCUSSION

This section may be divided by subheadings. Discussions should cover the key findings of the study: discuss any prior research related to the subject to place the novelty of the discovery in the appropriate context, discuss the potential shortcomings and limitations on their interpretations, discuss their integration into the current understanding of the problem and how this advances the current views, speculate on the future direction of the research, and freely postulate theories that could be tested in the future.

For further information, please check the descriptions defined in the journal's "Article Types" page, which can be seen from the "For Authors" menu on any Frontiers journal page.

1.16. Acknowledgments

This is a short text to acknowledge the contributions of specific colleagues, institutions, or agencies that aided the efforts of the authors. Should the content of the manuscript have previously appeared online, such as in a thesis or preprint, this should be mentioned here, in addition to listing the source within the reference list.

1.17. Contribution to the Field Statement

When you submit your manuscript, you will be required to briefly summarize in 200 words your manuscript's contribution to, and position in, the existing literature in your field. This should be written avoiding any technical language or non-standard acronyms. The aim should be to convey the meaning and importance of this research to a non-expert. While Frontiers evaluates articles using objective criteria, rather than impact or novelty, your statement should frame the question(s) you have addressed in your work in the context of the current body of knowledge, providing evidence that the findings—whether positive or negative—contribute to progress in your research discipline. This will assist the Chief Editors to determine whether your manuscript fits within the scope of a specialty as defined in its mission statement; a detailed statement will also facilitate the identification of the editors and reviewers most appropriate to evaluate your work, ultimately expediting your manuscript's initial consideration.

Example Statement on: Markram K and Markram H (2010) The Intense World Theory – a unifying theory of the neurobiology of autism. Front. Hum. Neurosci. 4:224. doi: 10.3389/fnhum.2010.00224

Autism spectrum disorders are a group of neurodevelopmental disorders that affect up to 1 in 100 individuals. People with autism display an array of symptoms encompassing emotional processing, sociability, perception and memory, and present as uniquely as the individual. No theory has suggested a single underlying neuropathology to account for these diverse symptoms. The Intense World Theory, proposed here, describes a unifying pathology producing the wide spectrum of manifestations observed in autists. This theory focuses on the neocortex, fundamental for higher cognitive functions, and the limbic system, key for processing emotions and social signals. Drawing on discoveries in animal models and neuroimaging studies in individuals with autism, we propose how a combination of genetics, toxin exposure and/or environmental stress could produce hyper-reactivity and hyper-plasticity in the microcircuits involved with perception, attention, memory and emotionality. These hyper-functioning circuits will eventually come to dominate their neighbors, leading to hyper-sensitivity to incoming stimuli, over-specialization in tasks and a hyper-preference syndrome. We make the case that this theory of enhanced brain function in autism explains many of the varied past results and resolves conflicting findings and views and makes some testable experimental predictions.

2. Figure and Table Guidelines

2.1. CC-BY Licence

All figures, tables, and images will be published under a Creative Commons CC-BY licence, and permission must be obtained for use of copyrighted material from other sources (including re-published/adapted/modified/partial figures and images from the internet). It is the responsibility of the authors to acquire the licenses, follow any citation instructions requested by third-party rights holders, and cover any supplementary charges.

For additional information, please see the Image Manipulation section.

2.2. Figure Requirements and Style Guidelines

- Frontiers requires figures to be submitted individually, in the same order as they are referred to in the manuscript; the figures will then be automatically embedded at the end of the submitted manuscript. Kindly ensure that each figure is mentioned in the text and in numerical order.

- For figures with more than one panel, panels should be clearly indicated using labels (A), (B), (C), (D), etc. However, do not embed the part labels over any part of the image, these labels will be replaced during typesetting according to Frontiers' journal style. For graphs, there must be a self-explanatory label (including units) along each axis.
- For LaTeX files, figures should be included in the provided PDF. In case of acceptance, our Production Office might require high-resolution files of the figures included in the manuscript in EPS, JPEG or TIF/TIFF format.
- In order to be able to upload more than one figure at a time, save the figures (labeled in order of appearance in the manuscript) in a zip file and upload them as 'Supplementary Material Presentation.'

Please note that figures not in accordance with the guidelines will cause substantial delay during the production process.

2.2.1. Captions

Captions should be preceded by the appropriate label, for example "Figure 1." Figure captions should be placed at the end of the manuscript. Figure panels are referred to by bold capital letters in brackets: (A), (B), (C), (D), etc.

2.2.2. Image Size and Resolution Requirements

Figures should be prepared with the PDF layout in mind. Individual figures should not be longer than one page and with a width that corresponds to 1 column (85 mm) or 2 columns (180 mm).

All images must have a resolution of 300 dpi at final size. Check the resolution of your figure by enlarging it to 150%. If the image appears blurry, jagged or has a stair-stepped effect, the resolution is too low.

- The text should be legible and of high quality. The smallest visible text should be no less than 8 points in height when viewed at actual size.
- Solid lines should not be broken up. Any lines in the graphic should be no smaller than 2 points wide.

Please note that saving a figure directly as an image file (JPEG, TIF) can greatly affect the resolution of your image. To avoid this, one option is to export the file as PDF, then convert into TIFF or EPS using a graphics software.

2.2.3. Format and Color Image Mode

- The following formats are accepted: TIF/TIFF (.tif/.tiff), JPEG (.jpg), and EPS (.eps) (upon acceptance).
- Images must be submitted in the color mode RGB.

2.2.4. Chemical Structures

Chemical structures should be prepared using ChemDraw or a similar program. If working with ChemDraw please use our Frontiers ChemDraw template. If working with another program please follow the guidelines given below:

- Drawing settings: chain angle, 120° bond spacing, 18% width; fixed length, 14.4 pt; bold width, 2.0 pt; line width, 0.6 pt; margin width, 1.6 pt; hash spacing, 2.5 pt. Scale 100% Atom Label settings: font, Arial; size, 8 pt.
- Assign all chemical compounds a bold, Arabic numeral in the order in which the compounds are presented in the manuscript text.

2.3. Table Requirements and Style Guidelines

- Tables should be inserted at the end of the manuscript in an editable format. If you use a word processor, build your table in Word. If you use a LaTeX processor, build your table in LaTeX. An empty line should be left before and after the table.
- Table captions must be placed immediately before the table. Captions should be preceded by the appropriate label, for example "Table 1." Please use only a single paragraph for the caption.
- Kindly ensure that each table is mentioned in the text and in numerical order.
- Please note that large tables covering several pages cannot be included in the final PDF for formatting reasons. These tables will be published as supplementary material.

Please note that tables which are not according to the guidelines will cause substantial delay during the production process.

2.4. Accessibility

Frontiers encourages authors to make the figures and visual elements of their articles accessible for the visually impaired. An effective use of color can help people with low visual acuity, or color blindness, understand all the content of an article.

These guidelines are easy to implement and are in accordance with the W3C Web Content Accessibility Guidelines (WCAG 2.1), the standard for web accessibility best practices.

A. Ensure sufficient contrast between text and its background

People who have low visual acuity or color blindness could find it difficult to read text with low contrast background color. Try using colors that provide maximum contrast.

WC3 recommends the following contrast ratio levels:

- Level AA, contrast ratio of at least 4.5:1
- Level AAA, contrast ratio of at least 7:1

You can verify the contrast ratio of your palette with these online ratio checkers:

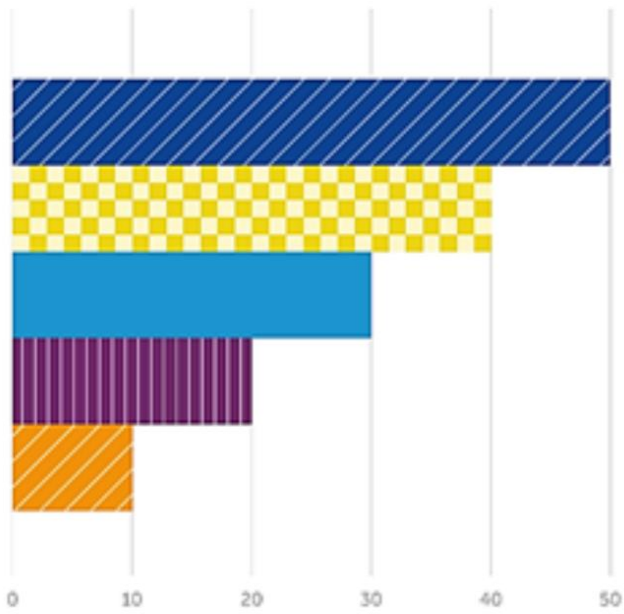
- WebAIM
- Color Safe

B. Avoid using red or green indicators

More than 99% of color-blind people have a red-green color vision deficiency.

C. Avoid using only color to communicate information

Elements with complex information like charts and graphs can be hard to read when only color is used to distinguish the data. Try to use other visual aspects to communicate information, such as shape, labels, and size. Incorporating patterns into the shape fills also make differences clearer; for an example please see below:



3. Supplementary Material

Data that are not of primary importance to the text, or which cannot be included in the article because they are too large or the current format does not permit it (such as videos, raw data traces, powerpoint presentations, etc.), can be uploaded as Supplementary Material during the submission procedure and will be displayed along with the published article. All supplementary files are deposited to Figshare for permanent storage and receive a DOI.

Supplementary Material is not typeset, so please ensure that all information is clearly presented without tracked changes/highlighted text/line numbers, and the appropriate caption is included in the file. To avoid discrepancies between the published article and the supplementary material, please do not add the title, author list, affiliations or correspondence in the supplementary files.

The Supplementary Material can be uploaded as Data Sheet (Word, Excel, CSV, CDX, FASTA, PDF or Zip files), Presentation (PowerPoint, PDF or Zip files), Image (CDX, EPS, JPEG, PDF, PNG or TIF/TIFF), Table (Word, Excel, CSV or PDF), Audio (MP3, WAV or WMA) or Video (AVI, DIVX, FLV, MOV, MP4, MPEG, MPG or WMV).

For Supplementary Material templates (LaTeX and Word), see our Supplementary Material templates.

4. References

- All citations in the text, figures or tables must be in the reference list and vice-versa.
- The names of the first six authors followed by et al. and the DOI (when available) should be provided.
- The reference list should only include articles that are published or accepted.
- Unpublished data, submitted manuscripts or personal communications should be cited within the text only, for the article types that allow such inclusions.
- For accepted but unpublished works use "in press" instead of page numbers.
- Data sets that have been deposited to an online repository should be included in the reference list. Include the version and unique identifier when available.
- Personal communications should be documented by a letter of permission.
- Website URLs should be included as footnotes.
- Any inclusion of verbatim text must be contained in quotation marks and clearly reference the original source.

- Preprints can be cited as long as a DOI or archive URL is available, and the citation clearly mentions that the contribution is a preprint. If a peer-reviewed journal publication for the same preprint exists, the official journal publication is the preferred source. See the Preprints section for more information.

4.1. Science, Engineering and Humanities Journals

4.1.1. In-text Citations

- For works by a single author, include the surname, followed by the year.
- For works by two authors, include both surnames, followed by the year.
- For works by more than two authors, include only the surname of the first author followed by et al., followed by the year.
- For Humanities and Social Sciences articles, include the page numbers.

4.1.2. Reference List

ARTICLE IN A PRINT JOURNAL

Sondheimer, N., and Lindquist, S. (2000). Rnq1: an epigenetic modifier of protein function in yeast. Mol. Cell. 5, 163-172.

ARTICLE IN AN ONLINE JOURNAL

Tahimic, C.G.T., Wang, Y., Bikle, D.D. (2013). Anabolic effects of IGF-1 signaling on the skeleton. Front. Endocrinol. 4:6. doi: 10.3389/fendo.2013.00006

ARTICLE OR CHAPTER IN A BOOK

Sorenson, P. W., and Caprio, J. C. (1998). "Chemoreception," in The Physiology of Fishes, ed. D. H. Evans (Boca Raton, FL: CRC Press), 375-405.

BOOK

Cowan, W. M., Jessell, T. M., and Zipursky, S. L. (1997). Molecular and Cellular Approaches to Neural Development. New York: Oxford University Press.

ABSTRACT

Hendricks, J., Applebaum, R., and Kunkel, S. (2010). A world apart? Bridging the gap between theory and applied social gerontology. Gerontologist 50, 284-293. Abstract retrieved from Abstracts in Social Gerontology database. (Accession No. 50360869)

WEBSITE

World Health Organization. (2018). E. coli. https://www.who.int/news-room/fact-sheets/detail/e-coli [Accessed March 15, 2018].

PATENT

Marshall, S. P. (2000). Method and apparatus for eye tracking and monitoring pupil dilation to evaluate cognitive activity. U.S. Patent No 6,090,051. Washington, DC: U.S. Patent and Trademark Office.

DATA

Perdiguero P, Venturas M, Cervera MT, Gil L, Collada C. Data from: Massive sequencing of Ulms minor's transcriptome provides new molecular tools for a genus under the constant threat of Dutch elm disease. Dryad Digital Repository. (2015) http://dx.doi.org/10.5061/dryad.ps837

THESES AND DISSERTATIONS

Smith, J. (2008) Post-structuralist discourse relative to phenomological pursuits in the deconstructivist arena. [dissertation/master's thesis]. [Chicago (IL)]: University of Chicago

PREPRINT

Smith, J. (2008). Title of the document. Preprint repository name [Preprint]. Available at: https://persistent-url (Accessed March 15, 2018).

4.1.3. Resources

Chicago Manual of Style

Frontiers Science Endnote Style

Frontiers Science, Engineering and Humanities Bibstyle

4.2. Health, Physics, and Mathematics Journals

4.2.1. In-text Citations

- Please apply the Vancouver system for in-text citations.
- In-text citations should be numbered consecutively in order of appearance in the text—identified by Arabic numerals in the parenthesis for Health articles and in square brackets for Physics and Mathematics articles.

4.2.2. Reference List

ARTICLE IN A PRINT JOURNAL

Sondheimer N, Lindquist S. Rnq1: an epigenetic modifier of protein function in yeast. Mol Cell (2000) 5:163-72.

ARTICLE IN AN ONLINE JOURNAL

Tahimic CGT, Wang Y, Bikle DD. Anabolic effects of IGF-1 signaling on the skeleton. Front Endocrinol (2013) 4:6. doi: 10.3389/fendo.2013.00006

ARTICLE OR CHAPTER IN A BOOK

Sorenson PW, Caprio JC. "Chemoreception,". In: Evans DH, editor. The Physiology of Fishes. Boca Raton, FL: CRC Press (1998). p. 375-405.

BOOK

Cowan WM, Jessell TM, Zipursky SL. Molecular and Cellular Approaches to Neural Development. New York: Oxford University Press (1997). 345 p.

ABSTRACT

Christensen S, Oppacher F. An analysis of Koza's computational effort statistic for genetic programming. In: Foster JA, editor. Genetic Programming. EuroGP 2002: Proceedings of the 5th European Conference on Genetic Programming; 2002 Apr 3–5; Kinsdale, Ireland. Berlin: Springer (2002). p. 182–91.

WEBSITE

World Health Organization. E. coli (2018). https://www.who.int/news-room/fact-sheets/detail/e-coli [Accessed March 15, 2018].

PATENT

Pagedas AC, inventor; Ancel Surgical R&D Inc., assignee. Flexible Endoscopic Grasping and Cutting Device and Positioning Tool Assembly. United States patent US 20020103498 (2002).

DATA

Perdiguero P, Venturas M, Cervera MT, Gil L, Collada C. Data from: Massive sequencing of Ulms minor's transcriptome provides new molecular tools for a genus under the constant threat of Dutch elm disease. Dryad Digital Repository. (2015) http://dx.doi.org/10.5061/dryad.ps837

THESES AND DISSERTATIONS

Smith, J. (2008) Post-structuralist discourse relative to phenomological pursuits in the deconstructivist arena. [dissertation/master's thesis]. [Chicago (IL)]: University of Chicago

PREPRINT

Smith, J. Title of the document. Preprint repository name [Preprint] (2008). Available at: https://persistent-url (Accessed March 15, 2018).

ADDENDUM G: ADDITIONAL TABLES AND FIGURES

Demographics of participants

	Urban	Rural	Total:
Number of participants (N)	393	338	731
Girls N (%)	264 (67%)	186 (55%)	450 (62%)
Boys N (%)	129 (32%)	152 (45%)	281 (38%)
Mean age (yrs)	10.2 ±2.5	11.6 ±2.4	10.86±2.55

BMI categories of participants

	Urban N=393		Rural N=338		Total N=731	
	(N)	%	(N)	%	(N)	%
Underweight (N)	14	4	19	6	33	5
Healthy (N)	256	65	207	61	463	63
Overweight (N)	80	20	71	21	151	21
Obese (N)	30	8	31	9	61	8
Morbidly obese (N)	13	3	10	3	23	3