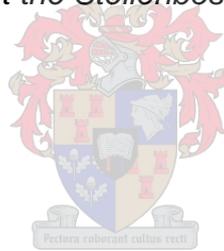


Growing feet: Foot metrics and shoe fit in South African school-aged children and adolescents

by
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DECLARATION

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DEDICATION

I dedicate this dissertation to my parents in heaven.

Mom and pa Thinus – You have taught me a lot of things in my life and it would have been an honour to have you here to share this with you, but I know you are looking down with proud hearts!

ABSTRACT

The foot undergoes numerous developmental changes during the first few years of life. Due to this continued development of the foot during childhood, it leaves the feet of children exposed to external influences. Factors such as age, gender and footwear can have a significant impact on the development of the foot.

The primary aim of the study was to investigate whether the foot metrics of South African children and adolescents are influenced by age, gender, race and body mass index (BMI). A secondary aim of this study was to establish if South African children and adolescents wear well-fitting shoes.

A total of 568 children and adolescents between the ages of six and eighteen years from schools within the Western Cape, South Africa, participated in the study. Static foot length and width were measured with a self-manufactured calliper and school shoe length and width were measured with a flexible straw and sliding calliper respectively. Shoe fit was determined by the difference between the width of the foot and the width of the shoe as well as the difference between the length of the shoe and the length of the foot. A toe allowance was also considered. Dynamic arch index (AI) was measured by using the Emed c50 pressure plate (Novel GmbH, Munich, Germany). The effect of age, gender, race, and BMI on foot length, width and dynamic AI was evaluated, as well as its effect on the shoe fit. Statistical analyses were done by using the one-way ANOVA and two-way ANOVA with Fisher's least significant differences as post-hoc test, as well as its effect on the shoe fit. Cohen's effect size (ES) for each parameter was calculated to determine practical differences.

Gender and race significantly ($p < 0.05$) influenced the foot length and width of children and adolescents. Girls had shorter and narrower feet than boys. The girls showed no significant increase in foot length and width measurements after 12 years of age. White children had significantly ($p < 0.05$) and medium practically longer and wider feet, and a lower AI ($p < 0.05$) than the brown children and adolescents. Statistically ($p < 0.05$) and practically significant differences in foot length, width and AI were found between the different BMI categories. Furthermore, results show that 67 percent of the children and adolescents wore ill-fitting shoes when looking at the

length of school shoes compared to the length of the feet, taking toe allowance into account. There was a significant difference in shoe fit for the width between genders, with girls wearing more tight fitting shoes than boys. Significant differences were seen in the shoe fit for length measurements between the different races, where the brown children's shoes were a tighter fit than the white children's shoes. The obese South African children have worn shoes that were too narrow for their feet.

Keywords: children; footwear; foot metrics; shoe measurements; ill-fitting shoes

OPSOMMING

Gedurende die eerste paar jaar van die mens se lewe ondergaan die voet verskeie stadiums van ontwikkeling. Weens hierdie voortdurende ontwikkeling gedurende kinderjare, is die groeiende voet vatbaar vir eksterne invloede. Faktore soos ouderdom, geslag en skoene kan 'n beduidende invloed op die ontwikkeling van die voet hê.

Die primêre doel van die studie was om te bepaal of ouderdom, geslag, ras en liggaamsmassa-indeks (LMI) 'n betekenisvolle effek op die voetafmetings van Suid-Afrikaanse kinders en adolessente het. Die sekondêre doel van die studie was om vas te stel of die Suid-Afrikaanse kinders en adolessente die regte grootte skoene vir hul voetgrootte dra.

'n Totaal van 586 kinders en adolessente tussen die ouderdom van ses en agtien jaar, uit skole van die Wes-Kaap, Suid-Afrika, het aan die studie deelgeneem. Die kinders se voetlengtes en -breedtes is met 'n selfgemaakte kaliper gemeet terwyl die sportskoenlengtes en -breedtes en skoolskoenlengtes en -breedtes onderskeidelik met 'n buigsame strooitjie en glypasser gemeet is. Die verhouding tussen voet- en skoengrootte is bepaal deur die voetlengte en -breedte onderskeidelik af te trek van die skoenlengte en -breedte. Toonspasie is in ag geneem met die bepaling van die gepaste skoengrootte. 'n Drukplatform (Emedc50) is gebruik om die voetbrugindeks te meet (Novel GmbH, München, Duitsland). Die effek wat ouderdom, geslag, ras en LMI op die voetlengte, -breedte en voetbrugindeks gespeel het is bepaal, asook die effek daarvan op hoe die skoen die voetgrootte pas. 'n Eenrigting ANOVA en 2- rigting ANOVA is gebruik tydens die ontleding van die data met Fisher se minste beduidende verskille as post-hoc analise. Cohen se effekgrootte (ES) is gebruik om praktiese verskille tussen die veranderlikes te bepaal.

Die resultate van die studie toon betekenisvolle ($p < 0.05$) verskille in die voetlengte en -breedte tussen seuns en dogters, asook die rasse vanaf 12 jarige ouderdom. Die dogters se voete was oor die algemeen nouer as die van die seuns. Na 12 jarige ouderdom was daar 'n afplating in die groei van die dogters se voete in beide lengte en wydte. Die wit kinders se voete was betekenisvol ($p < 0.05$) en prakties

betekenisvol (medium) langer en breër as die voete van die bruin kinders. Daar was egter slegs 'n medium prakties betekenisvolle verskil in die voetbrugindeks, met die wit kinders wat 'n laer voetbrugindeks gehad het as die bruin kinders en adolessente. Die verskillende LMI kategorieë het ook betekenisvolle verskille in die voetlengte en breedte en voetbrugindeks gehad. Resultate het getoon dat 67 persent van die Suid-Afrikaanse kinders en adolessente swakpassende skoolskoene dra. Die gevolgtrekking is gemaak nadat die voetlengte afgetrek is van die skoolskoenlengte, met toonspasie wat ook in berekening gebring is. Betekenisvolle verskille tussen seuns en dogters dui daarop dat die dogters se skoene, in terme van breedte, swakker pas as seuns se skoene. Die bruin kinders se skoene was ook betekenisvol korter in verhouding tot hul voetlengte teenoor die wit kinders se skoene. Die Suid-Afrikaanse vetsugtige kinders het skoene gedra wat te nou was vir hulle voete.

Sleutelwoorde: kinders; skoene; voetmetings; skoenmetings; swakpassende skoene

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LIST OF ABBREVIATIONS

%	:	percentage
ABW	:	anatomical ball width
AHW	:	anatomical heel width
AI	:	arch index
BMI	:	body mass index
cm	:	centimetre
ICC	:	interclass correlation co-efficient
kg	:	kilogram
kg/m ²	:	kilogram per metres squared
LMI	:	liggaamsmassa-indeks
LSD	:	least significant difference
m	:	metre
mL/kg/min	:	millilitre per kilogram per minute
MLA	:	medial longitudinal arch
mm	:	millimetre
MTH1	:	first metatarsal
MTH5	:	fifth metatarsal
TBW	:	technical ball width
THW	:	technical heel width
VO ₂ max	:	maximal oxygen consumption

CHAPTER ONE

Introduction

A. Overview of literature

The foot has numerous functions, it must be pliable to absorb stress and adapt to different surfaces. Besides the pliability, it also should be relatively rigid to withstand propulsive forces. Last but not least, the sensory feedback to the lower limb muscles and rest of the body plays an important role in the protection against injuries (Neumann, 2010).

Foot dimensions as well as shape changes during growth. Between birth and three years of age, the foot grows fast, while from three years onward there is a constant growth rate (Volpon, 1994). According to Echarri and Forriol (2003), Pfeiffer, Kotz, Ledl, Hauser and Sluga (2006), as well as Delgado-Abbelán, Aguado, Jiménez-Ormeño, Mecerreyes and Alegre (2014), there is a gradual increase in the medial longitudinal arch (MLA) with an increase in age.

Different measurements have been used to assess the height of the MLA and foot shape. Development of the MLA is usually linked to the change in height of the arch (Fritz & Mauch, 2013). Some indirect or visual non-quantitative methods include the use of ink, digital footprint or photographic techniques (Gilmour & Burns, 2001; Razeghi & Batt, 2002; Stavlas, Grivas, Michas, Vasiliadis & Polyzois, 2005; Mauch, Grau, Krauss, Maiwald & Horstmann, 2009; Xiong, Goonetilleke, Witana, Weerasinghe & Au, 2010; Menz, Fotoohabadi, Wee & Spink, 2012).

Initially, the only classification for foot shape was either flat (planus) or high (cavus). According to Volpon (1994), these terms describe not only the anatomical variations but also the complex conditions involving adjustments in other parts of the foot that cannot be detected on footprints. Fritz and Mauch (2013); however, categorised children's feet in five different clusters which represent different foot types. This was done based on not just the MLA, but also the length and volume of the foot.

The latter classification is also an important aspect to consider when developing footwear. According to Mauch et al. (2009), footwear should support the foot's physiological functioning and the shape and dimensions of the shoe must be the same as that of the foot. The researchers found that volume, forefoot shape, and the flex line of the shoe is very important when designing shoes (Mauch et al., 2009).

According to Scott, Menz and Newcombe (2007), the human foot is regarded as one of the most important structures in the human body. However, since children's feet develop up until the age of almost 15 years (Walther, Herold, Sinderhauf & Morrison, 2008), it is vulnerable to external influences (Fritz & Mauch, 2013).

Genetics and exogenic factors such as body weight (Mickle Steele, & Munro, 2006b), age and gender influence the development of the foot (Echarri & Forriol, 2003).

Echarri and Forriol (2003) argue that being barefoot reinforce the fascia and ligaments (the passive components of the foot) and the muscles (the active components of the foot). This would influence the foot shape. Results show that barefoot running decreases the impact transient or loading rate. The magnitude of the impact transient has been correlated with risk of developing tibial stress injuries (Lieberman et al., 2010).

There is; however, limited research on foot metrics in a culture where children and adolescents habitually walk barefoot and in many instances participate in sport (team and individual) in a barefoot condition. There is also limited research on the foot metrics of South African children and adolescents.

Mauch (2016) recently stated that, "During the whole growth of a child's foot, the tissue is more flexible and therefore more vulnerable to the influence of external factors like shoes. This means that wearing a too tight shoe over time can influence or delimitate foot development. Consequences can be foot deformities like claw toes" (Mauch, personal communication, 11 August 2016).

B. Context of the study

This research study forms part of the “Barefoot Locomotion for Individual Foot- and health Enhancement (Barefoot-LIFE)” project. This project is conducted on German and South African children and adolescents between six and eighteen years of age. The primary aim of the Barefoot-LIFE project is to determine the long-term effects of being habitually barefoot on motor performance and foot mechanics (Hollander et al., 2016). The researcher is one of five researchers in South Africa using only some of the South African data as a research project. Specific topics or research questions were demarcated for the Barefoot-LIFE project. The topics or research questions that did not form part of the Barefoot-LIFE project were open to being used by the author of this thesis and four Masters students in South Africa.

C. Aim of the study

The primary aim of the study was to determine foot metrics (foot length, foot width, and arch index) of South African children and adolescents and to investigate whether the foot metrics of South African children and adolescents are influenced by age, gender, race and body mass index (BMI).

A secondary aim of this study was to establish if South African children and adolescents wear well-fitting shoes.

D. Objectives

The following objectives guided the research.

Objective 1: To determine the effect of age on foot length, foot width and the dynamic arch index of school-aged children and adolescents in the Western Cape, South Africa.

Objective 2: To determine the effect of gender on foot length, foot width and the dynamic arch index of school-aged children and adolescents in the Western Cape, South Africa.

Objective 3: To determine the effect of race on foot length, foot width and the dynamic arch index of school-aged children and adolescents in the Western Cape, South Africa.

Objective 4: To determine the effect of BMI categories on foot length, foot width and the dynamic arch index of school-aged children and adolescents in the Western Cape, South Africa.

Objective 5: To determine the effect of age on the shoe fit of school-aged children and adolescents in the Western Cape, South Africa.

Objective 6: To determine the effect of gender on the shoe fit of school-aged children and adolescents in the Western Cape, South Africa.

Objective 7: To determine the effect of race on the shoe fit of school-aged children and adolescents in the Western Cape, South Africa.

Objective 8: To determine the effect of BMI categories on the shoe fit of school-aged children and adolescents in the Western Cape, South Africa.

E. Hypotheses

Hypothesis 1: The foot metrics of South African children and adolescents are not influenced by age, gender, race and BMI categories.

Hypothesis 2: South African school-aged children and adolescents wear well-fitting school shoes.

F. Outline of the thesis

The thesis comprises five chapters. Chapter Two provides the theoretical context for this study. This chapter reviews current literature and related studies on foot development, measuring of foot shapes, classification of foot shapes, factors affecting foot development and foot shape, as well as the barefoot condition. In Chapter Three, the specific methods for data collection are discussed. The results are presented in Chapter Four. Chapter Five contains a discussion of the results, as well as a conclusion to this study, limitations of this study, and recommendations for future research. The guidelines from the American Psychological Association (APA) are used as referencing system.

CHAPTER TWO

Theoretical Context

A. Introduction

The human foot is regarded as one of the most important structures in the human body. It is not the sole connection with the earth which is seen as the supporting surface (Scott, Menz & Newcombe, 2007), but it also plays an important role in bipedal locomotion, balance and sensory feedback. Due to the bipedal gait, there are specific structural changes the foot must undergo, from birth to adulthood, to be able to withstand external pressure and still function normally. Although both an adult's foot and a child's foot generally have 26 bones with numerous muscles and ligaments that assist the foot in its static and dynamic functioning, as well as providing shape to the foot, the feet of children are anthropometrically different to the feet of adults (Mauch et al., 2009). As the feet of children are still maturing, they are more vulnerable to external influences (Fritz & Mauch, 2013). Parents and healthcare workers should, therefore, be aware of the effects that footwear, body mass and physical activity, or the lack thereof, have on the developing foot.

In this chapter, the development of the foot, the external factors that can influence the development of the foot, and the measurement of the foot size and shape will be discussed in detail. Due to the relative novelty of the current study and a lack of published research in this field, reference to a few specific authors might occur more regularly, for example the work of Echarri and Forriol (2003), Mickle, Steele and Munro (2008), Mauch et al. (2009), and Fritz and Mauch (2013).

B. Development of the foot

The human foot generally consists of three arches, 20 muscles, 24 ligaments, 26 bones, 33 joints, and 7 800 nerves (Gray, 1918; Mauch et al., 2009). Each one of these structures goes through different developmental stages at different times. As mentioned earlier, the feet of children are anthropometrically different from adult feet although they look similar (Mauch et al., 2009). Foot dimensions, as well as shape change during growth. Between birth and three years of age, the foot grows fast, while from three years onward there is a constant growth rate (Volpon, 1994).

The following section will discuss the development of the soft tissue, bony structures, and the arches of the foot.

Development of soft tissue

Infants are born initially with a high arch, but it is soon replaced by Spitzky's fat pad (Stavlas et al., 2005; Pfeiffer, Kotz, Ledl, Hauser & Sluga, 2006; Walther, Herold, Sinderhauf & Morrison, 2008). Spitzky's fat pad is a fat pad situated underneath the midfoot and helps to protect the foot against excessive pressure until the muscles become strong enough to perform that role (Mickle et al., 2008; Müller, Carlsohn, Müller, Baur & Mayer, 2012). The fat pad is responsible for distributing and reducing the forces applied to the talonavicular joint (Fritz & Mauch, 2013). Hills, Hennig, Byrne and Steele (2002) studied the plantar fat pad in detail and mentioned two aspects. Firstly, the plantar fat pad is formed by a specially organised adipose tissue and gives cushioning to the underlying foot structure. Secondly, although the heel pad thickness increased as the BMI increased, it still has the same compressibility index.

The infant foot is more flexible than the adult foot due to the fact that there are fewer crosslinks of collagen fibres (Fritz & Mauch, 2013). Another possible reason for the flexibility is that the mechanical stability of ligaments and tendons only develops from around four years of age until puberty (Walther et al., 2008; Fritz & Mauch, 2013). Pfeiffer et al. (2006) stated that at birth, the foot consists largely of soft tissue. The shape and structure of the young foot are therefore determined by soft tissue (Mickle

et al., 2008). The feet of children are often misdiagnosed as being flat feet (Walther et al., 2008). Other reasons for the misdiagnosis of flat feet are the high static pressure the foot has to undergo once children start to walk and Spitzky's fat pad (Walther et al., 2008). The ligaments are the primary structure in supporting and stabilising the foot, while it also acts as an energy storing mechanism. Ligaments rarely fatigue and can give higher resistance to stress than muscles. However, repeated excessive loading may stretch ligaments. This can lead to damage of the soft tissue, increased risk of discomfort, and other pathologies (Dowling, Steele & Baur, 2001).

Muscles of the foot can be seen since the eight weeks of gestation and it only strengthens once gravity and motion start to play a role (Fritz & Mauch, 2013). Muscles (Figure 2.1), give secondary support to the arches of the foot (Dowling et al., 2001) with the bones giving the primary support. Eighty percent of muscle strength in the foot is used for tension, while the other 20 percent is used for locomotion (Fritz & Mauch, 2013).

Development of the bony structure

Fritz and Mauch (2013) referenced Sarrafian and Kelikian (2011), stating that the growth of the foot is based on the changes that occur in the bony structure (Figure 2.2). Bones harden and they change form. A rapid transformation from cartilage to bone occurs and the most rapid growth happens within the first three years after birth. There is; however, still ongoing changes that occur until five or six years of age where certain features similar to that of adult feet are obtained (Mickle et al., 2008).

Initially, an infant's foot has a "sandal grip", with the big toe being away from the other toes (Walther et al., 2008). The ossification process of the foot starts at the distal phalanx of the big toe followed by the metatarsals, the distal phalanges of the lesser toes, the proximal phalanges, and then ends with the mid phalanges. Forefoot ossification is completed prenatally, between the third and fifth month. Forefoot ossification occurs before hindfoot ossification which also starts and is completed prenatally.

Hindfoot ossification happens in the following order: the calcaneus, followed by the talus, and then talar bones, ending with the cuboid bone (Kelikian, Sarrafian & Sarrafian, 2011). The forefoot of an infant is square-shaped and changes to a more pointed forefoot during childhood (Mauch et al., 2009). At birth, most of the bones are ossified (Fritz & Mauch, 2013), but complete ossification occurs throughout the first ten years of life, with the navicular ossification taking place around three years of age, although this has a high variance between individuals. Calcification of the foot occurs around 22 months in girls and 30 months in boys (Walther et al., 2008).
Figure 2.1 and 2.2

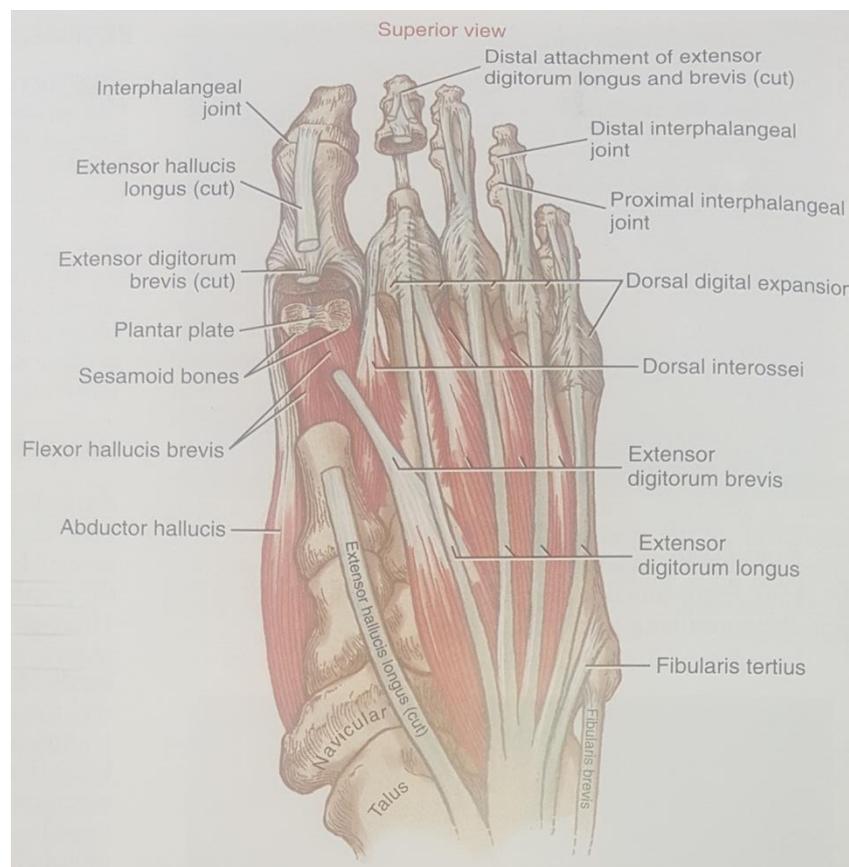


Figure 2.1: Muscular anatomy of the foot (Source: Neumann, 2010)

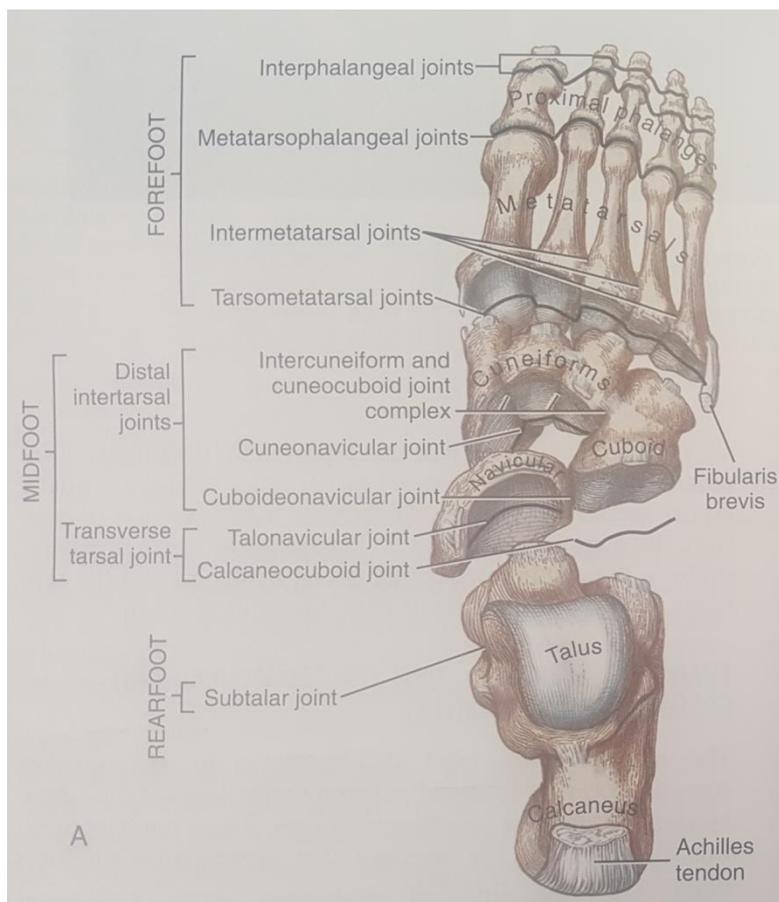


Figure 2.2: Bony anatomy of the foot (Source: Neumann, 2010)

Development of the arches

The main arch of the foot is known as the anteroposterior arch and can be divided into a medial- and lateral arch (Figure 2.3). The lateral arch is formed by the calcaneus, cuboid and fourth- and fifth metatarsal bones. It is a very solid arch and is known for its slight elevation. On the medial side, several small joints form part of the elastic medial arch. The medial arch is comprised of the calcaneus, talus, navicular, all three cuneiforms and the first to the third metatarsal bones. This arch is also known as the MLA.

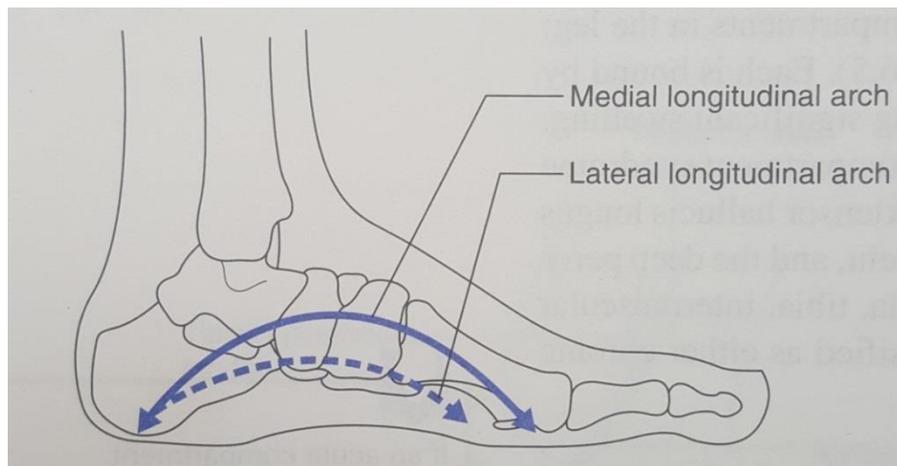


Figure 2.3: Longitudinal arches of the foot (Source: Shultz, Houglum, & Perrin, 2010)

Reprinted, with permission, from S.J. Shultz, P.A. Houglum, and D.H. Perrin, 2010, Examination of musculoskeletal injuries, 3 rd ed. (Champaign, IL: Human Kinetics), 404.

Another arch, known as the fundamental longitudinal arch, consists of parts of the medial- and lateral arches with the calcaneus, cuboid, third cuneiform and the third metatarsal forming this arch. A remarkable feature of this arch is that if all the other bones in the foot are destroyed, this arch will still be intact. The last arch of the foot is the transverse arch formed by the three cuneiforms, the cuboid, and the bases of the five metatarsal bones (Gray, 1918).

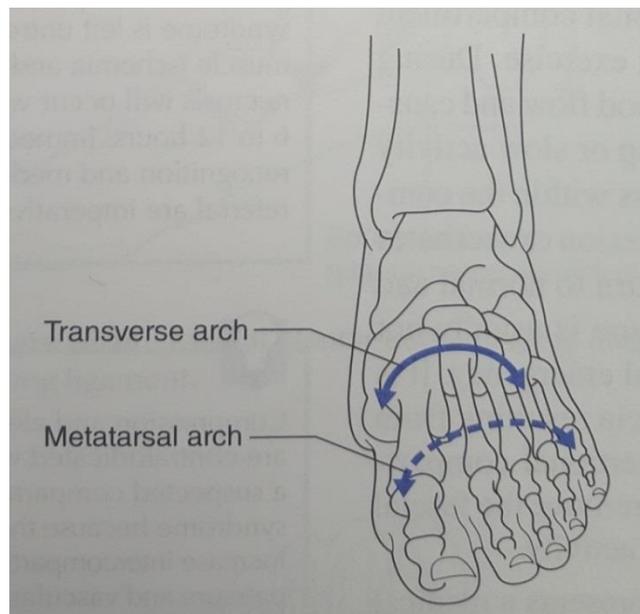


Figure 2.4: Transverse- and metatarsal arch of the foot (Source: Shultz et al., 2010)

Reprinted, with permission, from S.J. Shultz, P.A. Houglum, and D.H. Perrin, 2010, Examination of musculoskeletal injuries, 3 rd ed. (Champaign, IL: Human Kinetics), 404.

The bony structures of the MLA cannot solely carry all the forces acting on the foot. Other structures like muscles and ligaments tighten in an active and passive manner to provide additional support to the bony structures (Fritz & Mauch, 2013).

It is important to know about the different stages of the development of the MLA, since the absence of the longitudinal arch or an abnormally low arch is usually diagnosed as flat feet (Buerk & Albert, 2001; Aymelek et al., 2011). Flat feet is a common condition seen in paediatric orthopaedic practices (El et al., 2006). As stated earlier in this chapter, most children are born with a high arch, but it soon changes to a low arch due to the presence of Spitzzy's fat pad (Volpon, 1994; Stavlas et al., 2005; Pfeiffer et al., 2006; Walther et al., 2008; Fritz & Mauch, 2013).

Researchers have different time frames for the development of the MLA. According to Echarri and Forriol (2003), Pfeiffer et al. (2006), and Delgado-Abbellán et al. (2014), there is a gradual increase in the MLA with an increase in age. Volpon (1994) and El et al. (2006) noted that there is a rapid progression of the arch height between the ages of two to six years, with the critical time for the development of the MLA being around the age six years. From age two years up until preschool age, Fritz and Mauch (2013) regard this time as the most important developmental stage of the MLA. A lower MLA until the age of five or six years was also reported by Mauch et al. (2008). However, Stavlas et al. (2005) found that development of the MLA still occurs until the age of ten years.

Various reasons could exist for the different findings on the development of the MLA. One major difference is the equipment used. Echarri and Forriol (2003), Stavlas et al. (2005) and El et al. (2006) used footprints, while Pfeiffer et al. (2006) and Delgado-Abellán et al. (2014) made use of technology by using a 3D foot digitiser and laser scanner respectively to determine the shape of the foot.

Another factor that contributed to the different results was the different ages of the children tested. Ages varied from newborn to 15 years (Volpon, 1994), six to twelve years of age (El et al., 2006; Delgado-Abellán et al., 2014), children between three and six years of age (Pfeiffer et al., 2006), three to twelve years (Echarri & Forriol, 2003) and six to seventeen years (Stavlas et al., 2005).

The MLA assists in the protection of the foot against injury, as it helps to absorb the forces working on the foot while standing and walking (Xiong et al., 2010). In a review study on foot type classification, Razeghi and Batt (2002) mentioned that there is controversy regarding the importance of the shape of the MLA, since both high and low arch heights have been associated with injuries during physical activity.

Although researchers agree that the medial longitudinal arch develops with age, the external factors playing a role in the development thereof and which might lead to flat-footedness, are very controversial (Fritz & Mauch, 2013). A wrong diagnosis of flat foot can easily be made and it is, therefore, important to know the different factors that could influence the development of the foot. These factors are not only limited to the development of the MLA but can also influence the development of the soft tissue and bony structures of the foot. In the following section, factors that could influence foot development and which formed part of the current research project will be discussed in more detail.

C. Measuring the shape of the foot

It is generally believed that foot function depends on foot shape. A lot of clinical research has been done on the foot with the focus on the MLA being susceptible to external influences (Razeghi & Batt, 2002). Different measurements have been used to assess the height of the MLA and foot shape. Development of the MLA is usually linked to the change in the height of the arch (Fritz & Mauch, 2013). Some indirect or visual non-quantitative methods include the use of ink, digital footprint or photographic techniques (Gilmour & Burns, 2001; Razeghi & Batt, 2002; Stavlas et al., 2005; Mauch et al., 2009; Xiong et al., 2010; Menz et al., 2012). Razeghi and Batt (2002) reported that these methods are very subjective and only give limited data. There is also a very poor inter-rater reliability and Interclass Correlation Co-efficient (ICC). Direct methods consist of anthropometric methods, clinical assessment, radiographic evaluation and ultrasonography quantification. 3D analysis of the foot shape was used to do cluster sampling and analysis of the foot (Mauch et al., 2009). Some of the direct methods like radiography are a health risk and costly to perform and are therefore not used often (Stavlas et al., 2005). Although the measurement of

the height of the MLA from a flat surface has been shown as valid and reliable, it is not used as often (Gilmour & Burns, 2001).

Footprints

Footprints are often used as an objective alternative to the clinical measurements. These measurements are usually measured statically (Redmond, Crane & Menz, 2008). It does have its limitations, though. There is a lot of uncertainty on how to interpret the footprint and there is a lack of means to extract parameters measured (Xiong et al., 2010). Nine possible parameters of footprints will be explained briefly.

Clarke's angle - Clarke's angle (Figure 2.5) is also known as the modified Schwartz's angle or arch angle. This is the angle between 1) the line connecting the most medial border of the heel and metatarsal regions and 2) the line connecting the most lateral point on the medial border of the foot to the most medial point of the metatarsal region (Razeghi & Batt, 2002; Echarri & Forriol, 2003; Stavlas et al., 2005). Mean and standard deviation values for children between three and twelve years are 23.3 ± 10.5 to 36.3 ± 10.3 (Echarri & Forriol, 2003). Reliability has been reported as 0.971 (Razeghi & Batt, 2002).



Figure 2.5: Clarke's angle (Source: Echarri & Forriol, 2003)

Chippaux-Smirak index –This is described as the ratio of the maximum width of the metatarsal region to the minimal width of the arch region of the footprint, as reflected in Figure 2.6 (Echarri & Forriol, 2003; Stavlas et al., 2005; Fritz & Mauch, 2013). Typical values for children between three and twelve years are 38.1 ± 14.9 to 54 ± 12.3 , according to Echarri and Forriol (2003).

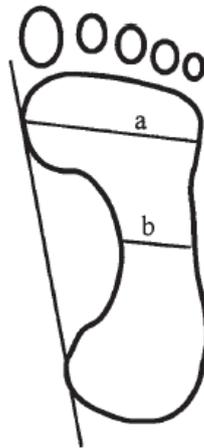


Figure 2.6: Chippaux-Smirak index (Source: Echarri & Forriol, 2003)

Staheli's index - Figure 2.7 shows the markers of Staheli's index. It is a ratio calculated by using the smallest distance of the midfoot (b) and the longest distance of the heel parallel to a line between MTH1 and MTH5 (c) (Fritz & Mauch, 2013). Values for the ratio are 0.71 ± 0.29 to 0.96 ± 0.25 in children three to twelve years of age (Echarri & Forriol, 2003).

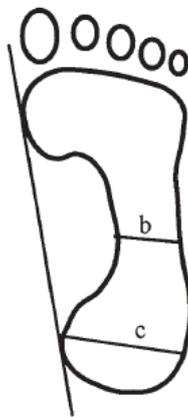


Figure 2.7: Staheli's index (Source: Echarri & Forriol, 2003)

Arch index (AI) - The AI was developed by Cavanagh and Rogers (1987) and is calculated by using the ratio of the area of the middle third of the toeless footprint and the total toeless footprint area (Figure 2.8) (Gilmour & Burns, 2001; Razeghi & Batt, 2002; Echarri & Forriol, 2003; Stavlas et al., 2005; Xiong et al., 2010). A higher ratio is indicative of flatter feet. The mean value for AI has been reported as 0.193 ± 0.045 for the dynamic measurement in 20- to 40-year-olds (Cavanagh & Rodgers, 1987).

This measurement has excellent reliability and it also correlates with the navicular height, angular measurements, pressures under the midfoot, and the rearfoot motion during walking. It is sensitive to age-related differences in foot posture. Menz et al. (2012) questioned the validity of the AI with the question of whether it is not the fat pad that is still present rather than structural flat feet. When using AI to determine foot shape, researchers should consider body composition as a possible confounding factor, since adiposity may influence the middle third of the footprint (Menz et al., 2012).

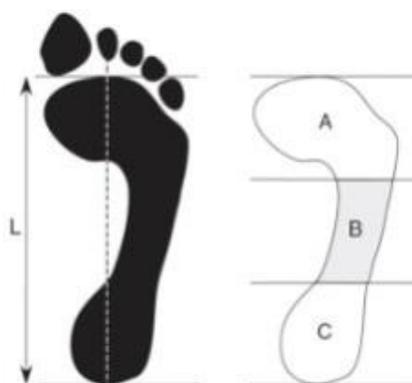


Figure 2.8: Arch Index (Source: Murley, Menz & Landorf, 2009)

Modified arch index - The modified AI includes the use of digital imaging to include pressure data instead of just the contact area. It has a high repeatability and a low subjectivity (Razeghi & Batt, 2002; Xiong et al., 2010). Ranges for modified AI values have been reported to be 0.006 – 0.245 in men and 0.005 – 0.207 in women (Xiong et al., 2010).

Arch length index – This is the ratio of the length of the medial borderline between the most medial points of the metatarsal and heel region and the arch length of the arch outline between these points (Razeghi & Batt, 2002; Xiong et al., 2010), as graphically depicted in Figure 2.9. Typical values for the arch length index are 0.741 ± 0.083 (Queen, Mall, Hardaker & Nunley, 2007).

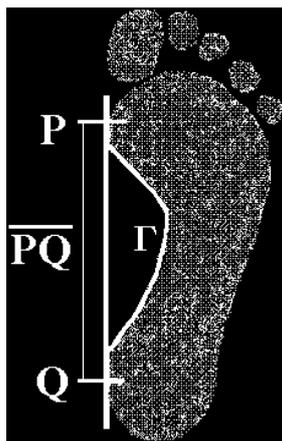


Figure 2.9: Arch length index (Source: Razeghi & Batt, 2002)

Truncated arch index - The index is determined by the ratio of the arch area to the truncated foot area. The arch area is described as the medial borderline and medial footprint outline (Razeghi & Batt, 2002; Xiong et al., 2010) as depicted in Figure 2.10. Values for the truncated AI for individuals 24.8 ± 2.1 years of age have been reported by Queen et al. (2007) as 0.521 ± 0.208 .

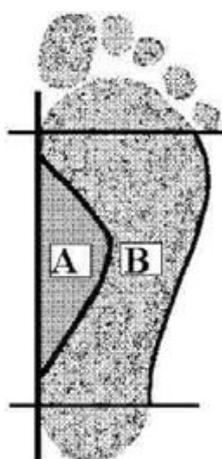


Figure 2.10: Truncated arch index (Source: Razeghi & Batt, 2002)

Bruckens index – A line is drawn on the medial and lateral borders of the footprint. A series of perpendicular lines (EnGn) are then drawn from the line representing the medial border to the line representing the lateral border. The points of intersection (Fn) with the medial outline of the footprint and the line representing the lateral

border are marked. The index is then the average of the ratio's $EnFn$ to $EnGn$ (Razeghi & Batt, 2002; Xiong et al., 2010). Figure 2.11 shows the different lines and markers. No typical values were available in the literature.

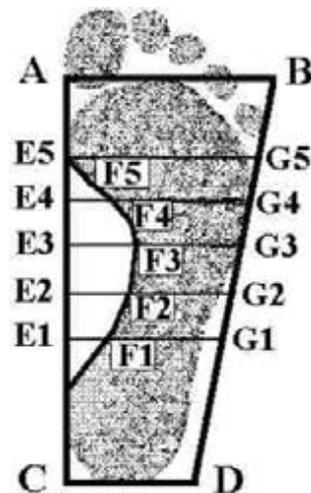


Figure 2.11: Bruncken index (Source: Razeghi & Batt, 2002)

Footprint index – This is calculated by using the ratio of the non-contact to contact areas of the toeless foot, where the non-contact area is between the medial borderline of the footprint and medial footprint outline. The contact area is the area of the footprint without the toes, as seen in Figure 2.12. Reliability has been reported as 0.982 (Razeghi & Batt, 2002). Typical values for men range between 0.068 and 0.453 and 0.119 to 0.498 for women (Xiong et al., 2010).

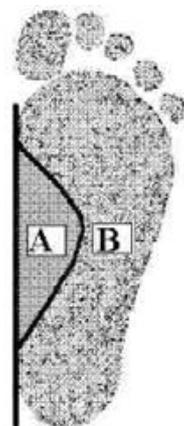


Figure 2.12: Footprint Index (Source: Razeghi & Batt, 2002)

The overall reliability of footprint parameters has been reported by Hawes, Nachbauer, Sovak and Nigg (1992). While comparing footprint parameters with measurements of the arch height, the researchers found a four to fifteen percent variation in arch height. This variation in arch height was reportedly explained by footprint variations. The study concluded that by using footprint analysis, one would only be able to report on angles and indices of the plantar surface (Hawes et al., 1992). In another study, to determine the reliability of the AI, researchers found the ability to predict the arch height from the measurement of the AI to be only 50 percent, which was not regarded as being adequate (McCrary, Young, Boulton & Cavanagh, 1997).

A major limitation of footprint analysis is the inability to assess the extremes (Razeghi & Batt, 2002). A too high or too low arch will influence the use of the parameters. There might be a non-contact area in certain individuals presenting with flat-footedness while the contact area in people with high arches might be discontinued (Razeghi & Batt, 2002).

Anthropometric parameters

This is the direct measurement of landmarks and bony eminences to define different structures of the foot (Razeghi & Batt, 2002). These parameters can be used within a ratio to determine the dimension of the foot (Xiong et al., 2010). Six possible anthropometric parameters will be discussed in the following section.

Arch height – The highest point of the MLA in the sagittal plane is usually represented by the navicular. The arch height is measured between the flat surface the participant is standing on and the navicular bone or the highest point along the soft tissue of the medial plantar curvature and the surface. The navicular height is measured by palpating the skin and the most prominent point of the navicular bone is marked (Gilmour & Burns, 2001). Callipers are used to take the measurement. The navicular height measurement has shown an ICC of 0.924 at 10 percent weight-bearing and 0.608 at 90 percent weight bearing for inter-rater reliability (Razeghi & Batt, 2002). Arch height is an objective approach in determining foot structure. One

of the limitations mentioned is that it limits researchers to only perform static measurements of the MLA and no dynamic measurements (Razeghi & Batt, 2002).

Longitudinal arch angle – This is represented by a line from the medial malleolus to the navicular tuberosity and a line on the most medial edge of the first metatarsal head while being non-weight bearing. The line is examined again whilst weight bearing and any changes in form/shape of the reference line is measured. ICC has been reported as 0.90 for intra-rater reliability and 0.81 for inter-rater reliability (Razeghi & Batt, 2002).

Rearfoot angle – The angle is determined between a longitudinal line bisecting the rearfoot with a line bisecting the distal third of the lower limb or floor. This gives information regarding the frontal plane position and movement of the hindfoot, as well as the motion at the subtalar joint. To a lesser extent, it also gives information regarding movements of the talus within the ankle mortise (Razeghi & Batt, 2002).

Navicular drop – This measurement determines the sagittal plane excursion of the navicular bone from a seated to a 50 percent weight bearing position by using a ruler. It has been shown to have moderate intra- (0.61 and 0.79) and inter-rater (0.57) reliability (Picciano, Rowlands & Worrell, 1993; Razeghi & Batt, 2002). The navicular drop is often used to determine the pliability of the foot (Kothari, Dixon, Stebbins, Zavatsky & Theologis, 2014).

Navicular drift – The navicular drift is measured by the medial displacement of the navicular bone in the transverse plane. It reflects movements of the MLA in the sagittal and frontal plane, but there is no validity of reliability reports on this measurement (Razeghi & Batt, 2002).

Valgus index – The valgus index is determined by projecting the relative position of the malleoli onto an imprint of the supporting plantar area. The centre of the intermalleolar line is related to a line from the centre of the heel to the centre of the third toe print. The formula used to calculate the valgus index is: $VI = \frac{1}{2} \text{ intermalleolar line} - \text{line from centre of heel to third toe print} \times (100/AB)$ (Razeghi & Batt, 2002). The ICC has been reported as 0.83 for intra-rater reliability (Redmond, Crosbie & Ouvrier, 2006).

Radiographic evaluation

Radiographic evaluations of foot shape are done in a weight-bearing condition. There are three measurements that will be discussed in more detail in the following section.

Calcaneal inclination angle – This angle is formed between the tangent and the inferior surface of the calcaneus and the surface contact area as seen in Figure 2.13 (presented as C) (Razeghi & Batt, 2002). Excellent inter- and intra-rater reliability has been reported (0.98) (Murley et al., 2009).

Height-to-length ratio – The ratio is determined by the height which is measured as the distance between the contact surface and the inferior surface of the talar head (most distal aspect of the anterior subtalar facet) and the length which is measured from the most posterior surface of the calcaneus to the anterior surface of the first metatarsal head (Razeghi & Batt, 2002). Data regarding the reliability of this testing is not available.

Calcaneal – first metatarsal angle – The angle subtended by the tangent to the inferior surface of the calcaneus and line along the dorsum of the midshaft of the first metatarsal. Excellent intra-rater and inter-rater reliability have been reported with an ICC of 0.90 and more (Razeghi & Batt, 2002). In Figure 2.13, the calcaneal – first metatarsal angle is presented as D.

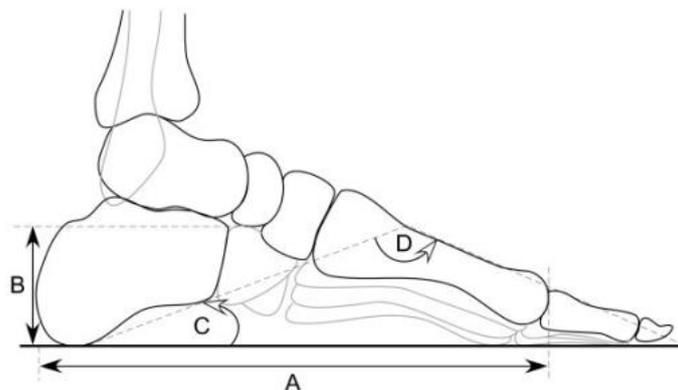


Figure 2.13: Calcaneal inclination and calcaneal first metatarsal angle (Source: Menz, Zammit, Landorf & Munteanu, 2008)

As with most research, there are also problematic areas identified by researchers regarding the measurements of the foot shape. Each researcher has his/her own aim

and approach to the research they are undertaking, therefore different measurements are used. The use of callipers, footprints and measuring tapes are more affordable, but they have a low reliability and it is time-consuming. On the other hand, there is very little data regarding 3D analysis. This could possibly be attributed to the fact that most of the research done on children was done in remote areas, as well as the cost of the 3D analysis (Mauch et al., 2009). In this current study, the researcher visited remote areas. The researcher made use of callipers for foot measurements due to its mobility and cost effectiveness. A summary of the advantages and disadvantages of the type of measurements is depicted in Table 2.1.

Table 2.1: Summary of foot measurements

Type of measurement	Footprints	Anthropometric parameters	Radiographic evaluation
Advantages	More affordable	Moderate to high reliability	High reliability
	Can be used in remote areas	Can be used in remote areas	
Disadvantages	Cannot measure extremes	Time-consuming	Expensive
	Only angles of plantar surface can be measured		Cannot be used in remote areas
	Low reliability		
	Time-consuming		

D. Classification of foot shape

The foot can be classified as either flat (planus) or high (cavus). According to Volpon (1994), using these terms describe not only the anatomical variations but also the complex conditions involving adjustments in other parts of the foot that cannot be detected on footprints (Volpon, 1994). In clinical evaluation, the classification of the foot is based on its morphology (Razeghi & Batt, 2002). Razeghi and Batt (2002) reported that a correlation needs to be established between the static foot structure

measurement and dynamic foot function if static structural measurements will be used for defining foot shape.

Numerous studies have been done on the classification of foot shape in children. Most of the studies used different methods to classify the foot shape.

In a study focusing on footprints of Mediterranean children between six and seventeen years of age, Stavlas et al. (2005) mention a method (Grivas' classification method) that enables researchers to classify the foot into six different footprint types. With these six footprint types, the foot can be classified as high arched, normal arch or low arch.

Other researchers (Fritz & Mauch, 2013) used a cluster analysis where arch angle, volume and foot length were used to identify and classify children's feet into the five categories, as described in Table 2.2 and Figure 2.14.

Table 2.2: Classifying children's feet according to Fritz and Mauch's (2013) cluster analysis

Categories	Description
Flat feet	Flattened MLA with medium volume and length
Slender feet	Small volume, typical narrow ball and heel width, low dorsal arch height, long toes, relatively high arch
Robust feet	Large volume, short toes, and average MLA height
Short feet	Short hind foot, long forefoot, high arch and high volume
Long feet	Long hind foot with short toes, both arch and volume show medium characteristics

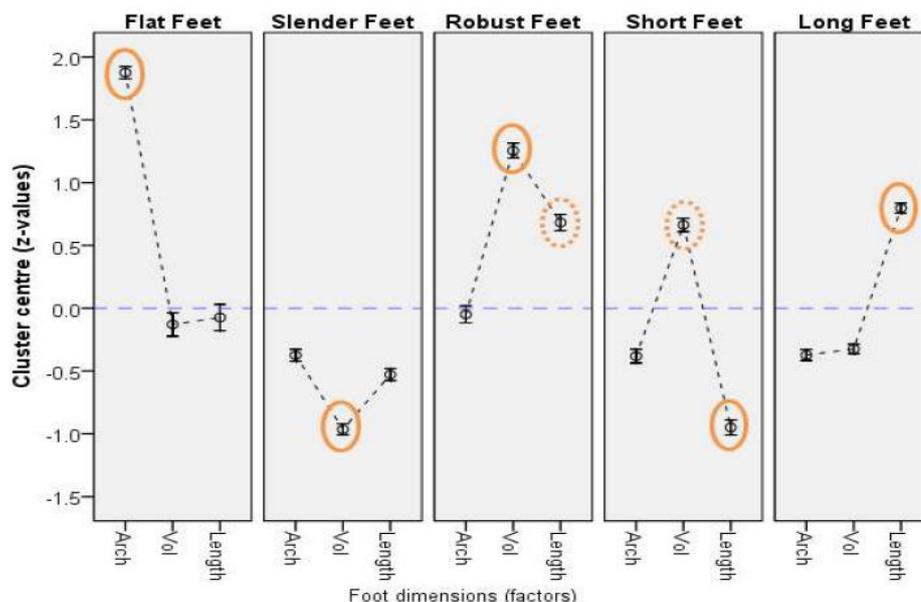


Figure 2.14: Profiles of the five foot types (Source: Fritz and Mauch, 2013)

The x-axis shows the three principal components. The y-axis shows z-values of the cluster centres of each cluster: large positive (negative) z-values correspond to an increased (decreased) dominance of the factor characteristic within the particular foot clusters, whereas a value around zero represents a medium characteristic (Mauch et al., 2008).

In their study, Fritz and Mauch (2013) found that 59 percent of two-year-olds represented with flat feet; however, they noted that it decreased with an increase in age. Flat feet is, however, one of the biggest concerns parents have when their children start to stand and walk (Pfeiffer et al., 2006), therefore flat footedness or flat feet will be discussed in detail.

Flat Feet

Flat feet is defined as the lack of the longitudinal arch, a valgus heel and a prominence on the medial side of the talar bone (Buerk & Albert, 2001) or an abnormally low longitudinal arch (Buerk & Albert, 2001; Aymelek et al., 2011). Two types of flat feet are identifiable, rigid flat feet and flexible flat feet. Flexible flat feet is when the arch is visible when the person goes on his/her toes (Aymelek et al., 2011) or if there is an arch visible while sitting and it disappears during weight bearing (El et al., 2006). Pain and instability might be experienced, depending on the severity of the flat-footedness (Aymelek et al., 2011). The pain could be either caused by an injury

to the muscle or tendon, especially that of the tibialis posterior muscle that supports the MLA, or it could be that a congenital abnormality exists (Lin, Lai, Kuan & Chou, 2001).

Flexible flat feet usually subsides with an increase in age (Lin et al., 2001; Echarri & Forriol, 2003; Pfeiffer et al., 2006; Aymelek et al., 2011; Delgado-Abellán et al., 2014). Other researchers see it as a transitory stage in the development of the foot and not necessarily as a pathology (Müller et al., 2012).

The cause of flexible flat feet is still unknown. A possible reason can be the laxity of the ligaments since muscles and ligaments support the MLA during loading (Buerk & Albert, 2001; Lin et al., 2001; Echarri & Forriol, 2003; Aymelek et al., 2011). Another reason can be due to excessive weight or being overweight (Aymelek et al., 2011). Since muscles are dynamic stabilisers, the shape of the MLA is dependent on the bone-ligament complex. It is common to see joint hypermobility in children with flexible flat feet (El et al., 2006).

Several studies have included the prevalence of flat feet. As mentioned earlier, most researchers noted that flat feet decreased with age. Pfeiffer et al. (2006) found the prevalence of flat feet to be 54 percent in three-year-olds, but it decreased to 24 percent in six-year-olds. They also mentioned that the probability of being flat footed would decrease with 36.8 percent per year.

Flat footedness is a rarity in India and it was observed that only children from urban families have been diagnosed. Joseph and Rao (1992) identified that a prevalence of 6.7 percent of the 2 300 children they examined had flat feet. This percentage decreased with age. An interesting observation was that the prevalence in English speaking schools was higher (12.1%) versus the non-English speaking schools (3.5%). The researchers narrowed it down to the possible cause of flat feet. The percentage, because of ligament laxity, was 14.4 percent in contrast to no ligament laxity that led to only 3.3 percent of flat-footedness (Joseph & Rao, 1992).

Lin et al. (2001) grouped 377 Taiwanese children according to the appearance of their MLA during weight bearing. The results they gathered also showed a much higher percentage of younger children having flat feet (57% in two- to three-year-

olds), while the older children had a much lower percentage (21% in five- to six-year-olds) (Lin et al., 2001).

While using the footprint analysis on 1 851 Congolese children, it was established that 70 percent of the children between the ages of two to three years had flat feet, while the percentage dramatically decreased to 40 percent between the ages of five to eight years (Echarri & Forriol, 2003).

Aymelek et al. (2011) found that among 526 Turkish school children, 51.7 percent of the six-year-olds and 24.3 percent of the eleven-year-old children presented with flat feet.

In a study comparing children from two different continents and countries (Germany and Australia), (Mauch et al., 2008) found a big difference in the prevalence of flat feet. In the German preschool children, 50 percent had flat feet, while only 12.3 percent of the Australian children had flat feet while using the Chippaux-Smirak index. The researchers explained that this could be attributed to the fact that the Australian children spent more time barefoot during their preschool years (Mauch et al., 2008).

There have been different opinions on the treatment of flat feet. While many of the researchers believe and have shown that it is only a developmental phase in younger people, some still want to correct it through arch support or corrective shoes. These options can be very uncomfortable. The effect of this treatment on the development of the MLA can not be proved and some authors reckon that it weakens the foot muscles and would, therefore, increase foot problems (Pfeiffer et al., 2006). According to Leung, Cheng and Mak (2005), there have been negative and positive reports on orthotic interventions.

Summary

The controversy with regards to the treatment of flat feet might be related to the various definitions used for flat feet and the selected parameters that were investigated. Most research has shown that flat feet subside with age. Parents of children should therefore not act prematurely with regards to flat feet. An abnormality

in the MLA structure is; however, thought to be a predisposing factor to injury (Williams & McClay, 2000).

E. Factors affecting foot development and foot shape

Genetics and exogenic factors such as body weight (Mickle et al., 2006b), physical activity, and footwear play a role in the development of the feet of children. External influences can cause deviations and adaptations in the development process (Fritz & Mauch, 2013). Other researchers have stated that age and gender influence the development of the foot (Echarri & Forriol, 2003).

Previous cross-sectional studies have shown that children going barefoot have a higher MLA than shod children, but prospective studies concluded that the MLA develops naturally and independent of footwear (Wegener, Hunt, Vanwanseele, Burns & Smith, 2011). According to Echarri and Forriol (2003), being habitually barefoot during the first years of life could be a possible reason for the increased height in the MLA.

South Africa is regarded as a country with habitually barefoot children. There are various reasons for this. One of the reasons is poverty. Other reasons can be our warm climate and that parents are educated on the effect shoes have on their children's feet and therefore choose not to let the children wear shoes. Due to the variety of results from previous research, this part of the literature overview will be dedicated to the different factors that might affect the development of the foot.

Footwear

Feet of children are still maturing and are prone to external influences. It is, therefore, important that footwear allows the foot to function and develop normally (Fritz & Mauch, 2013). It is important to know when the foot is sensitive to external influences and, if possible, to adapt the shoes (Fritz & Mauch, 2013). Some researchers also state that more people in the West experience foot problems compared to people

living in Africa. This may be due to their shoe wearing habits, foot shape and the loading pattern (Stolwijk, Duysens, Louwerens, van de Ven & Keijsers, 2013).

Researchers have various opinions with regards to the influence of footwear on the development of feet. Children's footwear sizes are currently based on adult sizes, the proportions are the same, with just the size that differs. For this reason, footwear can influence the normal development of the foot (Delgado-Abellán et al., 2014). Researchers Fritz and Mauch (2013) formulated it well by saying that shoe proportions must meet feet proportions and the functional aspects of the feet. If not, it can be harmful to the development of the feet (Fritz & Mauch, 2013).

Another way shoes can influence the foot is by atrophying the intrinsic muscles of the foot. The function of the intrinsic muscle is to support the arch of the foot and to stabilise the foot during the propulsive phase of gait. Due to prolonged shoe wearing, these muscles; however, become weak and the best way to train the intrinsic muscles is to go barefoot (Hamill, Knutzen & Derrick, 2015)

In response to the question of what the most important feature of footwear is to classify it as being foot-friendly, Dr. Bettina Barisch-Fritz replied the following, based on her observations regarding barefoot and in particular foot morphology: "The most important 'feature' is an anatomical shape of a shoe, especially of the forefoot area. Furthermore, in this area, a shoe should be very flexible to allow the widening of the forefoot (between MTH1 to MTH5), as well as the forward movement. The midfoot area of a shoe should also be flexible; however, in a different way. Within this area, the foot must be prevented from sliding forward within the shoe. The reason is furthermore, that this anatomical area is very special with the plurality on bones, joints and soft tissue" (Barisch-Fritz, personal communication, 23 August 2016).

According to researchers Barton, Bonanno and Menz (2009), footwear has been modified to fulfil various functions. It needs to provide protection to the foot, assist the foot in its daily function, accommodate foot deformities, treat muscle injuries and be fashionable. There is; however, negative aspects that have been linked to footwear. Footwear is said to be one of the main reasons for falls in the elderly population and in children (Barton et al., 2009; Schwarzkopf, Perretta, Russell & Sheskier, 2011). It is also linked to the development of osteoarthritis in the foot and knee and lower back

pain, as well as foot deformities such as hallux valgus, hammer toes, foot ulcerations and amputations (Barton et al., 2009).

Menz and Morris (2005) noted that although one of the main functions of footwear is to protect the feet from trauma, it can, on the other hand, cause foot deformities like hallux valgus, corns and calluses and lesser toe deformities. They mentioned that there is a low prevalence of foot problems in people that have never worn shoes. There was an increase in hallux valgus surgical procedures after Japanese women started to wear Westernised footwear. High heel shoes put more pressure on the metatarsal heads and could, therefore, interfere with the metatarsophalangeal joint function. In their study on older people, they saw that women are more prone to corns, hallux valgus and lesser toe deformities and general foot pain. Most of the conditions mentioned could be due to the inadequate width of the shoes, except for lesser toe deformities, which can be due to the inadequate length of the shoes.

As mentioned earlier, in a study conducted in India, it was found that flat footedness is a rarity, since only 6.7 percent of the 2 300 participants presented with flat feet. The prevalence in children wearing shoes were higher (8.6%) compared to children who do not wear shoes (2.8%). If it occurred, it was only in children from urban families, never children from manual labourers. Joseph and Rao (1992) speculated that one of the main reasons for this is that whenever the children play, they will take off the footwear they use, which would usually be sandals or slippers, not closed shoes. The researchers, therefore, suggested that closed-toe shoes inhibit the development of the foot more than slippers and sandals.

Probably the best example of how badly footwear can influence the foot is when looking at 'Chanzu' (Chinese feet binding). Bound feet existed in China for almost one thousand years. The initial aim for binding feet was to modify the feet into small feet or 'three-inch golden lotus'. This was believed to be the aesthetic standard and was essential for a woman if she wanted to marry into a wealthy family (Gu, Mei, Fernandez, Li, Ren & Feng, 2015). In a study conducted by Gu et al. (2015), the researchers examined the foot loading characteristics of Chinese bound feet women. Results of this study showed that during walking, the rearfoot and forefoot regions bear the most loading, compared to a normal foot where the whole foot bears the load. There was also a decreased range of motion in the ankle during the stance

phase of walking due to the broken MLA (Gu et al., 2015). Another article reported that subjects with bound feet walked slower when walking at a self-selected speed, therefore giving shorter steps when walking a similar speed to normal feet. The researchers found that toe-off rather looked like a 'pull-off' instead of a 'push-off' (Zhang, Feng, Hu & Gu, 2015).

Summary

Footwear has been developed to protect the foot against the environment and harsh elements; it is however not supposed to influence foot development. Various research studies have shown that footwear could lead to foot problems such as corns and calluses. Some studies have shown that people who often go barefoot have a lower prevalence of flat feet.

Criteria for footwear

During childhood, different developmental stages place more demands on footwear than other. Walther et al. (2008) gave detailed criteria on the demands that footwear needs to fulfil during the different stages of childhood. The criteria and the reasons for the criteria are set out in Table 2.3.

According to Mauch et al. (2009), footwear should support the foot's physiological functioning and the shape and dimensions of the shoe must be the same as those of the foot. The researchers found that feet that are similar in volume have different forefoot shapes. They also stated that the volume of the foot seemed to be more important than the forefoot shape when determining foot characteristics, but forefoot shape is still important to consider when constructing shoes. Another important feature when designing shoes is the flex line of the shoe. This should be in line with the metatarsal-phalangeal-joint which can be specified by the ball angle and ball-of-foot length (Mauch et al., 2009).

Krauss et al. (2005) stated that there is a big difference in foot shape between men and women. According to Krauss, Langbein, Horstmann and Grau (2011), the foot

dimensions are very important in the manufacturing of footwear. Women's shoes are usually manufactured by downscaling the men's sizes. This could be one of the main reasons why so many women wear ill-fitting shoes.

Ill-fitting shoes

Many researchers have looked at the size of footwear in comparison with the size of the foot. It has been stated that ill-fitting shoes can hinder the normal development of the maturing foot and that it can lead to foot problems in children as well as adults (Mauch et al., 2009).

Janisse (1992) mentioned that ill-fitting shoes lead to foot deformities. He defended this by referring to a study conducted by the American Orthopaedic Foot and Ankle Society's Women Footwear Committee on 356 women between the ages of twenty and sixty years. They found that 88 percent of the women wore ill-fitting shoes and 76 percent of them presented with a forefoot deformity (Frey, Thompson, Smith, Sanders & Horstman, 1993).

Walther et al. (2008) noted in their research that at an event (the event type was not mentioned) where children's feet were monitored, only 46.7 percent of the children wore footwear that fitted properly. There were children (33.4%) who wore shoes that were one size too large for their feet and 10.3 percent wore footwear that was two sizes too large for them.

In a study conducted by Menz and Morris (2005), the indoor and outdoor shoes of older individuals were investigated. They found that 13.7 percent of the indoor and 10.2 percent of the outdoor shoes were too short for the length of their feet. When looking at the width of the shoe, 81.4 percent of indoor shoes and 78.4 percent of outdoor shoes were too narrow for the foot. For the total area, 43.7 percent of indoor shoes and 47.3 percent of outdoor shoes were too small for the individual wearing them. Women showed a higher variance between their foot sizes and shoe sizes.

Table 2.3: Footwear criteria at different stages (Source: Walther et al., 2008)

Age	Criteria and reason
0 - 1 years	<ul style="list-style-type: none"> • No need for a child to wear footwear.
1 – 2 years	<ul style="list-style-type: none"> • Most children start to walk. • Children still do not really need footwear. • If shoes are worn, it should be soft, flexible and give the foot as much freedom to move as possible. • The shoe sole should be thin to avoid adding strain to the foot.
2 – 4 years	<ul style="list-style-type: none"> • Ossification of the short foot bones occur. • Footwear should not interfere with the ossification process. • Footware should not provide additional loads on the foot. • The shoe sole should be soft and flat.
4 – 6 years	<ul style="list-style-type: none"> • Spitzzy's fat pad is still present - no additional arch support or special absorption is needed in footwear. • The shoe should have a stable rear foot and needs to come up over the ankle, because the medial part of the foot grows faster than the rest, leading to a smaller width and reduced height when compared to the length of the foot. • The sole should be flat. • Good forefoot flexibility in the shoe.
6 – 10 years	<ul style="list-style-type: none"> • Connective tissue provides more stability. • Mobility within the foot is less. • In this phase, more pressure is put on the heels than in adulthood. • Increased need for stimuli to help with the growth of muscles and bones. • A difference in foot shape between the two genders starts to develop. • The shoe should not have too much cushioning. • Stability can be added to the midfoot and rearfoot sections.
12 – 15 years	<ul style="list-style-type: none"> • Foot reaches its final size. • Since children become more physically active, there are more stresses on the foot. • These stresses are tolerated by the bones, muscles and soft tissue. • Footwear for this age group is similar to the footwear of adults. • Cushioning should be medium. If too soft, it could lead to neuromuscular transmission problems. If too little, it could lead to injuries.

Another study showing women, or in this case girls, wearing ill-fitting shoes more often, was conducted on Spanish school children. It was mostly the girls that wore shoes too short for their feet. The researchers stated that shoe sizes are based on the length of one's foot and not the width (Delgado-Abellán et al., 2014).

Ill-fitting shoes can be detrimental to diabetics. In a study done on three different population groups in New York City, results show that more than 90 percent of the 235 participants did not know their shoe size and shoe width, and 34.9 percent of the participants wore ill-fitting shoes. The type of clinic (a private practice of a foot specialist, an academic diabetic foot and ankle clinic, and a charity care centre) had an influence on the prevalence of foot and shoe mismatches, where less ill-fitting shoes occurred at the private practice (Schwarzkopf et al., 2011).

Burns, Leese and McMurdo (2002) conducted a study to determine the proportions of elderly individuals in a general rehabilitation ward wearing the incorrect shoe size and looked for signs of complications. The outcome was that 37 percent of diabetic outpatients and 24 percent of general medical outpatients wore the wrong size shoe. The researchers stated that they were not sure if the participants bought the shoes too big because of pain or ulcers, or if the shoes were too big, which in turn led to the pain and ulcers.

Mauch et al. (2008) support the findings of Burns et al. (2002) that ill-fitting shoes may hinder foot development. They found a difference in the ball-of-foot lengths and the ball angles between German and Australian children. The researchers' reasoning for this difference can be ascribed to the difference between the shoes of German and Australian children. Since the shoe puts continuous pressure on the foot, the bone structure might be altered (Mauch et al., 2008).

Summary

Various methods and formulas were used to determine the shoe fit in the above-mentioned studies. From the results of these studies, it is evident that the general public are not well educated on shoe fit and they do not realise the importance of the correct shoe size, therefore the high occurrence of ill-fitting shoes.

Determining shoe sizes

Shoe sizes originated in the fourteenth century when King Edward II decreed that three barley corns should be taken from the centre of a barley ear and placed end-to-end, equal to one inch. Thirty-nine barley corns placed end-to-end measured 13 inches, being the largest foot anyone has seen; it was declared as the size 13. Other sizes were downgraded from the 39 barley corns by subtracting one barley corn, representing one and a third inch. This measurement is still used today. The golden standard when determining shoe size is by using the Brannock measuring device (Goonetilleke, Luximon & Tsui, 2000). This device measures the foot length (from heel to toe), the arch length (from heel to arch or first metatarsal) and the width of the foot (Janisse, 1992).

Various researchers have found different results on how to manufacture a proper shoe to achieve a proper shoe fit by means of a shoe shape that matches the foot shape. Janisse (1992) gave an elaborate explanation of the requirements of the art and science of fitting shoes, which will be described below. He mentioned that it is better if shoe sizes are determined by arch length, rather than foot length. The proper shoe size is one that accommodates the first metatarsal joint in the widest part of the shoe. Shoe shape depends on the last (a wooden form similar to the shape of the foot) or the mould. Different manufacturers have different shapes and sizes of lasts. A standard last is used for popularly priced shoes which are mass produced. The downfall to this last is that it has limited sizes and is often only available in medium width. An orthopaedic last comes in a variety of widths and sizes and different shapes, but it is more expensive since it is not mass-produced. The combination last is used in mass-produced shoes, and it is the primary orthopaedic last with a narrower heel and wider forefoot. This provides enough room for the metatarsals and toes to move while ensuring a good fit at the heel. A proper fitting shoe does not only depend on the shape but also on the upper as well. In orthopaedic shoes, the upper allows extra room for the foot and insoles and is commonly referred to as the in-depth type last. Shoes with tapered toe boxes or pointed shoes will increase the pressure on the toes and force them into unnatural shapes. This could lead to calluses, discomfort, and deformities.

According to Mauch et al. (2009), shoe sizes are determined by the last. A proper shoe manufacturer will adjust the shoe size by changing the dimensions of the ball, the instep, and the heel. However, since this is a more expensive procedure to follow, most shoe companies only change the shoe size by increasing or decreasing the length of the shoe (Mauch et al., 2009; Fritz & Mauch, 2013).

There are several measurements of the foot that can be used to determine the shoe size for a specific person. First, the foot length is used. This is the distance between the foremost point of the longest toe and the back point of the heel. Other length measurements that are used are the distance between the back point of the heel and the first metatarsals (MTH1) or the distance between the back point of the heel and the fifth metatarsals (MTH5). Different measurements can be done to determine the width of the foot. Anatomical ball width (ABW) is the distance between the MTH1 and MTH5. Technical ball width (TBW) can be determined by the orthogonal distance from the most medial to the most lateral point at 61.8 percent of the foot length. The anatomical heel width (AHW) is the widest distance between the most medial and lateral parts of the heel, and the last width measurement is referred to as the technical heel width (THW), which is the orthogonal distance between the most medial and lateral parts of the heel. Volume is determined by using the girth measurements at certain points. Some shoemakers have used instep height which is measured at 50 percent of the foot length (Fritz & Mauch, 2013).

Differences between populations (Delgado-Abellán et al., 2014) as well as the age of the person, should also be taken into account when designing shoes. Education on the correct shoe size for a particular foot size and the negative effect an incorrect shoe size has on the feet is of utmost importance.

Summary

Most shoes are manufactured in bulk and average measurements of various populations are used to determine the shape and size of the lasts. The most important features of a shoe are that it should fit the foot shape and have enough space in the front to allow some movement of the foot within the shoe while walking.

Body weight

Limited research is available on obesity and its effect on foot structure (Hills et al., 2002). Most of the studies report on flatter feet in overweight people. The cause of the flatter feet is unknown. It is speculated that the flatter feet might be due to the fat pad underneath the midfoot although it is thought to be resolved between the ages two to five years. Another possible reason for flatter feet could be attributed to the collapse of the MLA due to excessive loading because of extra weight (Hills et al., 2002; Mickle et al., 2006b).

Body weight and foot structure

In the study conducted by Mickle et al. (2006b) on 19 obese individuals, the researchers reported that the obese children between the age groups three to five and seven to twelve years had larger foot dimensions. The overweight children also had flatter feet with a higher AI. Mickle et al. (2006b) mentioned that the foot structure was affected by carrying extra weight. Results show that even the overweight children displayed a larger midfoot contact area, not just the obese children. There was no significant difference between the thicknesses of the fat pad between the two groups since both groups showed the existence of the fat pad. The researchers concluded that the reason for the flatter feet in overweight or obese children is not the fat pad, but that it is rather due to the lower plantar arch height. This could be attributed to the continual exposure to excess mass that can become even worse if the excess weight is carried into adulthood (Mickle et al., 2006b).

Dowling et al. (2001; 2004) also found the feet of obese children to have a bigger contact area. The researchers mentioned that long-term bearing of excessive weight could flatten the medial midfoot region. No longitudinal studies have been done on the long-term consequences and therefore the researchers were not able to comment on these consequences (Dowling et al., 2001; 2004). Another occurrence the researchers could not explain was the actual mechanism behind the bigger contact area and whether this flattening was reversible or permanent, and if it could be associated with foot discomfort and pathologies. If it was associated with foot discomfort, the researchers speculated that it could have an influence on the physical

activity of the child, but they recommended that further investigation is required (Dowling et al., 2001)

To demonstrate the influence of weight on the foot size, Cheng, Leung, Leung, Guo, Sher and Mak (1997) found a significant increase in the width and the length of the foot on weight bearing when compared to the non-weight bearing foot. The researchers studied 2 829 children between the ages of three and eighteen years of age. This can once again confirm that loading the foot or excessive loading can lead to a bigger foot contact area.

Another study describing the effect of body weight and height was conducted in Germany (Bosch, Gerß & Rosenbaum, 2010). The results show that body height had a significant influence on foot length and midfoot width. The study was a nine-year longitudinal study where the researchers measured 36 participants. A difference of five centimetres (cm) in height (identical weight, identical age of onset of walking, and same gender) led to a 0.4 cm longer, but a 0.3 cm narrower foot. A kilogram (kg) difference in body weight also made an impact on the foot; it led to a wider foot (\pm 0.08 cm) (Bosch et al., 2010).

Pfeiffer et al. (2006) observed that obese children had a higher tendency of flat feet than their normal BMI counterparts. The probability was three times higher in the obese children. The researchers did not give an explanation why this occurred, but they supposed that flat-footedness in children and its clinical relevance will increase.

Fritz and Mauch (2013) used the classification as described in Table 2.2 and found that overweight children presented with more robust (27%) and flat feet (22%) compared to the underweight children who only represented four percent of those having robust feet and 10 percent of those having flat feet. Underweight children tended to have more slender feet (26%), while the overweight group represented only seven percent of the slender feet group. The biggest differences between the underweight and overweight children were seen between seven to ten years and eleven to fourteen years of age.

In contrast to the abovementioned studies, a study done on Indian children showed no significant difference in BMI between the children who presented with flat feet and those who did not. The average BMI for flat-footed children were 14.72 kg/m²,

whereas the BMI for the children with normal feet were 14.61 kg/m² (Joseph & Rao, 1992).

By using the navicular drop test, Kothari et al. (2014) researched the link between BMI, foot posture and foot pliability. In the study, they found no statistically significant correlation between these measurements. The researchers concluded that the established link is based on weight-bearing feet, and although they did not find a correlation between BMI, flexibility, and the navicular excursion being mentioned, these factors may already have an influence on the positioning of the navicular in a sitting position.

Summary

Most of the research done on overweight and obese children has found that excessive weight influences the foot. Overweight and obese children presented with flatter feet (lower MLA), wider midfoot and longer feet for all age groups. The reason behind the flatter feet could not be explained and only speculations were made.

Body weight and kinematics

When looking at the pressures acting on the foot, more research is available on this specific topic.

In a study comparing plantar pressure distribution of school children with those of adults, researchers found a significant correlation between body weight and peak pressure under all regions of the 125 children's feet between six and ten years of age. This is different than what is found in the adult population. There was a significant correlation between body weight and plantar pressures in the midfoot region of the adults. Heavier adults tended to have a higher load underneath their MLA (Hennig, Staats & Rosenbaum, 1994).

Peak forces acting on the foot were also greater in the obese children than the non-obese children from Australia. Mean peak dynamic forefoot pressure generated by

the obese children was significantly higher than their non-obese counterparts (Dowling et al., 2001). Even while static, the obese children experienced higher plantar pressure compared to the non-obese children. Although the forces were distributed over a larger area while walking, the obese children could not decrease the plantar pressure and this can lead to foot pathologies, especially in the immature foot (Dowling et al., 2004).

Results from a study by Mickle, Steele and Munro (2006a) were consistent with the results of previous studies showing that obese and overweight children had a significantly larger contact area for the total foot, heel, midfoot and forefoot area when walking. There were also larger forces acting on the feet. Despite the additional contact area, it was still not enough to compensate for the increased forces generated during walking. The researchers mentioned that this could lead to the vicious cycle of obesity. High plantar pressures may cause foot pain during activity, and consequently, the person does not want to participate in a physical activity which, in turn, leads to an increase in sedentary behaviour which then leads to an increase in weight or eventually obesity. The researchers mentioned that the force-time integrals suggest a higher stress on the midfoot and MLA area in obese children. These children can, therefore, be more prone to bony fatigue. The threshold for bony structures exposed to this excess weight is unknown. It is of utmost importance to prevent overweight children become overweight adults. This will help to avoid musculoskeletal disorders or injuries (Mickle, Steele & Munro, 2006a).

Summary

As can be seen in the previous section, most researchers found that children with a higher BMI had larger forces acting on the foot.

Obesity

In the current study, one of the objectives was to determine the effect of BMI on the foot length, width and AI in school children of the Western Cape, South Africa. The

primary reason for the latter is because of the growing concern of obesity by health professionals.

According to the World Health Organization, the prevalence of obesity is increasing worldwide. The worldwide prevalence of overweight and obesity combined increased with 27.5 percent in adults and 47.1 percent in children between 1980 and 2013 (Ng et al., 2014). Obesity is a risk factor for various chronic diseases (Cole, Bellizzi, Flegal & Dietz, 2000; Riddiford-Harland, Steele & Storlien, 2000), musculoskeletal disorders and it also might impair quality of life (Riddiford-Harland et al., 2000). Overweight and obesity is defined by Rossouw, Grant and Viljoen (2012) as excessive fat accumulated to the extent that it may have negative effects on the health and well-being of individuals. The golden standard for determining obesity is through measuring fat percentage anthropometrically (Cole et al., 2000; Rossouw et al., 2012). This is; however, an impracticable method that cannot be used worldwide (Cole et al., 2000). Although BMI is not as sensitive as determining fat percentage, it is the measurement that is internationally agreed upon to determine childhood obesity (Cole et al., 2000; Riddiford-Harland et al., 2000).

BMI changes substantially with age, as can be seen in Table 2.4 (Cole et al., 2000).

Table 2.4: BMI median according to age (Source: Cole et al., 2000)

Age	BMI median
Birth	13 kg/m ²
1 year	17 kg/m ²
6 years	15.5 kg/m ²
20 years	21 kg/m ²

Stemming from the above, a BMI per age has been developed (Rossouw et al., 2012). According to Cole et al. (2000), no international values existed for BMI in children. Cole et al. (2002) used data from Brazil, Great Britain, Hong Kong, Netherlands, Singapore and the United States to establish an international cut-off point to define childhood obesity. The new definition of childhood obesity is based on the adult obesity cut-off point of 30kg/m² (Cole et al., 2000).

In two recent studies conducted in South Africa, Reddy et al. (2012) and Rossouw et al. (2012) report that obesity in South Africa has doubled between 1990 and 2010. In sub-Saharan Africa, the highest prevalence of obesity was recorded in South African women (42%) in 2013 (Ng et al., 2014). According to research, there is an age-dependant trend from early childhood with high obesity levels, to school-age, lower obesity levels into late adolescence, high obesity levels. This phenomenon especially occurs in the previously disadvantaged groups. The decrease at school age and the increase during adolescence are gender and race dependent (Rossouw et al., 2012).

Reddy et al. (2012) found the increase in obesity to be equally significant in all races and both genders. The prevalence did; however, change significantly in black youths. The study also found a dose-response relationship between socio-economic status and overweight or obesity in South Africa. The higher the socio-economic status, the higher the risk for overweight and obesity (Reddy et al., 2012).

Summary

Obesity is growing concern in the world, but especially in South Africa. A vicious cycle during adolescence could occur, where an increase in weight could lead to inactivity which leads to an ever-higher increase in weight. Several other socio-economic factors play a role in the occurrence of obesity in South Africa.

Ethnicity

The foot's maturation process occurs according to genetics (Fritz & Mauch, 2013). Therefore, there is an expectation to see different foot forms in different race groups and at different stages of the development.

Hawes et al. (1992) found a difference in the location and angularity of the metatarsophalangeal joint axis and the shape of the anterior foot between Oriental and North American men. Mauch et al. (2008) refer to research conducted by Kouchi (1998) who found Japanese and Indonesian feet to be similar to one another, but different when compared to Caucasian/Australian feet. For people with a mixed racial

background, it was not that easy to pin their foot shape to their race, since other factors might play an important role. Although most of the Australian and German populations consist of Caucasians, it was found that the German children's feet on average were ten millimetres (mm) longer than those of their Australian counterparts.

The laxity of the foot between different ethnic groups was noted in a study done on 2 360 Chinese and a large group of Caucasian children (Cheng, Chan & Hui, 1991). The researchers found that at three years of age 100 percent of the Chinese children presented with lax feet, where only 50 percent of the Caucasian children had lax feet. The percentage in both groups decreased with age and at six years, sixty-seven percent of Chinese and only five percent of Caucasian children had lax feet. The last age group they measured that still had a significant difference was 12 years old. Twenty-eight percent of Chinese children still presented with laxity in their feet when compared to only one percent of Caucasian children (Cheng et al., 1991).

Several research studies investigated adult feet. Some of the research was done while static and others while static and dynamic. All the research mentioned below had the same results: a difference in foot shape between different ethnicities.

Results of a study done on Malawians confirmed that their AI was significantly higher ($p < 0.001$) than Caucasian Americans and Europeans ($p < 0.01$) (Igbigbi & Msamati, 2002).

Dunn et al. (2004) found in their study that African Americans had the highest prevalence of flat feet, followed by the non-Hispanic Caucasians and then the Puerto Ricans.

D'Aout and colleagues (2009) evaluated the Indian population. They compared habitually barefoot Indians to habitually shod Indians and to a Western population. Results show that the feet of the habitually barefoot walkers are relatively wider than the habitually shod Indians. The Western population had a higher and more variable MLA, and the habitually barefoot Indians had significantly lower plantar peak pressures than the habitually shod Indians. When comparing the foot length and width of the Indian participants to those of the Westerners, the Westerners had relatively shorter and narrower feet (D'Aout, Pataky, De Clercq & Aerts, 2009)

In another study conducted on the adult feet of Malawian and Dutch individuals, Stolwijk et al. (2013) found the Malawians to have a statistically significant flatter MLA and higher loading patterns under the midfoot area. Malawians also presented a shorter period of forefoot loading during toe-off. The bigger loading area led to the plantar pressure being distributed more evenly. The AI was significantly higher for the Malawians; however, AI is related to BMI and body weight and the researchers did not account for that (Stolwijk et al., 2013).

Summary

From all the research done on different ethnicities and their foot shapes, it is evident that genetics and other factors determining ethnicity, like cultural habits has an influence on the shape of feet.

Gender

Gender differences exist in the adult foot shape. Studies between 1994 and 2014 show differences between genders regarding height, foot length and foot breadth from the first month of life into adulthood. There is; however, a difference in the order of skeletal changes between the genders, and these differences are seldom investigated in the early years (Unger & Rosenbaum, 2004). The discussion follows chronological development.

In their study on **infants**, Unger and Rosenbaum (2004) found that boys had a significant broader midfoot and lower arch in the first year of their life compared to those of girls. The AI was significantly different, with the boys having a larger midfoot area. Although the boys presented with a higher body weight, even after correcting the data for body weight, the differences were still significant.

Similar results were found when looking at a slightly higher age group. From a sample of 835 preschool children (**three to six years of age**), 52 percent of the boys presented with flat-footedness compared to the 36 percent of girls of the same age.

The rear foot angle for determining valgus or flat feet was higher in boys at every age group (Pfeiffer et al., 2006).

The difference between genders at certain age groups was also noted by Walther et al. (2008). In the age group **six to ten years**, the researchers found a difference in the foot shape between the genders, with boys having a more voluminous foot and girls a more slender and delicate foot. There was a difference in the ratio of circumference-to-length between the genders.

In a study conducted by Gilmour and Burns (2001), they investigated the medial arch angle of children. Their results show that girls had a higher arch between the ages of **five and ten years**.

Echarri and Forriol (2003) conducted a study on 1 851 Congolese children from urban and rural areas. These researchers also found that the girls tend to have a higher inner arch than the boys. This tendency was seen amongst the barefoot children as well. They found that footwear had very little influence on the morphology of the foot.

Stavlas et al. (2005) conducted a study on the feet of Mediterranean children between the ages **six and seventeen years**. Results show boys to have a higher percentage of lower arched feet than girls at the **ages seven, nine, eleven, fourteen and fifteen years**. Both genders; however, showed more normal footprints than higher or lower arched footprints. The researchers noted that this could be due to the difference in growth potential between the genders. Girls' feet showed earlier signs of changes from low arched feet to normal type feet than the feet of boys (Stavlas et al., 2005).

Another study concluded that between **eight and ten years** of age the differences in development between the genders can be seen. It seemed that there were a lot of differences, but when normalising for variability in foot length, the only significant difference was seen in the ball width and girth measurements (Delgado-Abellán et al., 2014).

Contrary to the study by Delgado-Abellán et al. (2014), Mickle et al. (2008) found that when normalising foot length there was no difference between the genders. The

researchers focused on gender and foot structure and found that boys had longer feet with larger girths around the ball-of-foot and instep than girls. Results show that the boys had higher AI values, which imply that there were bigger contact areas on the plantar surface relative to the ground. This flatter appearance could be caused by the significantly thicker midfoot fat pad that was noted in the boys, rather than a structural deficit. It could, therefore, be concluded that boys' feet develop at a slower rate when compared to the feet of girls (Mickle et al., 2008).

Fritz and Mauch (2013) noted that the differences in foot shape between the genders are more obvious from **12 years** of age. For most of the girls, growth of the foot length slows down and stops at 13 years, as for the boys, this happens two years later. They also mention that the foot is the first body segment to complete its growth and that the mature foot length is equal to 15 percent of body height. When looking at the dimensions of the foot, boys might still experience change until 18 years of age, whereas girls do not really experience any change from 13 years onward. According to the researchers, the ball and heel width of the girls were on average two to three mm smaller than that of the boys. Boys had bigger foot dimensions when compared to those of the girls, with a broader midfoot.

The difference in growth between genders was also reported by Volpon (1994). He mentioned that this difference in growth rate is evident from **12 years** of age. Similar to the abovementioned research, he found that boys' feet continue to grow, while girls' feet stop growing at 12 years.

The average weight-bearing foot length of 2 715 Chinese children in the age group **four to five years** and **twelve years** upward was significantly different between boys and girls. The boys had longer feet than the girls. This result confirmed previous research results that the foot length of girls increased linearly from three to twelve years where the boys' feet took slightly longer to develop (three to fifteen years) (Leung et al., 2005).

A longitudinal study conducted over nine years found that the midfoot of boys tended to be on average six mm wider than the midfoot of the girls. The boys had a flatter MLA and with that, they had a four percent smaller forefoot contact area (Bosch et al., 2010).

When looking at adult feet, researchers found similar results. A study on 287 Caucasians showed a significant and practical difference between the feet of men and women in the same length category. Men tended to have a bigger width and height measurement than the women (Krauss et al., 2011).

Summary

A difference in foot shape between the genders can be seen from the first years of life already. The most obvious differences develop around 12 years of age. Girls' feet tend to plateau in growth, while boys' feet continue to grow until 15 years of age.

Activity level

As the level of obesity is becoming higher, the level of physical activity is declining, especially in girls between the age of nine and eleven years (Truter, Pienaar & Du Toit, 2010). This could be due to our modern way of living with extended working hours and travel time. In children, physical activity is on the decline, this could be because of the rise in technology and more children being exposed to this technology. The fact that children do not play outside anymore, could be attributed to families living in smaller units as well as crime. Another reason, as mentioned earlier, is the cycle of obesity, where overweight or obesity leads to discomfort during physical activity which, in turn, results in a decline in physical activity and a reason for being overweight or obese (Grau, Steele, Hömme, Munro, Mauch, Chmelorova, Hlavacek, Sixtova, Romkes, Stacoff & Hennig, 2009; Truter et al., 2010).

Very little research regarding physical activity and foot shape has been done. Most of the results found in the literature were part of a bigger study or looked at other variables as well. One such study is the study investigating the feet of Turkish children. The researchers also took the activity levels of the children into account and found that only 13.6 percent of the children with flat feet lives in the rural areas, whereas 41.3 percent lives in the city centre. Children living in the rural area were

used to working in the cultural fields and therefore tended to be more active (Aymelek et al., 2011).

A decline in physical activity during childhood and adolescence was noted by researchers tracking physical activity in pubertal boys over two years. The boys aged nine to sixteen years showed a bigger decrease in physical activity, which is a worrying factor for health and obesity prediction. Previous research found a higher decline in the moderate-vigorous physical activity in children with a higher body fat percentage. In this study; however, the researchers found no difference in tracking moderate to vigorous physical activity. The decline in physical activity can be contributed to the increase in screen time and the number of hours spent at school. There is a seasonal influence on physical activity in boys, since some sports are only summer sports and others winter sports (Raask, Konstabel, Maestu, Latt, Jurimae & Jurimae, 2015).

There are many factors that can influence the development as well as the shape of the foot. The shape of the foot, on the other hand, has a direct influence on lower limb kinematics, muscle activity, balance and functional ability, and it can predispose one to overuse injuries (Menz et al., 2012). It is, therefore, important to minimise the external influences and to keep the foot form as it was designed to be. For the developers of shoes, it is of utmost importance to have knowledge of the human foot shape, its functioning and the influence shoes have on it (Fritz & Mauch, 2013; Krauss et al., 2011).

F. Summary

Numerous research has been done in a variety of fields regarding the development of the foot, the development of shoes, and the external influences that play a role in the development of the foot. There is; however, still a lot of people that have foot problems or wear ill-fitting shoes. The foot is our base of support and it is continually exposed to high ground reaction forces (Hills et al., 2002). We should, therefore, look after it and limit external pressure acting on it. Feet should be free to move and free to fulfil the task they were made to do.

CHAPTER THREE

Methodology

A. Introduction

Chapter Three focuses on the methodology used for data collection. The chapter firstly describes the study design. Secondly, participant recruitment, measurements, and tests, as well as the testing procedures will be described. Lastly, the focus will be on the statistical analysis that was used to test the objectives of the study.

B. Study design

This study followed a comparative cross-sectional design. A random sample of convenience was used to determine the schools in the Western Cape, South Africa, where testing would take place.

C. Schools and participants

The Western Cape is divided into six municipal areas namely, the City of Cape Town metropolitan municipality, and five district municipalities: the West Coast, Cape Winelands, Overberg, Eden and Central Karoo districts, as seen in Figure 3.1. The randomised sample of convenience included schools from five of the six regions in the Western Cape. The furthest point the researchers travelled to conduct testing were Oudtshoorn, 421 km from Stellenbosch (line A in Figure 3.1). Researchers spent four days at this destination to complete the testing at two separate schools. Children and adolescents were recruited through these schools. The principles of the chosen schools were contacted via email, telephone or by means of a personal visit from the researchers. Six high schools, five primary schools, and one combined school showed interest to take part in the study. Once principles gave permission for testing to take place at the schools, project information and informed consent forms

were either delivered personally or couriered to the schools. Informed consent forms were handed out to those children who showed interest to participate in the study. Participation was voluntary and only children with written consent from parents as well as themselves were included in the study (Addendum A). The informed consent forms were available in three of the eleven official languages of South Africa, namely Afrikaans, English, and Xhosa, as they are the most widely spoken in the Western Cape. Approval for the study was obtained from the Institutional Research Ethics Committee (protocol number HS1153/2014) as well as the Education Department of the Western Cape (Addendum B). Inclusion criteria comprised of children and adolescents from six to eighteen years of age, regular attendance at the randomly selected school and completed informed consent forms. Children and adolescents who had an injury during the time of testing and could not complete the tests were excluded. Small gifts, for example, rulers and tennis balls, were given to the children and adolescents after completion of the tests.



Figure 3.1: Municipal boundaries in the Western Cape (map by Htonl)

D. Procedures

A pilot study was conducted at one school to determine the duration of the testing per participant. The researchers also used this opportunity to familiarise themselves with the equipment and trained all the assistant researchers.

All children and adolescents from a specific school were tested within the same week during school hours. Children and adolescents underwent the following tests and measurements: standing height and weight, static foot measurements with a calliper as well as with the Emed pressure plate and measurements of school shoes. A layout of the testing procedure is shown in the form of a flowchart in Figure 3.2.

Children and adolescents were recruited during a one-year period. Multiple researchers performed the tests at different testing dates. All researchers were postgraduates and were trained in the execution of the tests.

E. Tests and measurements

Height

For height assessment, the participant was positioned with the heels shoulder width apart, and the heels, buttocks and upper back touching the stadiometer (Charder, HM-200P Portstad, Germany). The head was placed in the Frankfort plane and the reading was taken to the nearest 0.1 cm (Stewart, Marfell-Jones, Olds & de Ridder, 2012).

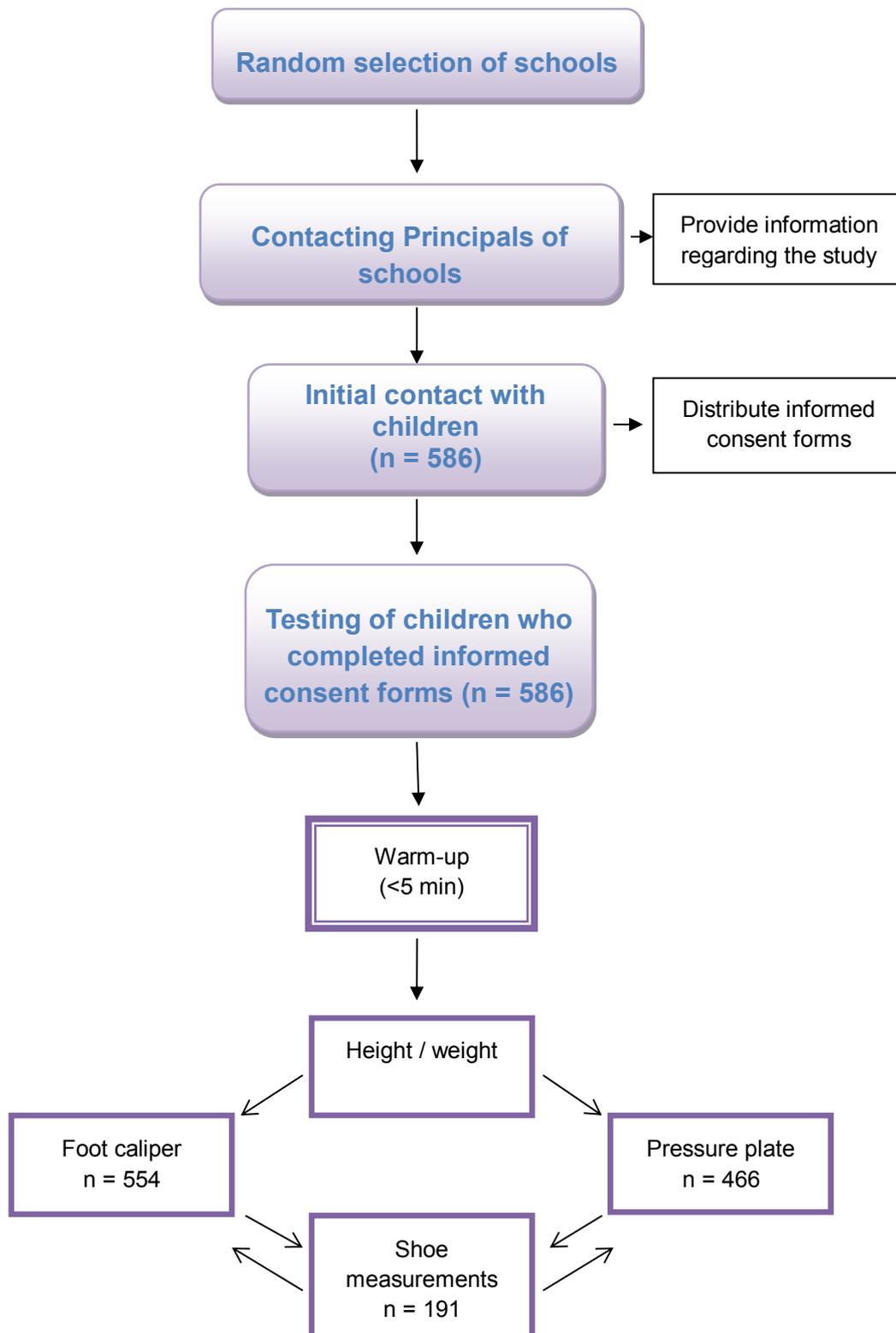


Figure 3.2: Flowchart of data collection procedures

Weight

Weight was determined with an electronic scale (A & D personal precision UC-321 scale, A & D Medical, Tokyo, Japan) and recorded to the nearest 0.05 kg. BMI was calculated with the formula body weight (kg) divided by the square of the body height (m). The values used to categorise adults in different BMI categories have been revised by Cole and Lobstein (2012) for children (Addendum C). These new international obesity task force BMI cut-offs (kg/m^2) used the pooled LMS curves (L - skewness; M - median; S - coefficient of variance) and allow the BMI for children to be expressed as centiles or SD scores according to their age (Cole & Lobstein, 2012). Although Cole and Lobstein (2012) used full-year and half-year ages (for example 12 and 12½ years) to determine the BMI values, in the current study only the full-year age was used.

Foot measurements

A self-manufactured foot calliper with a resolution of 1 mm was used for foot measurements (Figure 3.3). For the current study, the calliper was manufactured based on a calliper used in a previous study by Pohl and Farr (2010). Both feet were measured, the left foot before the right foot. The participant was asked to stand comfortably on both feet with the heels touching the back of the calliper. A sliding mechanism was then used to determine the length of the foot (measured from the most posterior part of the heel to the longest toe). The width of the foot was measured from the most medial point of the first metatarsal to the most lateral point of the fifth metatarsal (Barisch-Fritz, Schmeltzpfenning, Plank, Hein & Grau, 2014). This type of measurement was deemed reliable (ICC = 0.706) and valid when compared to radiographic measurements (ICC = 0.875) at 90 percent of weight bearing (Williams & McClay, 2000). In the current study, one researcher measured the foot length and width.

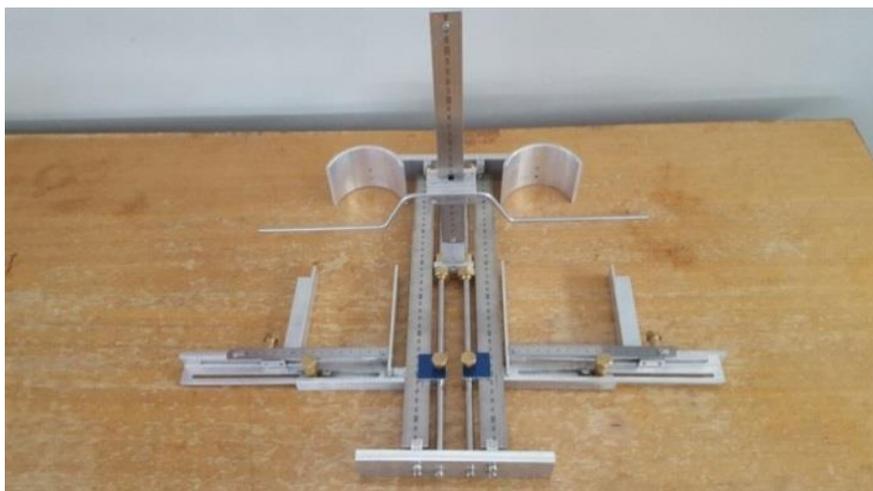


Figure 3.3: Self-manufactured foot calliper (Photo by E. Mathewson)

Shoe measurements

Children and adolescents had to provide the left shoe of their school shoes. The length of the shoe was measured using a flexible plastic straw. One end of the straw was placed in the toe area and the other end touching the heel was bent and cut according to guidelines used by Barton et al. (2009). The straw was then measured to the nearest 0.1 cm using a metal ruler. Shoe width was measured by using a sliding steel calliper. The calliper was placed over the upper of the shoe and adjusted to measure the most medial and most lateral part of the upper, covering the widest area of the shoe as was done by Burns et al. (2002). Reliability was shown to be between 0.79 and 0.81, but no validity tests have been done for this measurement (Barton et al., 2009). For the current study, shoe width measures were used without documenting the possible age and condition of the shoe. The measurements were completed by three different researchers.

Dynamic arch index

The Emed c50 pressure plate (Novel GmbH, Munich, Germany) was used to determine the dynamic AI. According to the manufacturers, the index is defined by the ratio of the midfoot area divided by the total foot area (without toes). The pressure plate was embedded in the middle of a wooden walkway with a width of 61

cm and a length of 480 cm. Children and adolescents were instructed to stand barefoot in a double leg stance on the pressure plate. They were asked to walk away from the plate at a self-selected pace to the end of the walkway while looking up. The researcher visually observed where the second foot landed and marked the spot. This spot served as the starting point for the two-step approach, where the second foot strike from the starting position had to land on the pressure plate. The two-step method has been shown to be an easy method to be performed by children. The fewer steps they have to give, the better chance for striking the pressure plate consistently (Dowling et al., 2004). The same procedure was repeated to the other side of the walkway. Children and adolescents started with their toes behind the mark made by the researcher on the walkway. They started once the laptop announced “let’s go” and was instructed to walk at a self-selected pace to the end of the walkway while looking up. Several researchers found the two-step approach at a self-selected speed to be reliable, with ICC values bigger than 0.80 (Akins, Keenan, Sell, Abt & Lephart, 2012) and between 0.52–0.94 for loading parameters and 0.66 – 0.98 for dynamic geometric measurements (Tong & Kong, 2013).

Only the foot strikes that landed in the middle of the pressure plate were recorded for analysis. If the foot did not land in the middle, the marker was adjusted forward or backward. In addition to the visual evaluation by the researcher, the Emed Novel software indicated whether the foot landed in the middle of the pressure plate or touched the border. If the foot did not land in the middle of the pressure plate, that specific trial was automatically rejected. The researcher also used her discretion on whether irregularities occurred during a specific trial and if that proved to be the case, that trial was also excluded. The participant had to complete three valid trials on each leg. Novel projects software was used to calculate the dynamic AI for each trial. Data was exported into Microsoft Excel and the mean AI of all three trials on both legs was used for statistical analysis. This method of analysis was shown to be reliable and valid in the testing of children (Cavanagh & Rodgers, 1987).

F. Data analysis

Participant information is described using descriptive statistics (mean (\bar{x}) and standard deviation (SD), unless otherwise specified). All data were tested for normalcy; the data were defined to be normally distributed when skewness is < 1.0 .

For the statistical analysis participants were grouped according to age groups, children younger than nine years, nine to eleven years, twelve to fourteen years and fifteen years and older, based on percentiles.

Comparisons between various groupings of children were done using a one-way ANOVA, ANCOVA, controlling for age, and a two-way ANOVA. For post hoc testing, Fisher's least significant difference (LSD) testing was used. A lettering system was used to indicate post hoc differences on mean graphs. When any two means are compared on a graph, if there is one overlapping letter of the corresponding letters (e.g. "a" vs. "ab"), then the difference between the two means are not significant ($p > 0.05$). If none of the letters overlap (e.g. "a" vs. "bc"), then the differences are significant ($p < 0.01$).

Cohen's effect size (ES) of changes for each parameter was also calculated because of the relative big sample size. The values used 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) (Talheimer & Cook, 2002).

Since the testing was done over a period and by different researchers, an ICC was used to calculate intra-rater reliability, this was done for the foot measurements (length and width). Inter-rater reliability was calculated for the shoe measurements (length and width). The two-way mixed single measures (absolute agreement) were performed to determine consistency among researchers and measurements. Throughout the project, one investigator was used to complete the foot metrics. Intra-rater reliability was quantified by having the same investigator analyse the same 44 feet on two separate occasions, one week apart. Three investigators were used to determine shoe sizes. Inter-rater reliability was obtained by measuring 20 different shoes. The three researchers measured the same 20 shoes on the same day.

STATISTICA was used for the statistical analysis of the data (DELL INC version 13.0.159.8).

CHAPTER FOUR

Results

A. Introduction

The aim of the study was to evaluate shoe fit compared to foot sizes in school-aged children and adolescents of the Western Cape. Data collected were statistically analysed and the results obtained will be presented in this chapter. The distribution of data was considered throughout the statistical analysis. The chapter contains descriptive and comparative statistics for the variables of interest. Practical significance was calculated by using Cohen's effect sizes. The level of significance was set at $p < 0.05$. Results will focus, according to the objectives formulated for the research project, on differences in foot length, foot width, as well as arch height index between 1) age groups, 2) boys and girls, 3) different races, and 4), children and adolescents in different BMI categories. The relationship between foot shape and shoe fit will be recorded according to gender, race, and BMI. The relationship between speed and different footwear conditions and the validity and reliability of measurements taken by the researcher will be reported on.

B. Descriptive statistics of participants

A total number of 586 children and adolescents between the ages six to eighteen years voluntarily participated in the study. Distribution between genders was 284 (49%) girls and 294 (51%) boys. Different races were represented in the study; 67% were white, 20% brown and 13% did not disclose their race. The latter was not included in the analysis when taking race into account. Further analysis showed gender to be equally distributed amongst age groups ($p = 0.08$) and both races ($p = 0.8$).

Participants came from different schools. Six high schools, five primary schools, and one combined school in the Western Cape, South Africa were chosen through a

random sample of convenience. The descriptive statistics of participants are outlined in Table 4.1.

Table 4.1: Descriptive statistics regarding the age, gender, race, height, weight, and BMI (Data are presented as mean \pm SD)

Age (years)	N	Gender	Race	Body height (m)	Body Mass (kg)	BMI (kg/m ²)
6	18	B: 4 ; G: 14	W: 7 ; Br: 12	1.21 (0.07)	25.08 (7.77)	16.34 (1.42)
7	21	B: 12; G: 9	W: 12; Br: 11	1.27 (0.04)	26.96 (4.71)	16.58 (2.47)
8	36	B: 12; G: 24	W: 42; Br: 4	1.32 (0.06)	30.90 (5.67)	17.42 (2.11)
9	45	B: 21; G: 24	W: 38; Br: 7	1.39 (0.06)	35.18 (7.26)	18.10 (2.96)
10	41	B: 26; G: 15	W: 24; Br: 15	1.43 (0.07)	38.53 (10.06)	18.55 (3.63)
11	35	B: 15; G: 20	W: 27; Br: 5	1.51 (0.07)	45.13 (9.52)	19.73 (3.38)
12	57	B: 32; G: 25	W: 38; Br: 19	1.56 (0.07)	50.18 (12.42)	20.35 (4.27)
13	69	B: 28; G: 41	W: 49; Br: 13	1.61 (0.08)	53.58 (12.65)	20.44 (3.80)
14	40	B: 19; G: 21	W: 29; Br: 5	1.69 (0.10)	63.95 (14.24)	22.26 (3.92)
15	38	B: 24; G: 14	W: 33; Br: 9	1.71 (0.09)	62.95 (11.01)	21.38 (3.01)
16	56	B: 23; G: 33	W: 47; Br: 9	1.70 (0.90)	64.88 (10.59)	22.07 (3.91)
17	44	B: 28; G: 16	W: 39; Br: 6	1.73 (0.10)	73.54 (16.51)	24.33 (4.32)
18	14	B: 10; G: 4	W: 7; Br: 3	1.77 (0.10)	78.99 (16.11)	25.06 (3.90)
6 - 18	514	B: 254; G: 260	W: 392; Br: 122	1.55 (0.18)	50.58 (18.98)	20.25 (4.29)

N – Number of children and adolescents, B - Boys, G – Girls, W – White, Br - Brown

C. The effect of age and gender on foot metrics

Foot length

In Figure 4.1, the average statistically significant differences in foot length between the genders and different age groups are presented. Boys older than 15 years had longer feet than all the other age categories. There were significant differences observed between boys 15 years and older and girls 15 years and older ($p < 0.01$), with the boys having longer feet than the girls. Boys 15 years and older also had significantly longer feet than the boys 12 to 14 years ($p < 0.01$). Girls 15 years and older did not have significantly longer feet than girls between 12 and 14 years of age ($p > 0.05$).

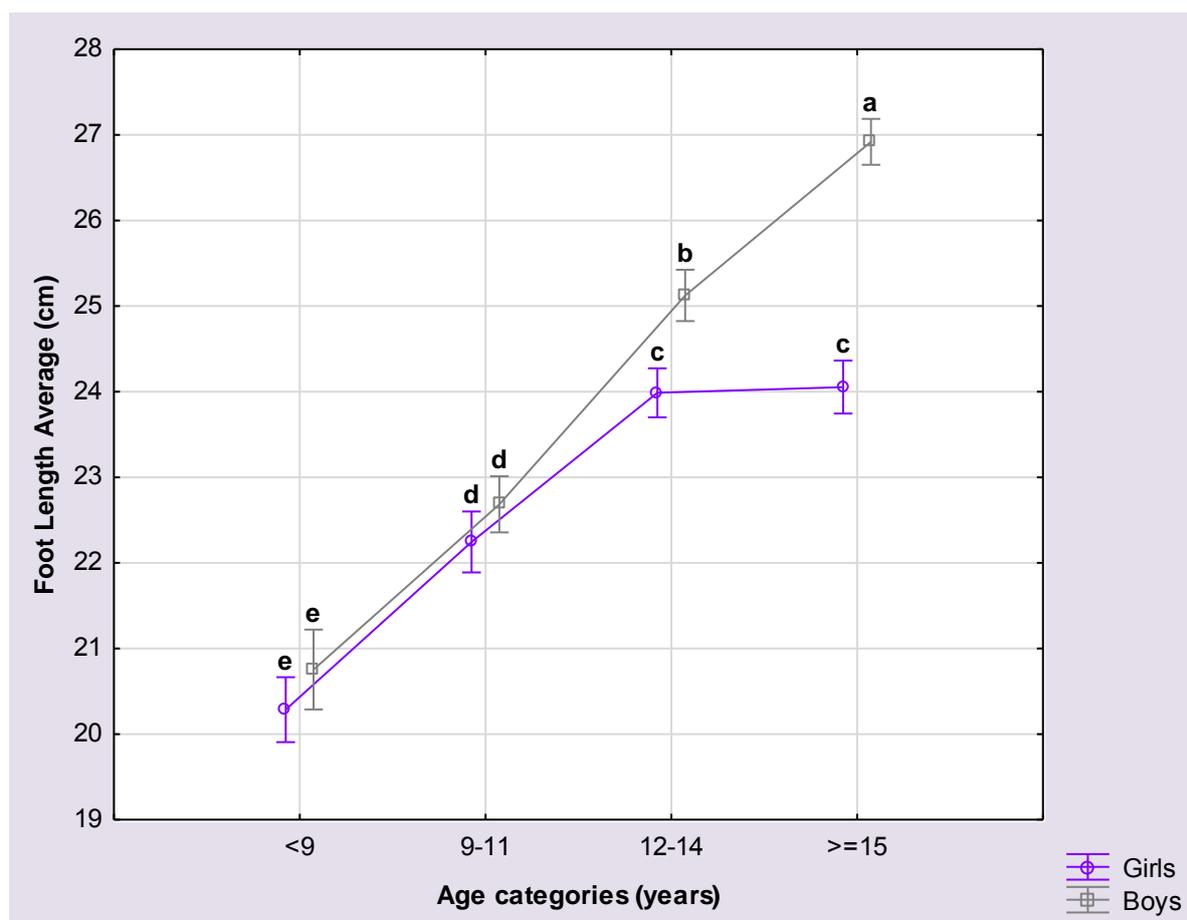


Figure 4.1: Differences in average foot length between genders and different age groups

Added to the statistically significant differences observed between genders and age groups, Cohen's effect sizes were very large to huge between all the different categories tested.

The mean differences in foot length between genders and specific age groups are presented in Table 4.2.

Table 4.2: Differences in mean foot length between the different age groups and genders (Data are presented as mean \pm SD)

Age groups	N	Average foot length (cm)	SD	95% Confidence Interval	
Girls					
<9	83	20.52	1.24	19.91	20.67
9-11	124	22.46	1.19	21.89	22.60
12-14	168	24.56	1.33	23.70	24.27
≥ 15	175	25.49	1.23	23.74	24.36
Boys					
<9	33	20.75	1.31	20.29	21.22
9-11	67	22.68	1.36	22.36	23.01
12-14	80	25.12	1.81	24.82	25.42
≥ 15	100	26.92	1.26	26.65	27.19

Foot width

Measurements of the foot width showed that the boys had significantly wider feet than the girls in most of the age categories, except for children younger than 9 years. The boys 15 years and older had significantly wider feet than all the other age groups of both genders. Once again there was no significant difference between the girls

older than 15 years and girls between 12 to 14 years of age. Figure 4.2 shows the average foot width of different age groups and genders.

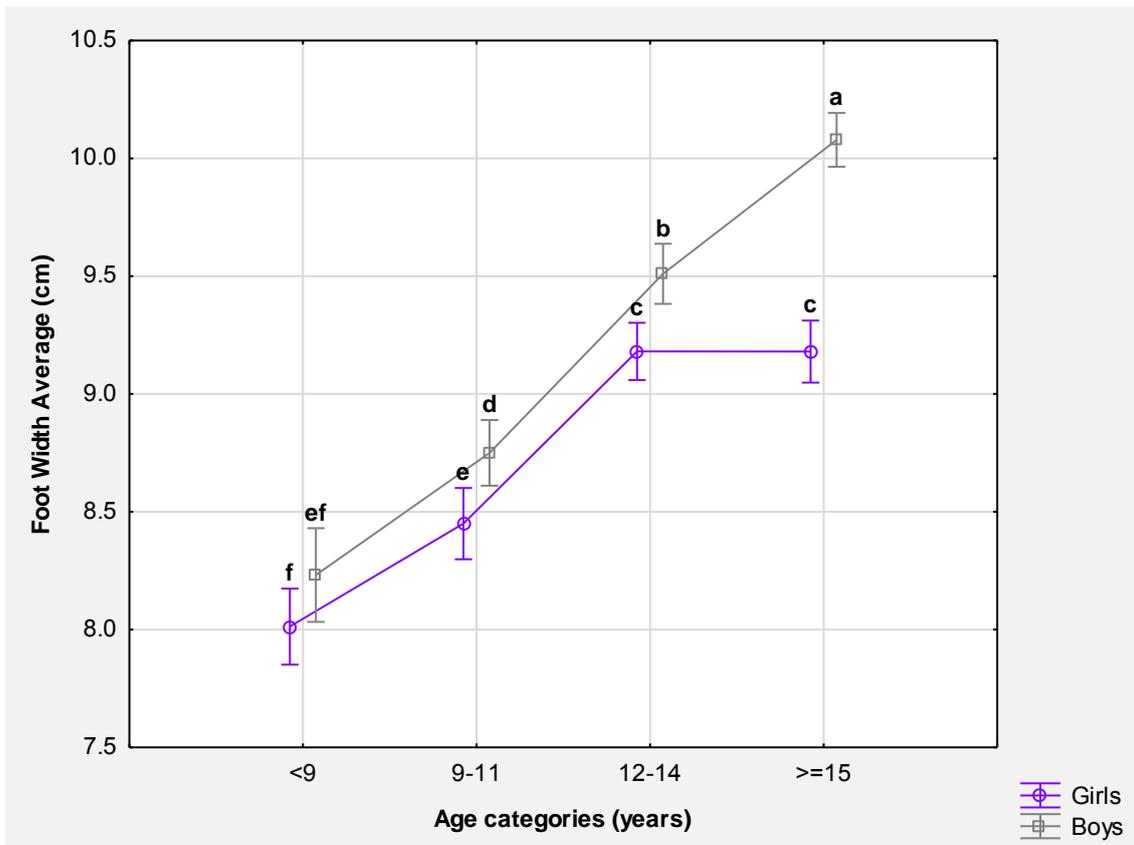


Figure 4.2: Differences in average foot width between genders and different age groups

Results of the differences in average foot width between genders and different age groups showed a medium to huge practical significance as well, according to Cohen's effect size.

Table 4.3 presents these results between the different genders and different age groups.

Table 4.3: Differences in average foot width between the different age groups (Data are presented as mean \pm SD)

Age groups	N	Average foot width (cm)	SD	95% Confidence Interval	
Girls					
<9	50	8.01	0.46	7.88	8.14
9-11	57	8.45	0.58	8.30	8.60
12-14	88	9.18	0.58	9.06	9.30
≥ 15	75	9.18	0.54	9.06	9.30
Boys					
<9	33	8.23	0.47	8.06	8.40
9-11	67	8.75	0.54	8.62	8.88
12-14	80	9.51	0.74	9.35	9.67
≥ 15	100	10.08	0.59	9.96	10.19

Dynamic arch index

Measurement of the dynamic AI showed statistically significant results between boys 15 years and older and girls 15 years and older ($p = 0.02$), with the boys having a higher AI than the girls. The boys older than 15 years had a significantly higher AI than the younger boys ($p < 0.01$). There was once again no significant difference between the girls older than 15 and between 12 and 14 years of age, with the girls older than 15 having a slightly lower AI than the younger girls.

The statistically significant results are graphically depicted in Figure 4.3, while the average values with no practical significance are noted in Table 4.4.

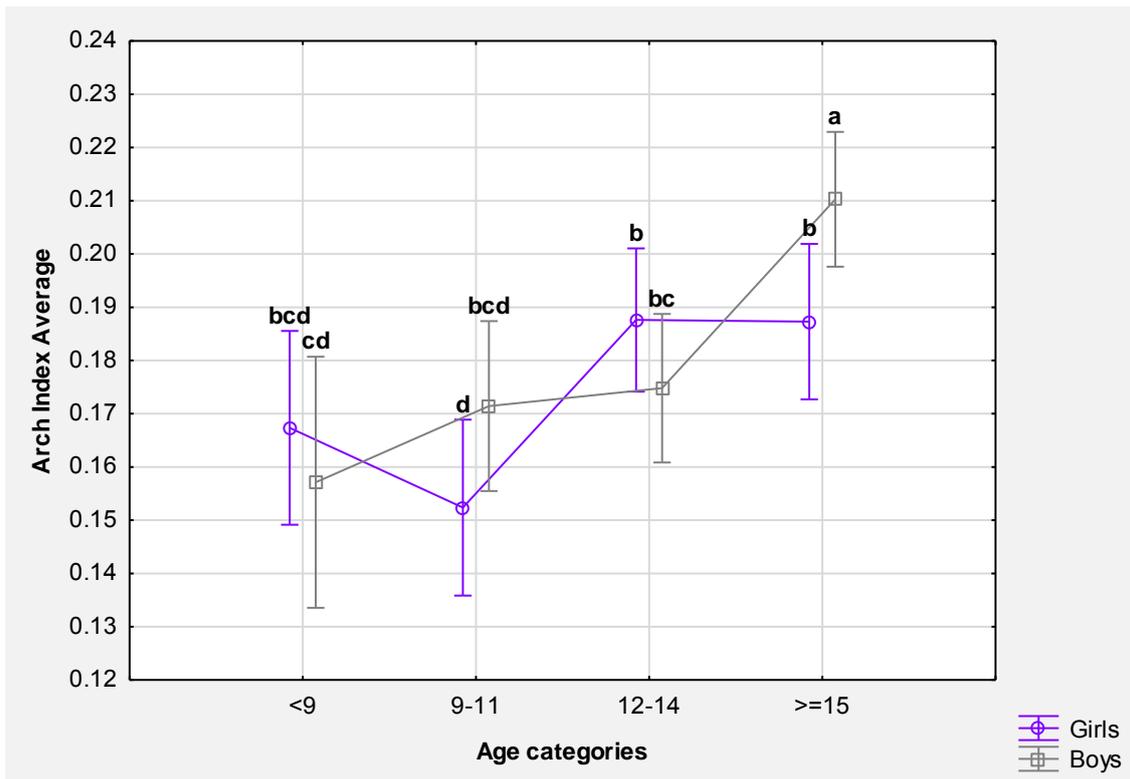


Figure 4.3: Differences in average dynamic AI between genders and different age groups

Table 4.4: Differences in dynamic AI between the different genders and age groups (Data are presented as mean ± SD)

Age groups	N	Average dynamic AI	SD	95% Confidence Interval	
Girls					
<9	47	0.17	0.07	0.15	0.19
9-11	57	0.15	0.07	0.13	0.17
12-14	86	0.19	0.07	0.17	0.20
>=15	73	0.19	0.06	0.17	0.20
Boys					
<9	28	0.16	0.08	0.13	0.19
9-11	61	0.17	0.06	0.16	0.19
12-14	80	0.17	0.06	0.16	0.19
>=15	97	0.21	0.05	0.20	0.22

D. The effect of race on foot metrics

As mentioned earlier, the distribution between the races was 67 percent white children and adolescents and 20 percent brown children and adolescents. There were several children and adolescents (13%) who did not classify their race and have thus been excluded from results based on race.

Foot length

The white children and adolescents had significantly longer feet than the brown children and adolescents. Figure 4.4 portrays the statistically significant difference in foot length between the white and brown children and adolescents ($p < 0.01$).

According to Cohen's effect size, the difference was of medium practical effect ($d = 0.48$). Table 4.5 presents the mean values in foot length between the different races.

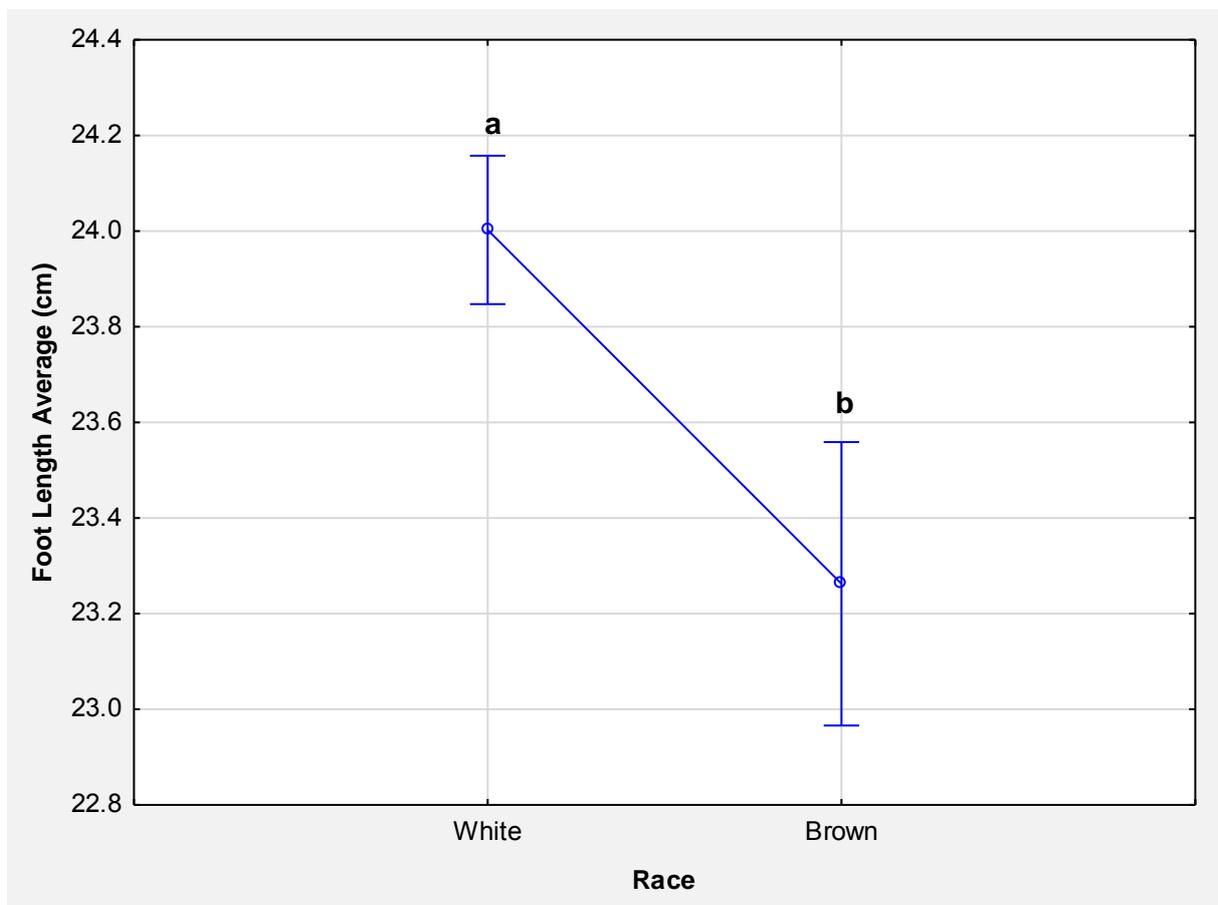


Figure 4.4: Differences in average foot length between different races

Table 4.5: Differences in foot length between the different races (Data are presented as mean \pm SD)

Race	N	Average foot length (cm)	SD	95% Confidence Interval	
White	381	24.09	2.39	23.85	24.33
Brown	105	22.97	2.25	22.53	23.40

Foot width

Results of the foot width measurements were similar to the results of the foot length between the different races. The white children and adolescents had significantly wider feet ($p < 0.01$) than the brown children and adolescents. The effect size for this analysis was of medium effect ($d = 0.49$). The significant differences and mean values are presented in Figure 4.5 and Table 4.6 respectively.

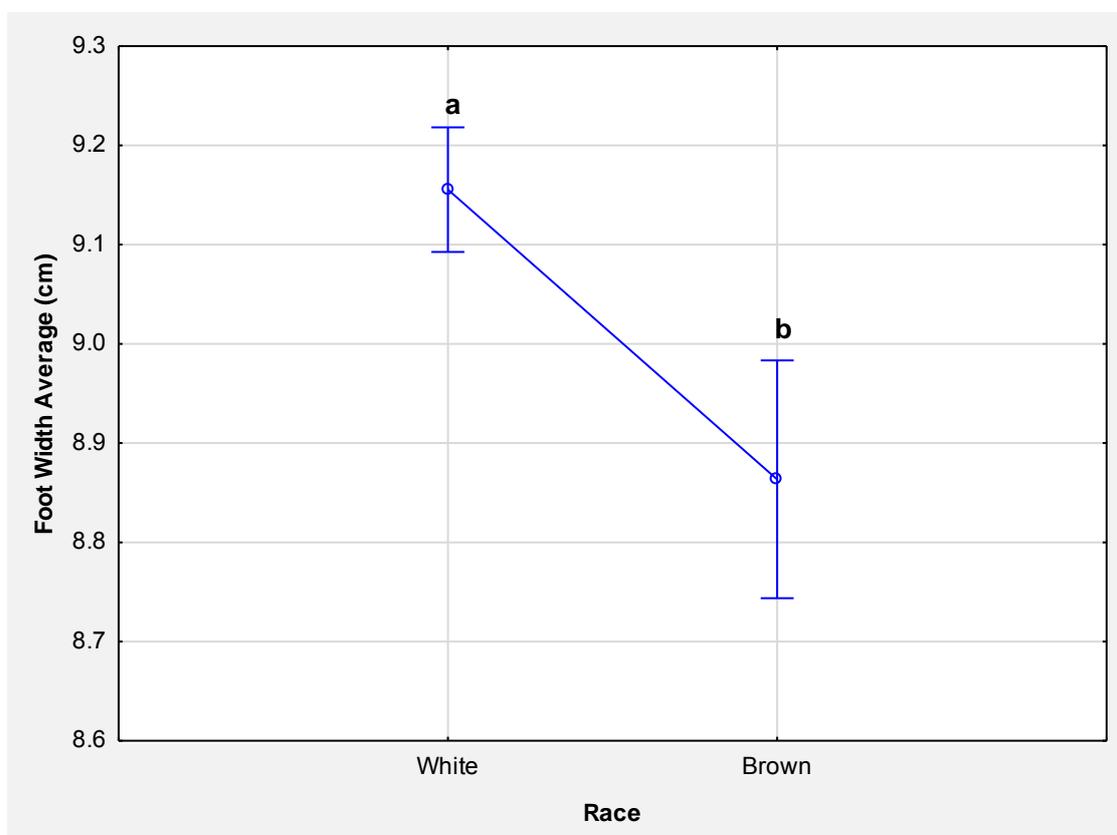
**Figure 4.5:** Differences in average foot width between different races

Table 4.6: Differences in foot width between the different races (Data are presented as mean \pm SD)

Race	N	Average foot width (cm)	SD	95% Confidence Interval	
White	381	9.18	0.86	9.09	9.27
Brown	105	8.77	0.75	8.62	8.91

Dynamic arch index

There was a statistically significant difference ($p < 0.01$) in the AI value between white and brown children and adolescents. The white children and adolescents had a lower AI than the brown children and adolescents. No practical significant difference was noted. Figure 4.6 shows the statistically significant differences between the two races, while Table 4.7 depicts the average AI values with their standard deviation and confidence interval levels for different races.

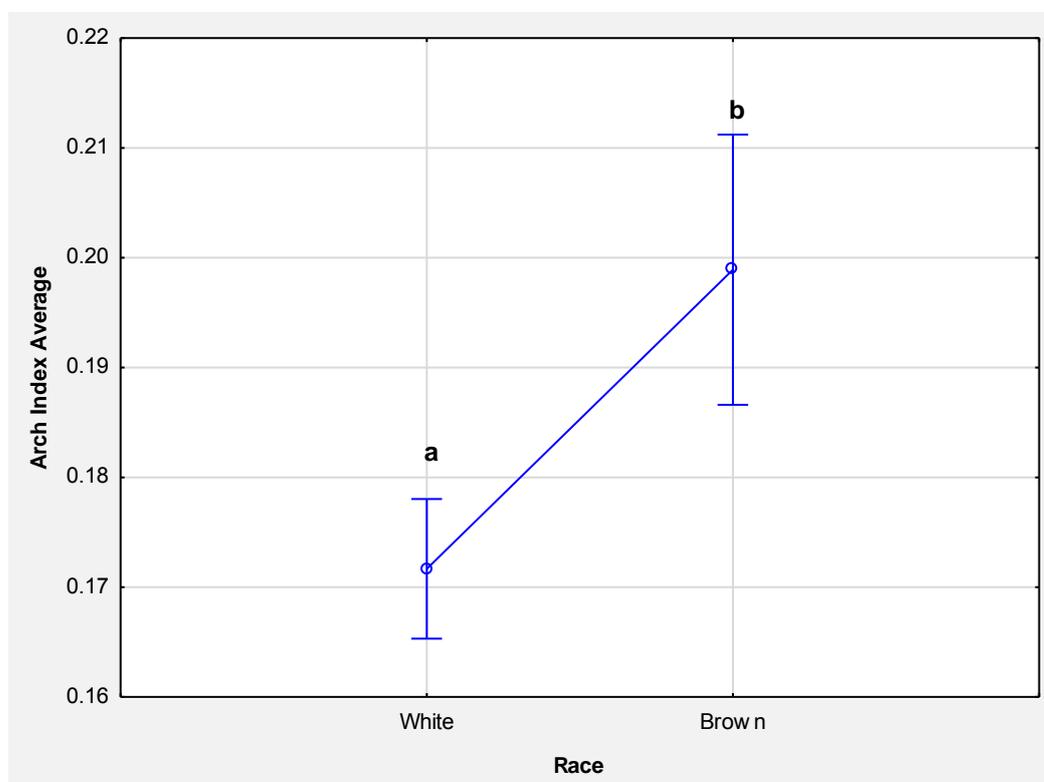
**Figure 4.6:** Differences in average dynamic AI between different races

Table 4.7: Differences in dynamic AI between the different races (Data are presented as mean \pm SD)

Race	N	Average AI	SD	95% Confidence Interval	
White	370	0.18	0.07	0.17	0.18
Brown	99	0.20	0.06	0.18	0.21

E. The effect of BMI categories on foot metrics

As mentioned in Chapter Three, BMI categories were determined by using the values presented by Cole and Lobstein (2012). Both genders and every year group have specific values for each category (Addendum C). The following categories were used based on the centiles at 18 years of age: underweight $< 18.5 \text{ kg/m}^2$, healthy weight $18.6 \text{ kg/m}^2 - 24.9 \text{ kg/m}^2$, overweight $25 \text{ kg/m}^2 - 29.9 \text{ kg/m}^2$ and obese $> 30 \text{ kg/m}^2$ (Cole & Lobstein, 2012).

The distribution of participants between the different BMI categories is displayed in Figure 4.7.

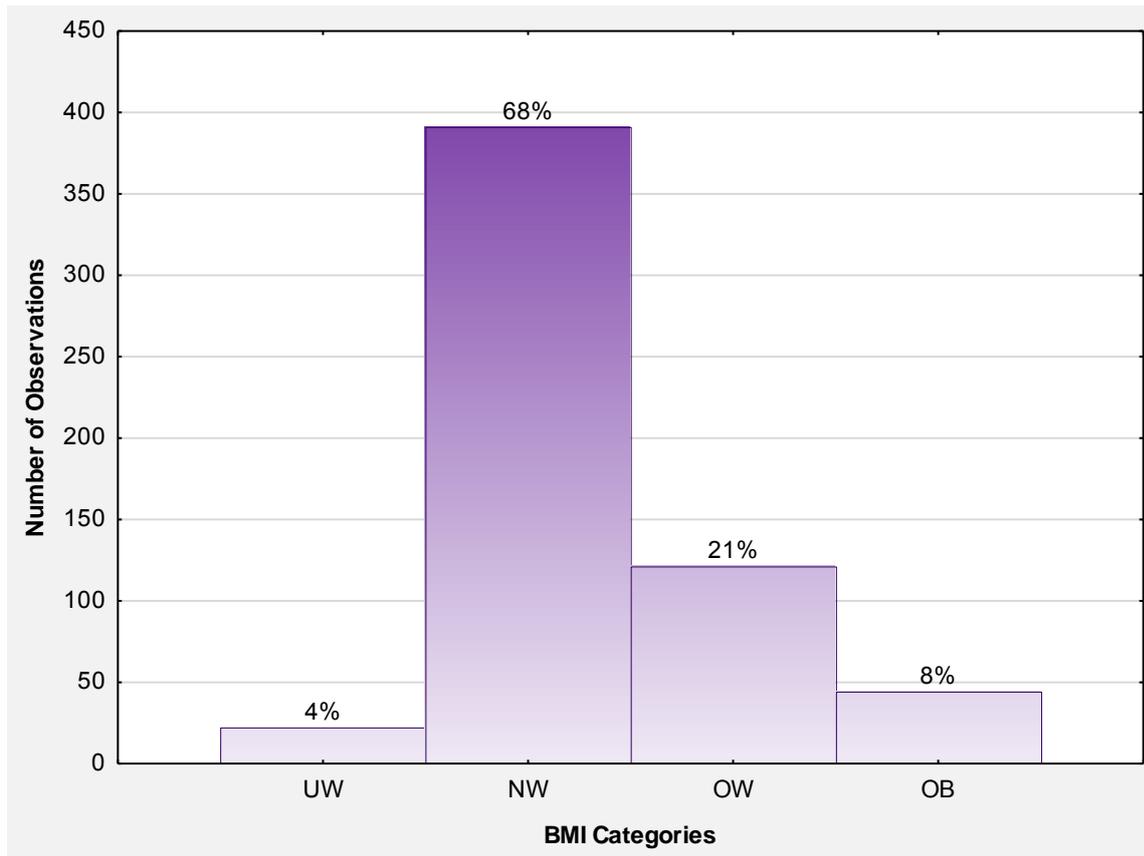


Figure 4.7: Distribution of participants within different BMI categories

- UW - underweight
- NW - healthy weight
- OW - overweight
- OB - obese

Foot length

Results between the different BMI categories show that the children and adolescents in the obese and overweight categories had statistically significant longer feet than the healthy ($p < 0.01$) and underweight ($p < 0.01$) categories respectively. A significant difference was also observed between the healthy weight and the underweight category ($p < 0.01$), with the underweight category having the shortest feet, as depicted in Figure 4.8.

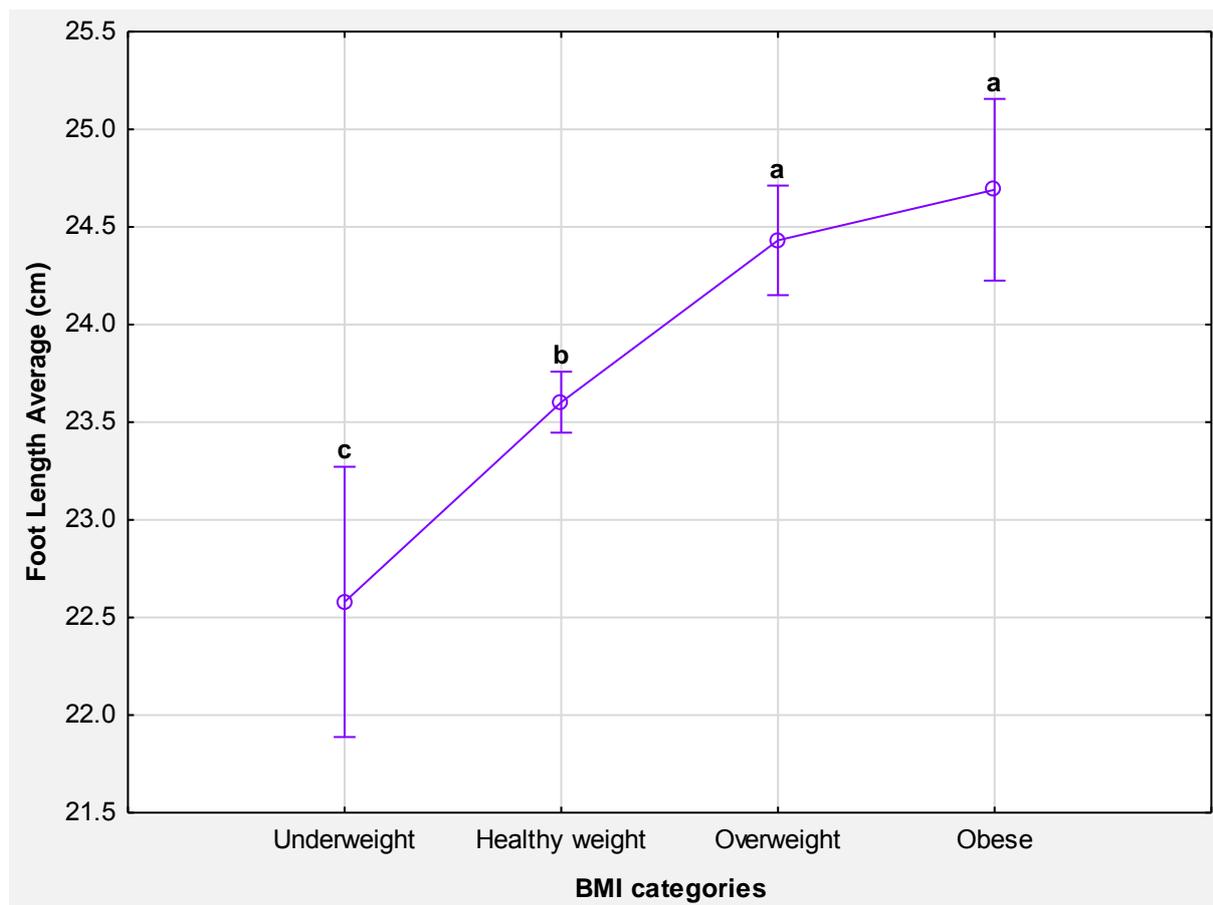


Figure 4.8: Differences in average foot length between BMI categories

There were practical significant differences based on Cohen's effect size calculations between the groups. The practical differences were all of small or bigger than small effect. The average foot length values for the different BMI categories are depicted in Table 4.8.

Table 4.8: Average foot length values for different BMI categories (Data are presented as mean \pm SD)

BMI categories	n	Average foot length (cm)	SD	95 % Confidence Interval	
Underweight	19	22.21	1.74	21.36	23.05
Healthy weight	373	23.56	2.43	23.32	23.81
Overweight	116	24.73	2.35	24.29	25.16
Obese	42	24.38	2.27	23.68	25.09

Foot width

The differences between the categories for width are similar to the differences in foot length. The obese and overweight children and adolescents had significantly wider feet than children and adolescents in the other categories. No significant difference occurred between the obese and overweight category, although the feet of the obese children and adolescents were wider than that of their overweight counterparts. Figure 4.9 portrays the significant wider feet of the obese and overweight category compared to the healthy weight ($p < 0.01$) category. The underweight category had significantly narrower feet compared to the obese and overweight category ($p < 0.01$), as well as the healthy weight category ($p < 0.01$).

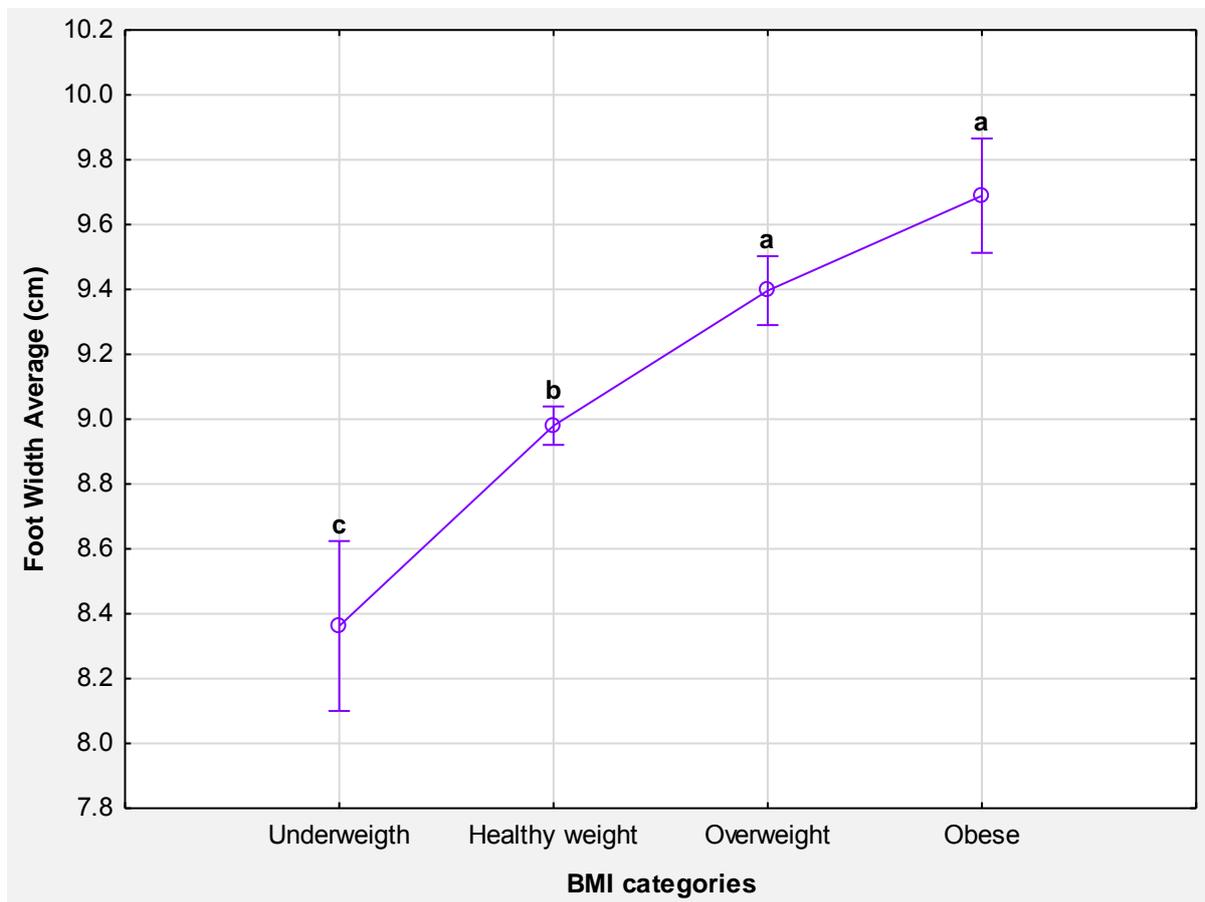


Figure 4.9: Differences in average foot width between BMI categories

According to Cohen's effect size, the practical effects between all the different groups were either of medium or bigger than medium effect. Average values are depicted in Table 4.9.

Table 4.9: Average foot width values for different BMI categories (Data are presented as mean \pm SD)

BMI categories	n	Average foot width (cm)	SD	95 % Confidence Interval	
Underweight	19	8.24	0.70	7.91	8.58
Healthy weight	373	8.97	0.82	8.88	9.05
Overweight	116	9.49	0.82	9.34	9.64
Obese	42	9.59	0.82	9.34	9.85

Dynamic arch index

The statistically significant differences in dynamic AI between the different BMI categories are depicted in Figure 4.10. Obese children and adolescents had significantly higher AI than all the other BMI categories ($p < 0.01$). There were significantly higher AI when comparing the overweight category with the healthy weight category ($p < 0.01$) as well as the underweight category ($p < 0.01$). The underweight category had significantly narrower feet than the healthy weight category ($p < 0.01$).

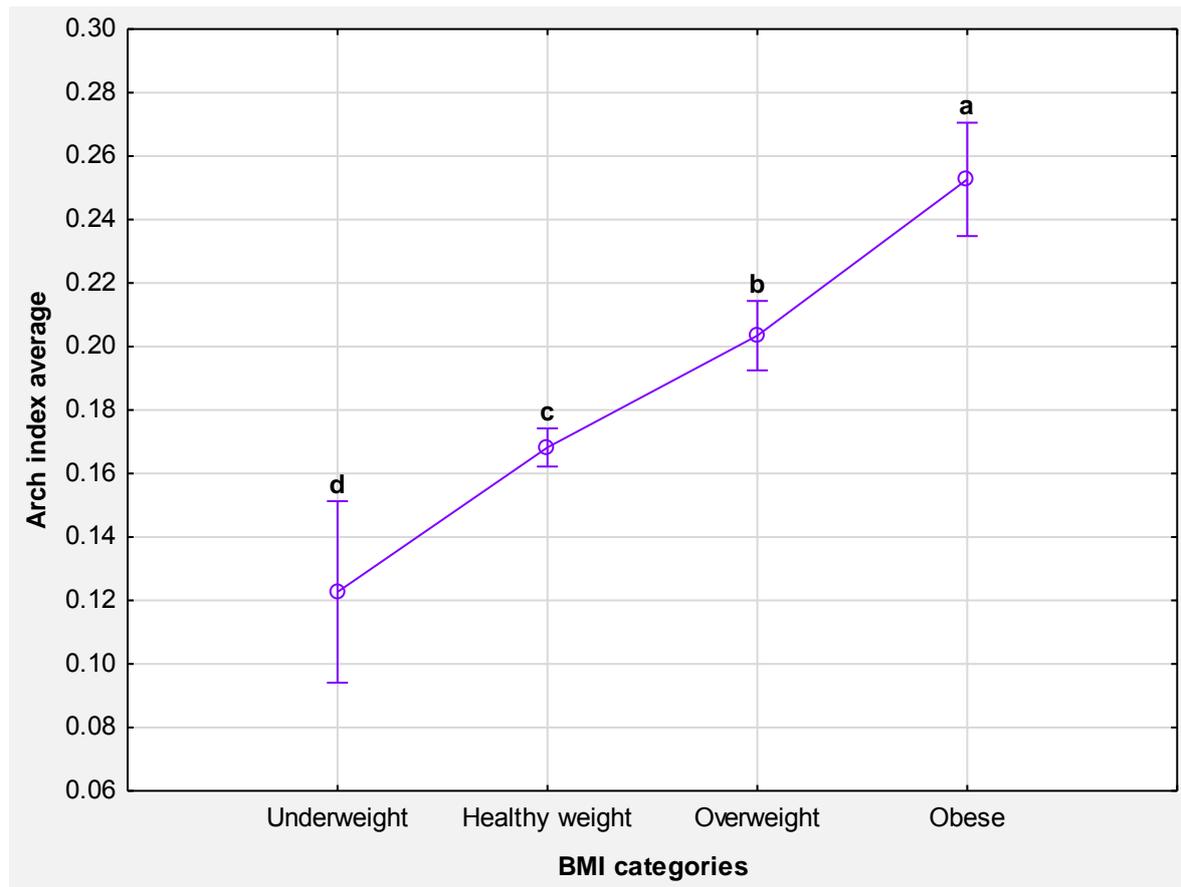


Figure 4.10: Differences in average dynamic AI between BMI categories

No practical significant differences existed between the different BMI categories with regards to AI. The average values with the standard deviation and 95% confidence interval are reported in Table 4.10.

Table 4.10: Average dynamic AI values for different BMI categories (Data are presented as mean \pm SD)

BMI categories	n	Average dynamic AI	SD	95 % Confidence Interval	
Underweight	16	0.12	0.08	0.08	0.16
Healthy weight	362	0.17	0.06	0.16	0.17
Overweight	110	0.21	0.05	0.20	0.22
Obese	41	0.25	0.05	0.23	0.27

F. Relationship between foot metrics and school shoe fit

The length of the shoe and the length of the foot were compared to determine the shoe fit. Shoe fit was calculated for length, subtracting the foot length from the shoe length and taking toe allowance into account. The difference between the shoe width and foot width was calculated.

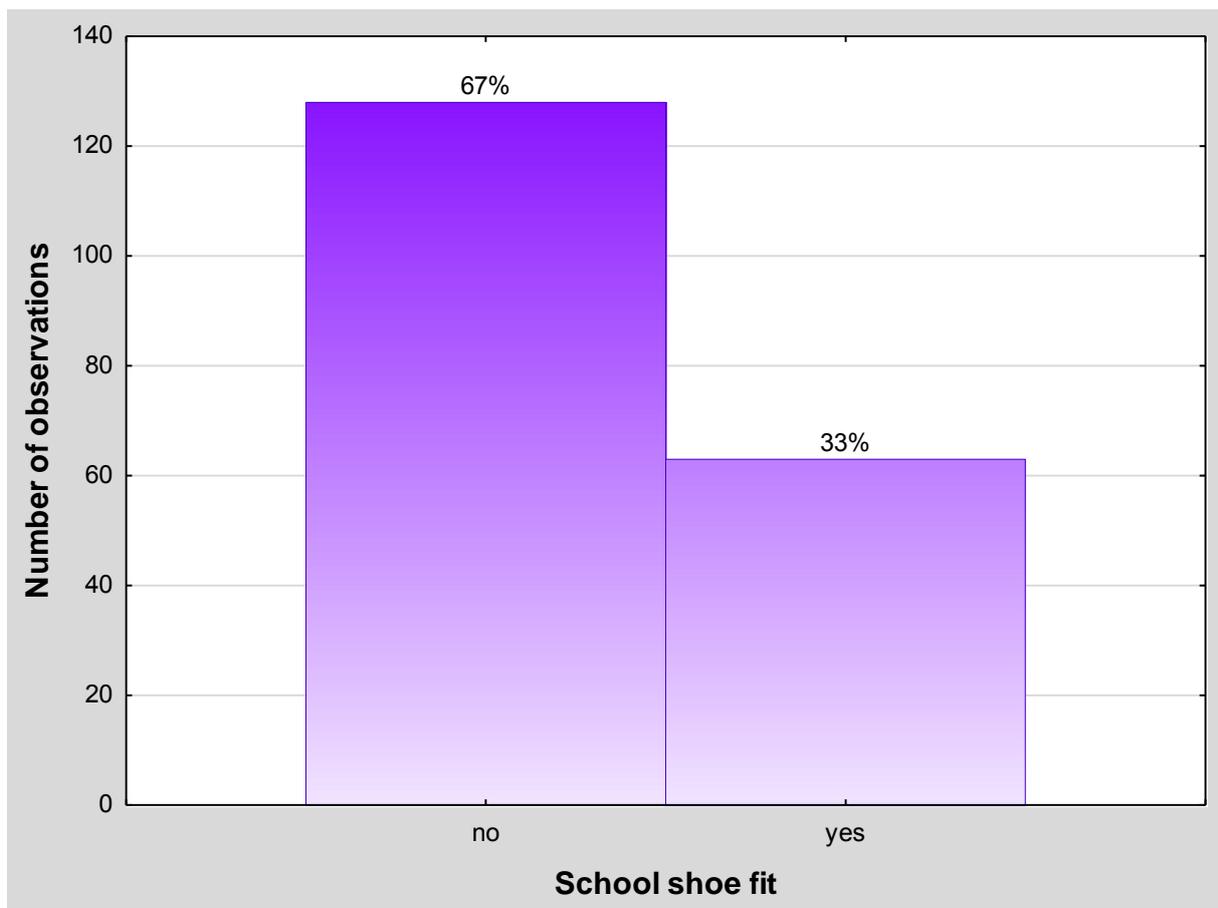


Figure 4.11: Prevalence of Ill-fitting shoes

The prevalence of ill-fitting shoes were calculated for the entire sample size. As can be seen in Figure 4.11, 128 children and adolescents (67%) of the sample size wore shoes that did not fit, compared to the 63 children and adolescents (33%) who wore shoes that did fit.

G. The effect of age on school shoe fit

Ill-fitting shoes occurred in all age groups that were analysed (Figure 4.12). A higher percentage (94%) of children and adolescents in the age group nine to eleven years wore ill-fitting shoes, compared to the sixty-three percent and sixty-six percent in the age categories twelve to fourteen years and fifteen years and older respectively.

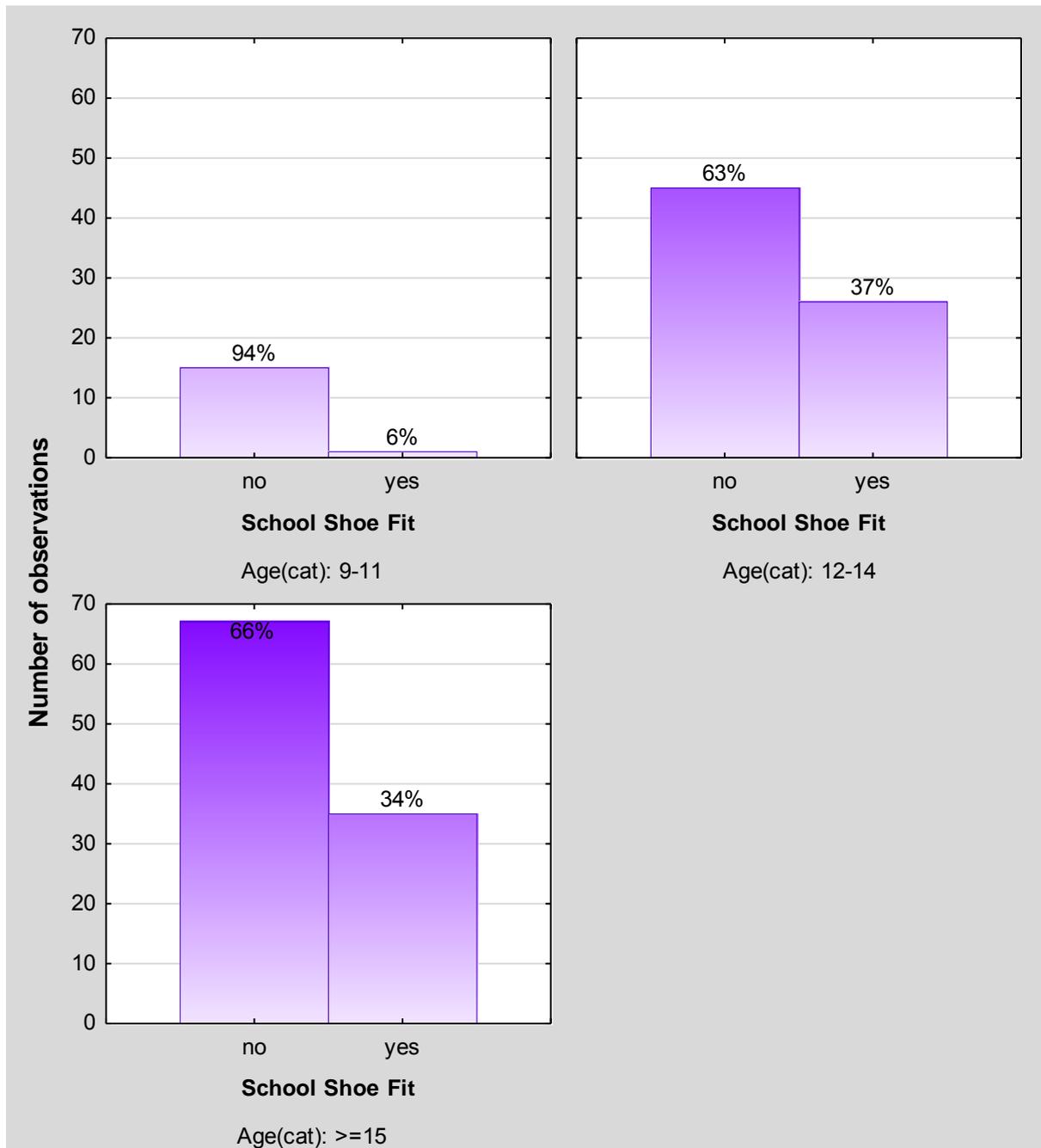


Figure 4.12: Prevalence of ill-fitting shoes in different age groups

H. The effect of gender on school shoe fit

Length

No significant difference ($p > 0.05$) was observed between school shoe length and foot length for different genders (Figure 4.13).

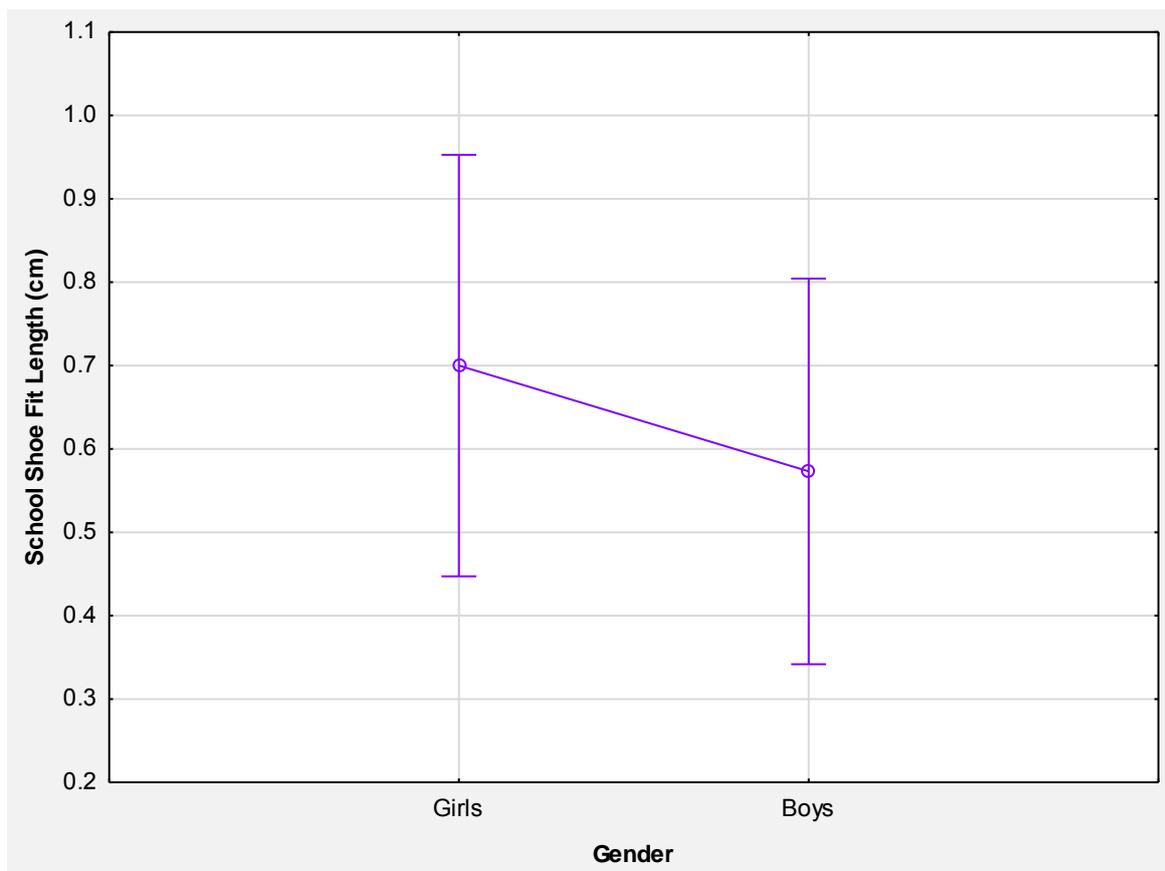


Figure 4.13: Differences in school shoe fit (length) between different genders

In both genders, a high percentage of children and adolescents (67%) wore ill-fitting shoes compared to the 33 percent that wore shoes that fitted well, as can be seen in Figure 4.14.

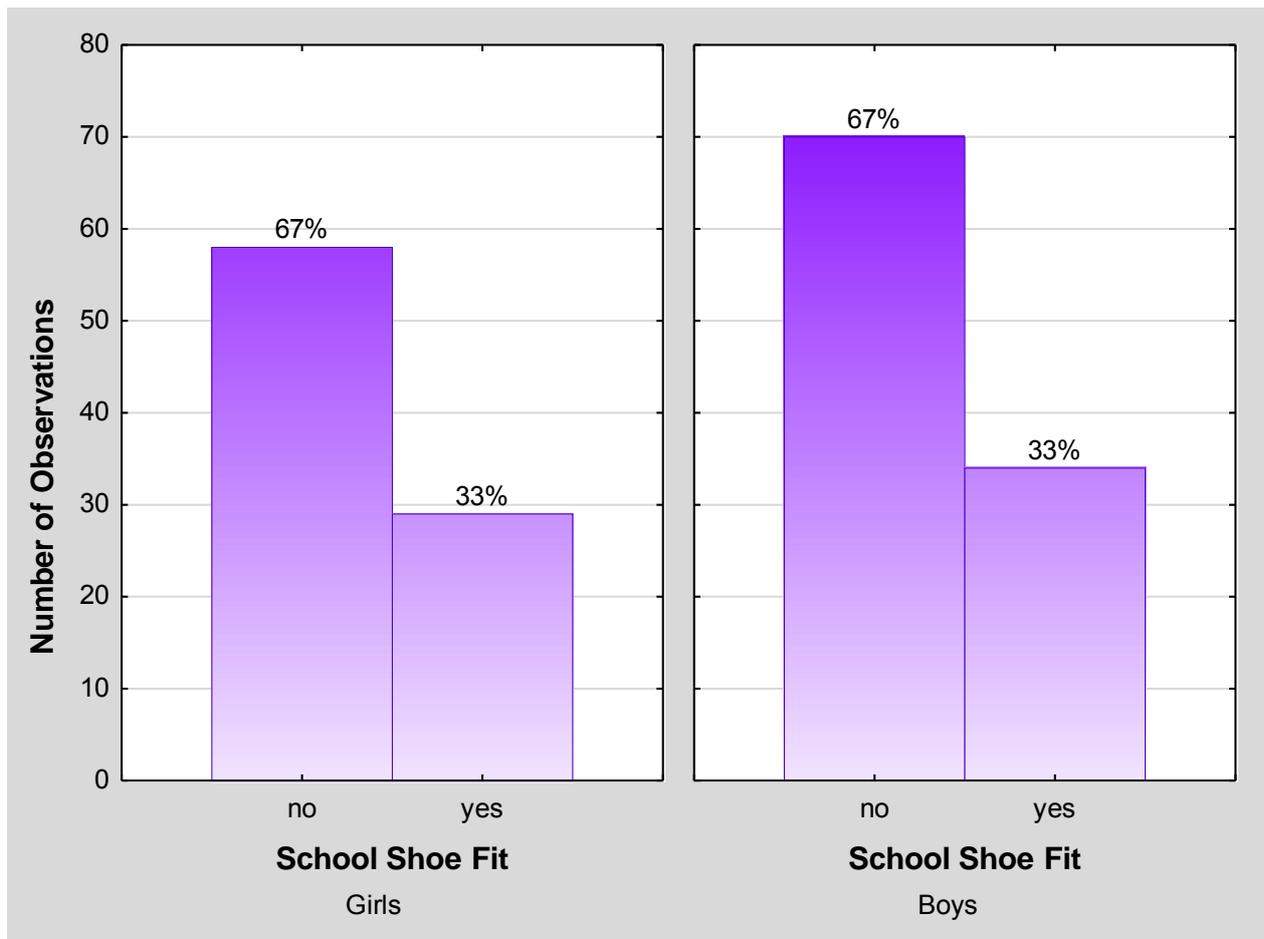


Figure 4.14: Prevalence of ill-fitting shoes in the different genders

Table 4.11: Average difference between school shoe length and foot length for different genders (Data are presented as mean \pm SD)

Gender	n	School shoe fit - length (cm)	SD	95% Confidence Interval	
Girls	87	0.70	1.17	0.45	0.95
Boys	104	0.57	1.21	0.34	0.81

There was no practical significance found between the different genders with regards to the difference in shoe length and foot length (Table 4.11).

Width

Significant differences ($p < 0.01$) in shoe fit were found between boys and girls with regards to foot and shoe width (Figure 4.15). The averages and other descriptive data are presented in Table 4.12. No practical significant difference was observed between the two genders.

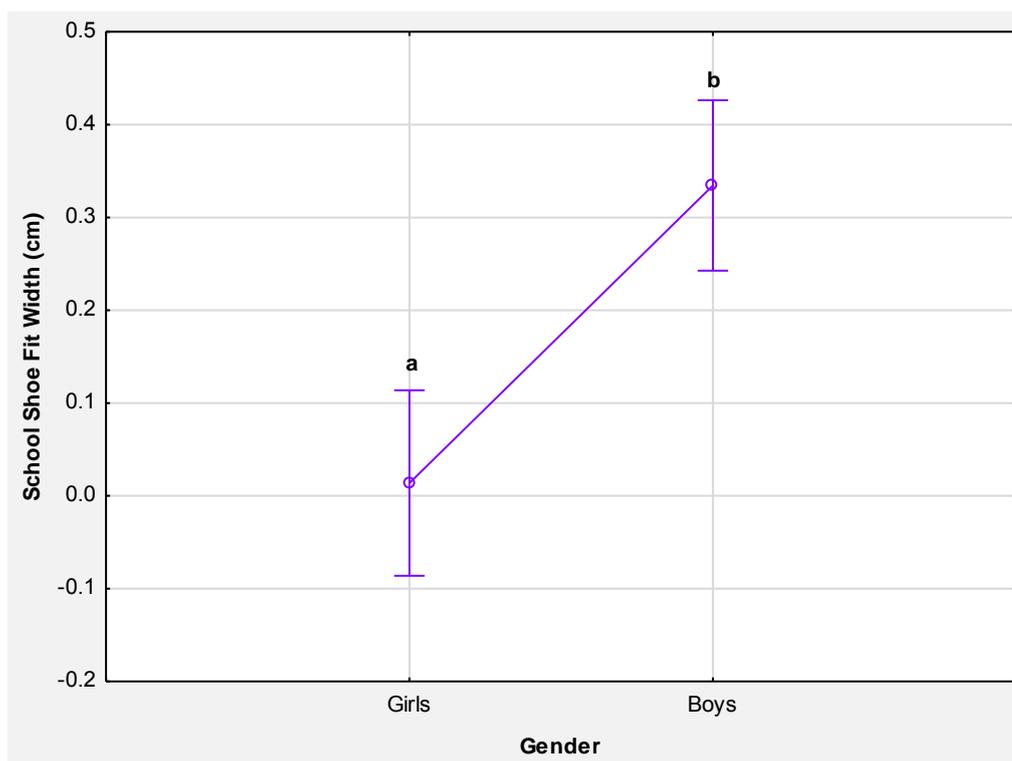


Figure 4.15: Differences in school shoe fit (width) between different genders

Table 4.12: Average school shoe fit (width) for different genders (Data are presented as mean \pm SD)

Gender	N	School shoe fit – width (cm)	SD	95% Confidence Interval	
Girls	87	0.01	0.52	-0.10	0.13
Boys	103	0.33	0.43	0.25	0.42

I. The effect of race on school shoe fit

Length

The difference between the length of the school shoe and the foot was significantly smaller in the brown children and adolescents when compared to the white children and adolescents ($p < 0.01$) as represented in Figure 4.16.

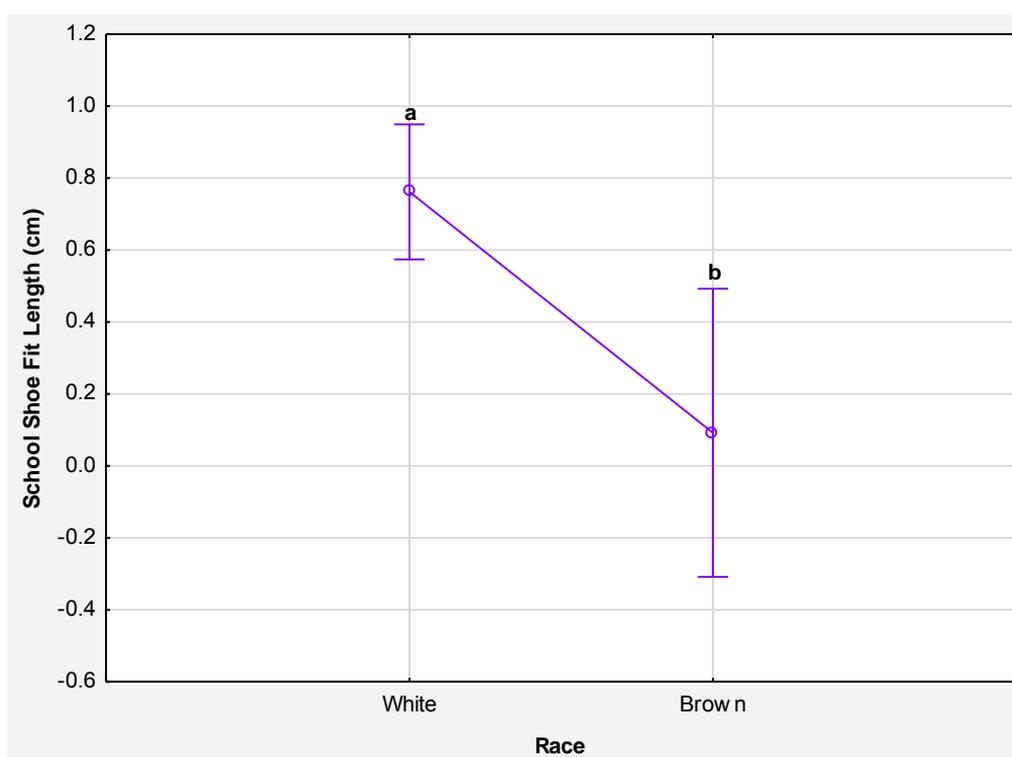


Figure 4.16: Differences in school shoe fit (length) between different ethnicities

A higher percentage of ill-fitting shoes were evident in the brown children and adolescent group, with 81 percent of them wearing ill-fitting shoes, compared to the 64 percent of white children and adolescents that wore ill-fitting shoes. Although this is lower than the brown race group, it is still a very high value as can be seen in Figure 4.17.

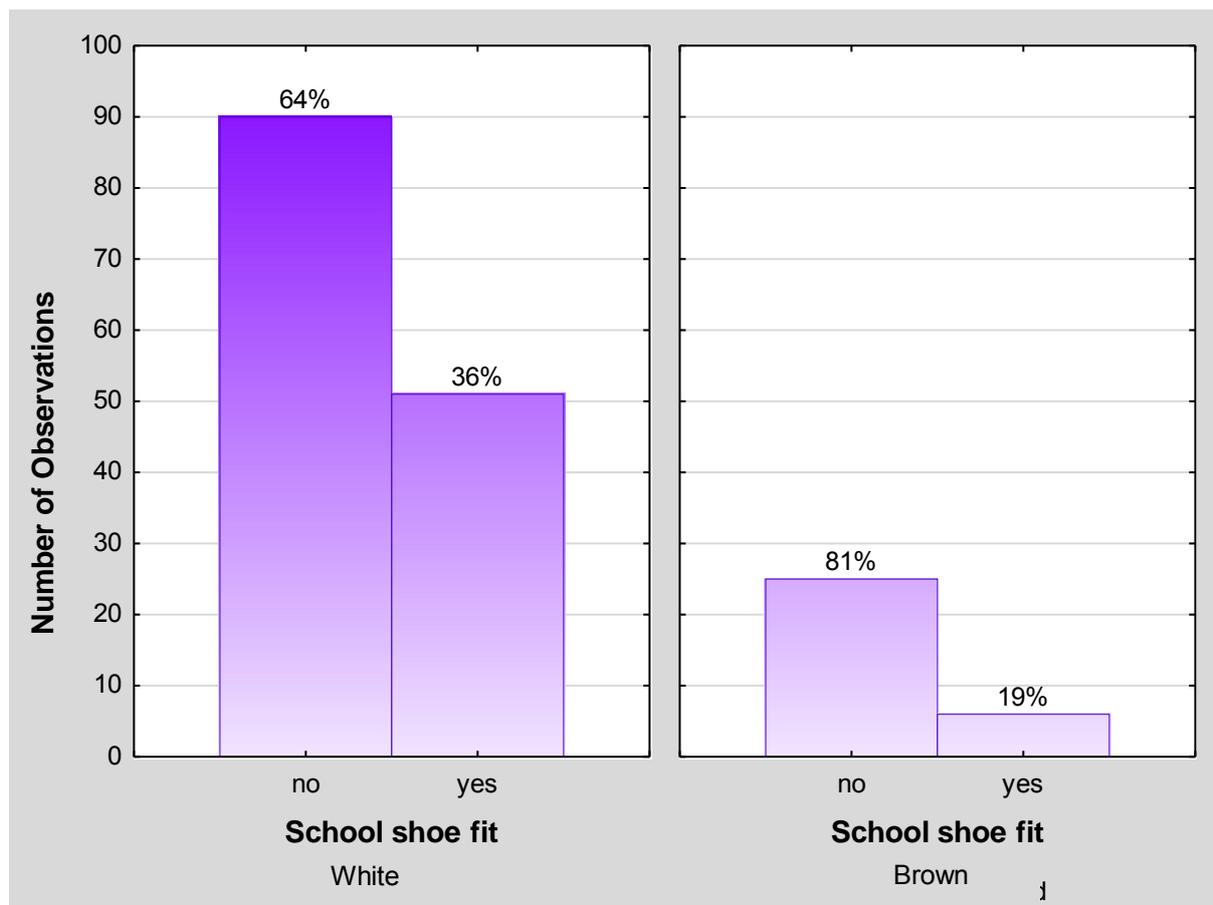


Figure 4.17: Prevalence of ill-fitting shoes in the different race groups

Results on the difference in foot length compared to shoe length between the different races did not show any practical significance. The averages are portrayed in Table 4.13.

Table 4.13: Average school shoe fit (length) for different races (Data are presented as mean \pm SD)

Race	n	School shoe fit – length (cm)	SD	95% Confidence Interval	
White	141	0.76	1.03	0.59	0.93
Brown	31	0.09	1.51	-0.46	0.65

Width

Other than the results of the shoe fit with regards to length, the width showed no significant difference between the brown- and white children and adolescents as depicted in Figure 4.18. The difference in school shoe width and foot width in brown children and adolescents were bigger than the difference in the white children and adolescents. Once again, no practically significant difference between the different races was observed, as stated in Table 4.14.

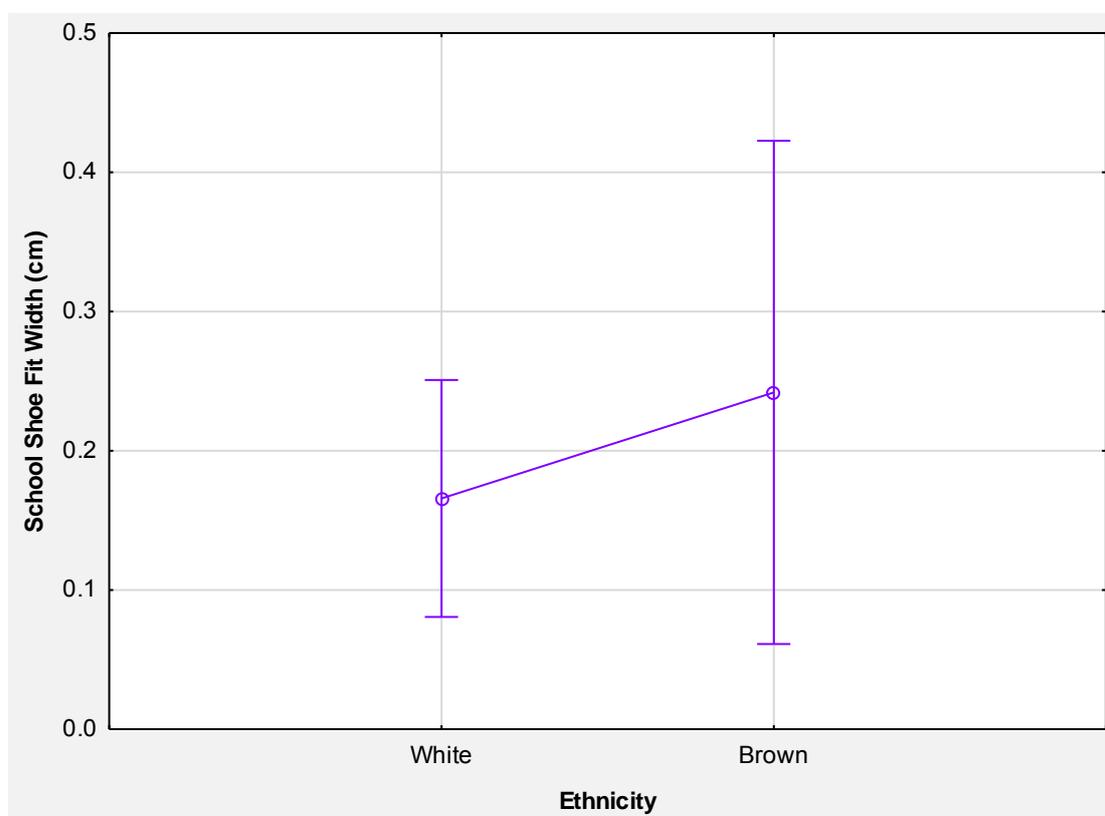


Figure 4.18: Differences in school shoe fit (width) between different races

Table 4.14: Average school shoe fit (width) for different races (Data are presented as mean \pm SD)

Race	n	School shoe fit – width (cm)	SD	95% Confidence Interval	
White	140	0.17	0.52	0.08	0.25
Brown	31	0.24	0.45	0.08	0.41

J. The effect of BMI categories on foot metrics

Length

No statistically or practical significant differences for shoe length and foot length between the different BMI categories were observed. Differences in the length of the shoe compared to the length of the foot between the different BMI categories are shown in Figure 4.19.

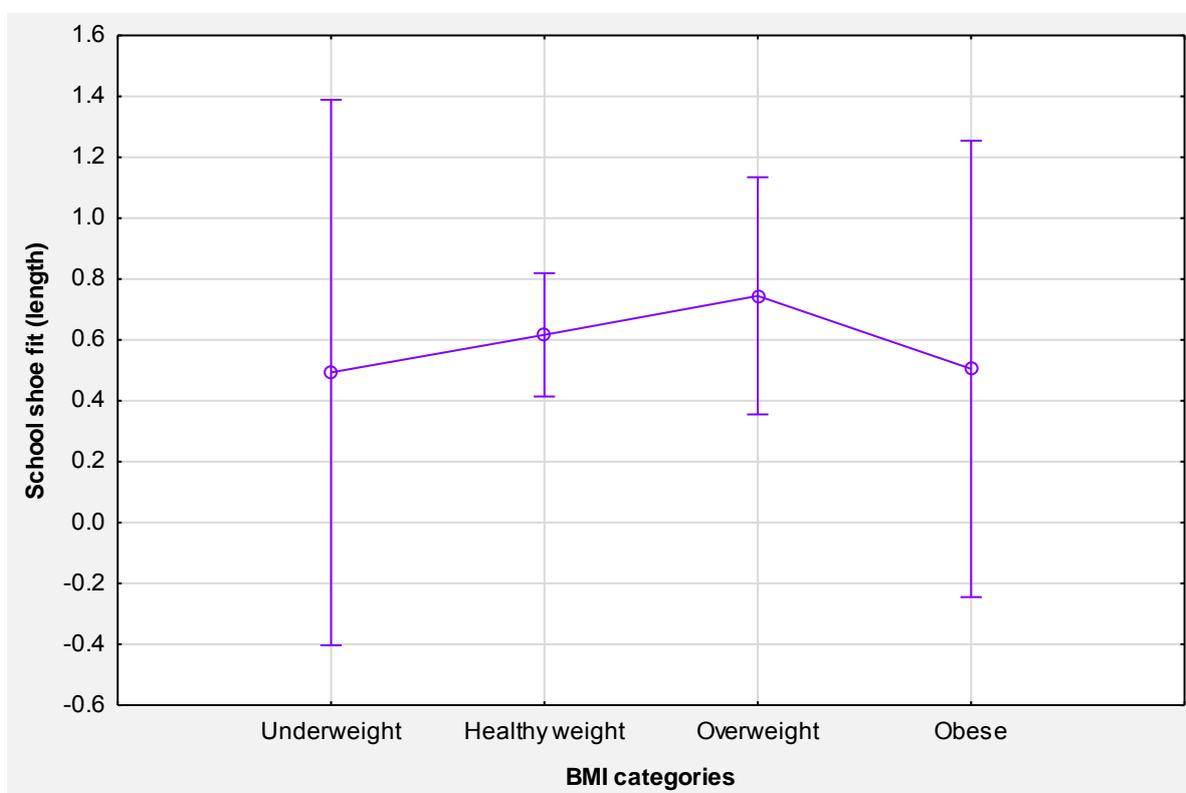


Figure 4.19: Differences in school shoe fit (length) between different BMI categories

Figure 4.20 shows the percentage of ill-fitting shoes in the different BMI categories. The underweight category had the highest prevalence of ill-fitting shoes with 86 percent of the children and adolescents wearing ill-fitting shoes. The healthy weight and overweight categories showed that 67 percent and 62 percent respectively, of children and adolescents, wore ill-fitting shoes. The obese category had a slightly higher prevalence of ill-fitting shoes with 70 percent wearing ill-fitting shoes.

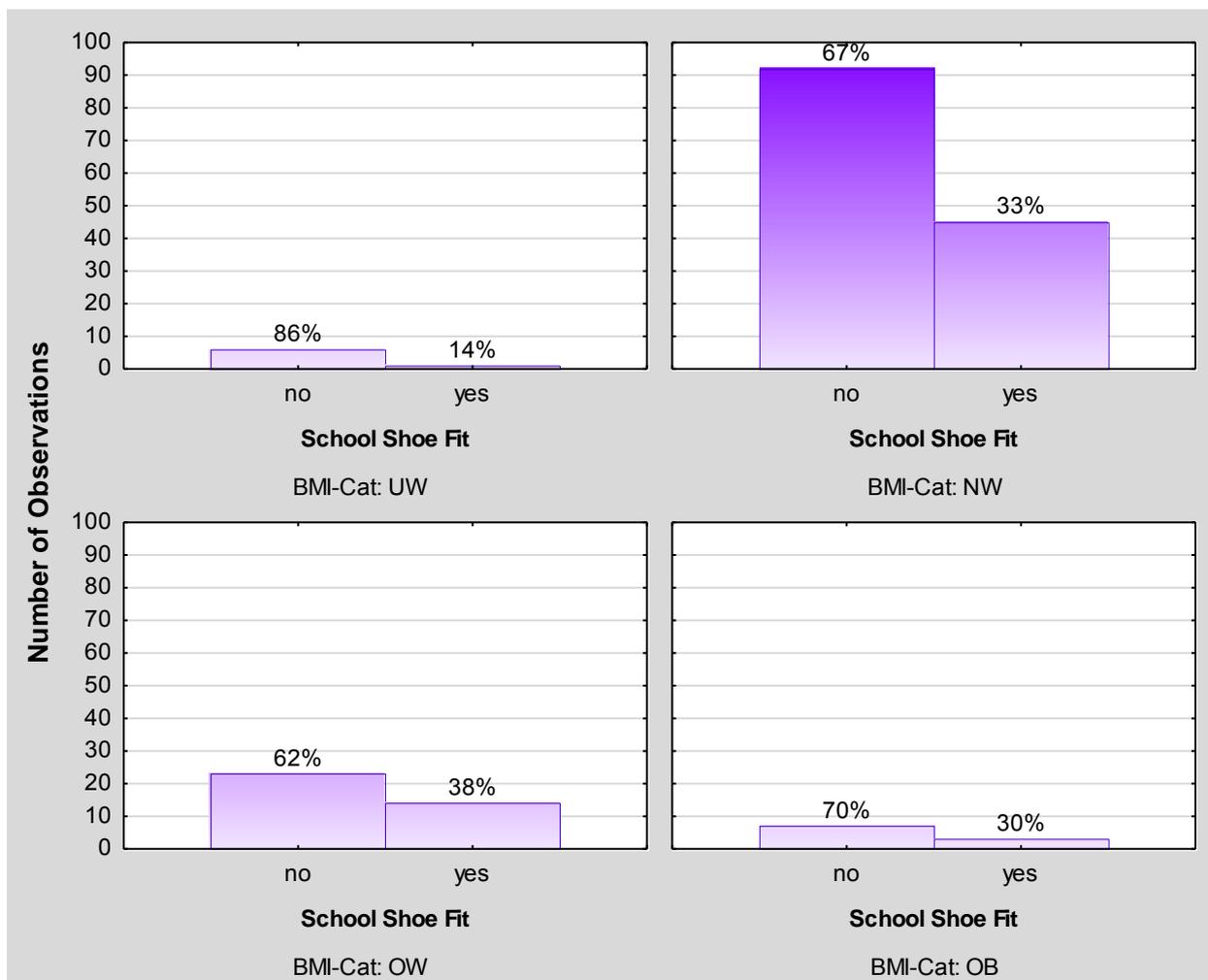


Figure 4.20: Prevalence of ill-fitting shoes in different BMI categories

- UW - underweight
- NW - healthy weight
- OW - overweight
- OB - obese

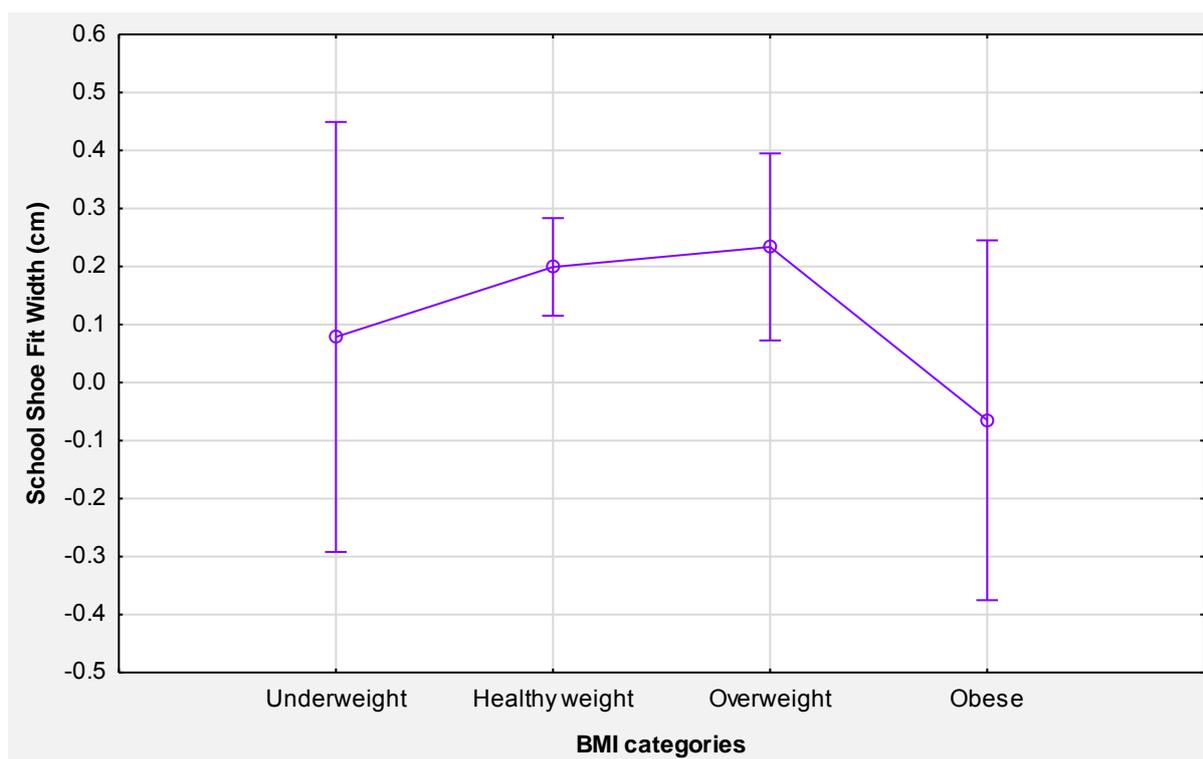
Descriptive statistics regarding shoe fit for the different BMI categories are reported in Table 4.15.

Table 4.15: School shoe fit (length) for different BMI categories (Data are presented as mean \pm SD)

BMI categories	n	School shoe fit - length (cm)	SD	95 % Confidence Interval	
Underweight	7	0.49	0.42	-0.53	1.52
Healthy weight	137	0.62	0.10	0.43	0.81
Overweight	37	0.74	0.24	0.27	1.22
Obese	10	0.51	0.42	-0.46	1.47

Width

No significant differences in shoe fit (width) were observed between the different BMI categories (Figure 4.21).

**Figure 4.21:** Differences in school shoe fit (width) between different BMI categories

There was no practically significant difference in the width fit of the shoe between the different BMI categories (Table 4.16).

Table 4.16: Average school shoe fit (width) for different BMI categories (Data are presented as mean \pm SD)

BMI categories	n	School shoe fit – width (cm)	SD	95 % Confidence Interval	
Underweight	7	0.08	0.38	-0.28	0.43
Healthy weight	136	0.20	0.47	0.12	0.28
Overweight	37	0.23	0.556	0.05	0.42
Obese	10	-0.07	0.72	-0.58	0.45

K. Validity and reliability

To determine the reliability and validity of the research an ICC was used. A high degree of reliability was found between the different measurements for foot length, foot width, and shoe length. The intra-rater reliability average for foot length was ICC = 0.990 and for foot width it was ICC = 0.930.

Inter-rater reliability was of a high degree for all the measurements, namely shoe length ICC = 0.881 and shoe width ICC = 0.902.

CHAPTER FIVE

Discussion

A. Introduction

The present study was guided by several research objectives. By discussing these objectives in the following paragraphs, a better understanding of the main aim, which is to compare factors associated with foot size and shoe fit between school children and adolescents of different ages, gender, race, and body mass index, will be obtained.

From the results, it is evident that boys had significantly wider feet than girls when comparing the same age groups, while there was only a significant difference in foot length between the older age groups when looking at gender. There were also significant differences between the different genders and age groups with regards to arch index. White children and adolescents had significantly longer and wider feet, with a significantly lower arch index compared to the brown children and adolescents. The obese and overweight children and adolescents had significantly longer and wider feet than the healthy weight and underweight children and adolescents, with significant differences between all categories for the arch index.

When looking at shoe fit, it was evident that South African children and adolescents wore ill-fitting shoes, independent of age, gender, race, and BMI categories. The differences in shoe width to foot width in girls were significantly smaller than the difference seen in boys. The difference between school shoe length and foot length for brown children and adolescents was significantly smaller than those of the white children and adolescents.

In South African schools, wearing a school uniform is compulsory. The uniform consists of prescribed pants and shirts for the boys and a dress with/without a shirt for the girls or pants and a shirt during the winter. This uniform is usually accompanied by either black or brown shoes. There are certain criteria that the shoe must adhere to, depending on the preference of the school. During winter months;

however, some primary school children and adolescents (ages six/seven to thirteen/fourteen years) are allowed to attend school wearing their school tracksuit and sports shoes. In Addendum E, an example of a code of conduct for schools regarding clothing (Department of Education, 2008) and extracts of school rules of two South African high schools (School-laws, 2016b; 2016d) and primary schools (School-laws, 2016a; 2016c) respectively, are given. Many primary schools; however, allow the children and adolescents to go to school without shoes. Most sports in primary schools are played barefoot. Figure 5.1 to Figure 5.5 are examples of the barefoot culture in South Africa, while Figure 5.6 gives a visual description of the school uniform in a high school.

Before discussing the objectives, the descriptive statistics of the participants will be discussed.



Figure 5.1: South African Primary school children (Picture with permission of parents. Picture by E. de Villiers)



Figure 5.2: Primary school children participating in rugby whilst being barefoot (Picture by E. de Villiers)



Figure 5.3: Primary school children participating in netball whilst being barefoot (Picture by E. de Villiers)



Figure 5.4: Primary school children participating in cricket whilst being barefoot (Picture by E. de Villiers)



Figure 5.5: Primary school children participating in athletics whilst being barefoot (Picture by E. de Villiers)



Figure 5.6: High School children in their school uniform (Picture by E. de Villiers)

B. Descriptive statistics

Participation in the study was voluntary. Children and adolescents from schools, chosen from a random sample of convenience, were included in the study if both informed consent forms were completed and if they fulfilled the requirements of the inclusion criteria. The following section will first focus on the distribution amongst genders, race, and ages and secondly, on the differences in height between the genders within the different age categories.

Both genders were well represented, with 49 percent of the children and adolescents being girls and 51 percent of them being boys. Race, on the other hand, was not as representative as the genders. Most the 578 children and adolescents were white (67%), while only 20 percent were brown, and the rest of the children and adolescents (13%) did not disclose their race. The ages six, seven and eighteen years were the ages with the least children and adolescents, while ages twelve, thirteen and sixteen years had the most children and adolescents. Children from six or seven to thirteen or fourteen years of age attended primary schools, while children and adolescents thirteen or fourteen to eighteen years of age attended high schools in South Africa. One of the reasons for the low number of children between the ages of six to eight, especially six-year-olds, could be that children in grade one are

usually seven years old or turning seven in that year. Another reason that made it difficult for the researchers to test children between the ages of six and eight, is that their school days are shorter than that of the other children. The low numbers in the higher age groups could be because of physical activity and the interest in physical activity declines with age, especially in the pubertal stage, as described by Raask et al. (2015). This representation in the various ages shows a similar trend to the study conducted by Barisch-Fritz et al. (2016) where 1 966 children were aged six to sixteen of which, most were between nine and thirteen years of age.

Results show that there is a steady increase in height amongst both genders up until the age of 12 to 14 years. From 12 years on, the height of girls almost reaches a plateau, while the height of boys still increases. This is similar to the findings of Dimeglio (2001) where the researcher saw an equal and steady increase in growth of 5.5 cm on average per year between the girls and boys from five to ten years of age. The researcher reported that the reason for the differences between boys and girls after 12 years of age is that the onset of puberty is experienced earlier in girls (11 years) compared to boys (13 years). During this time, the growth pattern starts to change between genders (Dimeglio, 2001). The rate of growth during puberty is approximately one cm per month. At the onset of puberty, girls still have 12 percent ($\pm 1\%$) to grow until they reach their final standing height. Boys, on the other hand, still have 14 percent ($\pm 1\%$) to grow (Dimeglio, 2001). Armstrong and colleagues (2006) reported a significant height increase each year in both genders in South African primary school children (Armstrong, Lambert, Sharwood & Lambert, 2006).

On average, South African children and adolescents are taller and heavier than German children and adolescents measured in the study by Barisch-Fritz et al. (2016). The average height of children and adolescents in the current study were 1.55 m, while the average weight was 50.58 kg. German children and adolescents between six and sixteen years of age had an average height of 1.45 m and an average weight of 39.0 kg (Barisch-Fritz, Plank & Grau, 2016).

C. Research Objective One

To determine the effect of age on foot length, foot width and the dynamic arch index of school-aged children and adolescents in the Western Cape, South Africa.

The findings of the current study show a steady increase in foot length for both genders up until the age of nine to eleven years. After 12 years of age, the increase in foot length occurs more rapidly, while the feet length of girls continues to increase steadily until 12 to 14 years of age, whereafter a plateau in the foot length growth is reached. These results are consistent with those of Cheng et al. (1997) who found a linear increase in foot length with an increase in age, from three up until the age of twelve years in girls and fifteen years in boys. Thereafter, a plateau in the growth of foot length occurred (Cheng et al., 1997).

In a study that included 7 788 children, Müller et al. (2012) reported an increase in foot length from 13.1 ± 0.8 cm in their youngest participant (one year old) to 24.4 ± 1.5 cm in the 13-year-old (Müller et al., 2012).

According to Fritz and Mauch (2013), the length of the foot at birth is one-third of the final foot length. Major growth takes place in the first three years of life, at an average of 2 mm per month. Growth rate decreases slightly to one mm per month between three and five years and plateaus down to eight to ten mm per year between five and twelve years of age (Fritz & Mauch, 2013).

Similar findings were reported by Delgado-Abellán et al. (2014). Progressive differences were found between the age groups six to twelve years since significant differences in foot length are seldom found in consecutive years. The average increase in foot length of the Spanish school children were 4.2 percent for boys and 3.8 percent for girls. The differences between genders started to occur between ages eight to ten years. Delgado-Abellán et al. (2014) found the critical age for foot development to be around six years, while it stabilises around 12 years of age. The average increase in foot length between the ages six to twelve years is eight to ten mm per year.

Few results are available on foot width measurements with an increase in age. Most research only mentions a progressive increase in foot width with age (Cheng et al., 1997; Delgado-Abellán et al., 2014). In the current study, results show that there was, just like with the foot length, a significant increase in foot width between both genders until 12 to 14 years of age. Thereafter, the foot width of the girls did not increase any further, while the foot width of the boys continued to increase significantly.

Müller and colleagues (2012) found an increase in foot width from 5.7 ± 0.4 cm in one-year-olds to 8.9 ± 0.6 cm in thirteen-year-olds. They did mention that the ratio of foot length to foot width declined with age and that up until eight years of age, the feet of children are wider according to foot length when compared to those of older children (Müller et al., 2012).

For continuity, the term "arch index" (AI) will be used in the discussion, since the dynamic AI was measured in the current study. Some researchers (Joseph & Rao, 1992; Aymelek et al. 2011) refer to flat-footedness, while others refer to arch height (Delgado-Abellán, 2014). In this study, dynamic AI is defined as the ratio of the midfoot area divided by the total foot area (without toes). A higher value describes a flatter foot.

Unlike previous research, the dynamic AI values of boys showed a steady increase with age, so the feet of boys were flatter in the older age groups compared to the younger age groups. The dynamic AI values of girls were lower in the nine to twelve-year-old group compared to the girls younger than nine years. From 12 years and up; however, the dynamic AI values increased until 15 years of age and plateaued thereafter. In other words, the girls younger than nine years had flatter feet compared to the girls between nine and eleven years of age. The girls older than 12 years had flatter feet compared to the girls between nine and eleven years of age.

As mentioned above, similar research did not find the same results. The following studies measured static AI and this could be one of the reasons why results from our study differed from the results previously reported on.

In a study done on Taiwanese children between the ages two to six years, results show a steady decrease in AI. The measurement of the AI was done by inspecting

the arch height and subjectively determining if the foot was flat or not (Lin et al., 2001).

Fritz and Mauch (2013) report that 59 percent of the two-year-olds they tested presented with a high AI, compared to the ten percent in fourteen-year-old children.

Results from the Spanish study also show that there was a great decrease in the static AI with an increase in age (Delgado-Abellán et al., 2014).

The present findings seem to be inconsistent with other research, which found that a high static AI decreased with age (Joseph & Rao, 1992; Volpon, 1994; Stavlas et al., 2005; Mickle et al., 2008; Aymelek et al., 2011).

In a study that examined the dynamic AI, results show a decrease in the dynamic AI value of German children from one year (0.32 ± 0.04) to five years of age (0.21 ± 0.13). The dynamic AI; however, remained constant from five years to thirteen years of age (Müller et al., 2012).

Although all the above-mentioned researchers stated that a high AI decreases with age, Scott et al. (2007) found that after the age of 30, feet start to flatten out again which, in turn, will lead to a high AI.

One of the reasons for the difference in results from the studies mentioned above, except for the study by Müller et al. (2012) and the current study, could be attributed to the fact that the researchers measured static AI values and not the dynamic values. Another possible reason could be the different age groups included in the studies. Some studies, for example, Fritz and Mauch (2001) and Lin et al. (2001), included children younger than the ages used in the current study. The medial longitudinal arch's, which forms a big part of the arch height, most crucial developmental stages are from birth to six years of age (Volpon, 1994; Echarri & Forriol, 2003; El et al., 2006; Walther et al., 2008; Fritz & Mauch 2013;) and it is in those years that Spitzzy's fat pad is present. The presence of this fat pad can, therefore, increase the prevalence of "flat feet" or the high AI. With age and the decrease in Spitzzy's fat pad, the high AI will change significantly. The only study reporting on the dynamic AI also used ages that were younger than the ages used in

the current study and where Spitzzy's fat pad still could have had an influence on the results.

D. Research Objective Two

To determine the effect of different genders on foot length, foot width and the dynamic arch index of school-aged children and adolescents in the Western Cape, South Africa.

In the current study, comparing foot length between different genders showed that there was no statistically significant difference between the genders up until the age of 12 to 14 years. After 15 years of age, the foot length of girls reached a plateau, while the boys' feet still showed a significant increase in length. This finding supports previous research with regards to foot length by Delgado-Abellán (2014), which also found that changes in foot length between the genders occurred, but that changes occurred slightly earlier, between eight to ten years of age. Significant differences in foot length between the genders existed at eight years, ten years and twelve years of age. When these measurements of foot length were normalised for height; however, the significant difference did not exist anymore (Delgado-Abellán et al., 2014).

Similar results were found in the study conducted by Cheng et al. (1997). The researchers reported that the growth of children's feet is similar until the age of three, but that the feet of boys grow faster from that stage on until 18 years of age. Foot length and width were measured with a special precision electronic calliper (Cheng et al., 1997).

Walther et al. (2008) reported in a systematic literature review that the feet of girls between the ages four to fourteen years grow at a rate of 0.25 cm less than the feet of boys of the same age. Another difference between genders that was revealed in the literature review was that girls' feet stopped growing at 14 years of age, while boys' feet only stopped growing at 16 years (Walther et al., 2008).

In the current study, results on foot width between genders showed similar results to that of foot length. The feet of boys were slightly broader than the girls' feet at age

groups younger than nine and nine to eleven years. Boys' feet became significant broader than girls' feet from the age of 12 onwards.

In a study done on Turkish individuals, a total of 294 men (age 32.70 ± 12.55) and 275 women (age 32.23 ± 12.71) were tested. Results show significant differences between the width of both the left and right foot between genders. The feet were measured by using a Harpenden anthropometry set (Ozden, Balci, Demirüstü, Turgut & Ertugrul, 2005).

Bosch et al. (2010) also found significant differences in the midfoot width during their longitudinal study, which was on average six mm wider in boys compared to girls.

Krauss et al. (2011) compared feet from both genders of the same length (grouped according to the European Scaling System). Results show that men's feet were significantly broader than that of women. The mean difference was 1.1 mm to 5.3 mm.

Delgado-Abbellán et al. (2014) measured both feet using a 3D foot digitiser. Results show a significant difference in foot width between the boys and girls within all the age groups tested (six to twelve years). These differences were still evident once the foot width was normalised to foot length (Delgado-Abellán et al., 2014).

In a study on the Taiwanese population, researchers found that the women had a significantly thinner foot than their male counterparts. These differences were especially seen in the foot length of 23.5 cm and 24.5 cm (Lee & Wang, 2014).

Results from the current study show that the dynamic AI values were similar between the genders for children younger than nine years. A bigger, but still not significant difference, was observed between the genders from the ages nine to eleven years and twelve to fourteen years. Where children were 15 years and older, a significant difference was found for the dynamic AI between the genders.

Stavlas et al. (2005) found in their study on Mediterranean children between six and seventeen years of age, that the boys had a higher AI at the ages seven, nine, eleven, fourteen and fifteen when compared to the AI of girls. The researchers

mentioned that results show more normal footprints overall than high or low arch indices for both genders (Stavlas et al., 2005).

Echarri and Forriol (2003) found that girls tend to have a higher inner arch than boys, which according to the AI, would mean that girls will have a lower AI value compared to boys. This was noted by other researchers, mentioning that boys have a flatter longitudinal arch than girls (Pfeiffer et al., 2006; Bosch et al., 2010).

Even though researchers used different methods to determine foot length, foot width and the AI results from the current study were similar to those found in previous studies. This just shows that a self-manufactured calliper and sliding calliper can be used for testing and measurements in remote areas.

E. Research Objective Three

To determine the effect of different races on foot length, foot width and the dynamic arch index of school-aged children and adolescents in the Western Cape, South Africa.

No research regarding foot shape on South African children has been published. Due to the novelty of the study, results could not be compared to South African data. The results of the current study are; however, similar to results from other research being done elsewhere in the world, comparing the foot shape from different ethnicities.

A medium practical significant difference and a statistically significant difference in foot length were observed between the white and brown children. The white children had on average longer feet than the brown children. Other research that has been done through the years, found differences in foot length between different ethnicities.

Hawes et al. (1994) compared the forefoot shape of North Americans to that of East Asians by using a modified Mitutoyo digital calliper. The researchers concluded that the East Asians had a longer foot axis than the North Americans.

Ashizawa, Kumakura, Kusumoto and Narasaki (1997) conducted a study on East Javanese and Japanese women. Results show that the East Javanese women had longer feet than the Japanese females.

Other researchers compared a few ethnicities with one another: Tongans, Japanese, French, Australian Aborigines, and West Africans. The researchers found that the feet of Tongans were significantly longer than the feet of the other ethnicities (Gonda & Katayama, 2006).

In a study conducted on the Australian and German population, the researchers found an average difference of around ten mm between the foot length of the German and Australian children. The German children's feet were significantly longer than that of the Australian children. This difference was found even though most of the participants in the study were white (Mauch et al., 2008).

In the study conducted by D'Aout et al. (2009), comparing the foot length and width of the Indian participants to those of the Westerners, it was found that the Westerners had relatively shorter and narrower feet.

Results in foot width from the current study were similar to the results found in the length measurements. A medium practically and statistically significant difference in foot width was seen between the different races. The feet of white children were wider than the feet of the brown children.

As mentioned earlier, Ashizawa et al. (1997) conducted a study comparing Japanese and East Javanese women's feet. The researchers found that the East Javanese women had wider feet than their Japanese counterparts.

Gonda and Katayama (2006) mentioned that despite the significantly longer feet, Tongans also had significantly wider feet than the Japanese, French, Australian Aborigines and West Africans.

D'Aout et al. (2009) evaluated the Indian population by using a plantar pressure plate. They compared habitually barefoot Indians to habitually shod Indians and to a Western population. Results show that the Westerners had relatively narrower feet than the Indian population.

A statistically significant difference was found in the dynamic AI between the different races. The white children had a significantly lower AI. This could either mean that white children have a higher arch or that the feet of brown children are more pliable. Pliability was not measured in this study.

The pliability of the foot measured by Cheng et al. (1991) showed that white children had less pliable feet than the Chinese children. Their results show that 100 percent of the Chinese children at three years of age had pliable feet, as to only 50 percent in white children. Although the percentage decreased with age in both groups to 67 percent of Chinese and only five percent of Caucasian children at six years of age, there was still a difference between the ethnicities. At 12 years of age, the prevalence of pliable feet was still significantly more in the Chinese children (28%) compared to only one percent of the Caucasian children presenting with pliable feet (Cheng et al., 1991).

Results of a study done on Malawians confirmed that the AI of the Malawians was significantly higher ($p < 0.001$) than that of Caucasian Americans and Europeans ($p < 0.01$) (Igbigbi & Msamati, 2002).

Dunn et al. (2004) found in their study that African Americans had the highest prevalence of flat feet (high AI), followed by the non-Hispanic Caucasians and then the Puerto Ricans.

Mauch et al. (2008) found that despite the significant longer feet of the German children, they presented with a significantly higher AI (flatter feet) than the Australian children. The Australians; however, presented with a significantly smaller ball angle, implying that the forefeet of Australian children are squarer in shape.

D'Aout et al. (2009) found that the Western population had a lower AI (higher MLA) compared to the habitually barefoot Indians and the habitually shod Indians.

In the study comparing Malawian and Dutch individuals' feet, the researchers found that the Malawians had a statistically significant (higher AI) flatter MLA compared to the Dutch individuals. The researchers mentioned that despite the significantly higher AI, AI is related to BMI and body weight and the researchers did not account for that (Stolwijk et al., 2013).

F. Research Objective Four

To determine the effect of different BMI categories on foot length, foot width and the dynamic arch index of school-aged children and adolescents in the Western Cape, South Africa.

Results from this study show that obese and overweight children had significantly longer feet than that of the healthy weight and underweight children respectively. No significant differences were found between the foot length of the obese and overweight category. The same trend was observed in foot width, where the obese and overweight children had significantly broader feet than the healthy weight and underweight children. Just as with the foot length, no significant differences were found between the foot width of the obese and overweight children.

Although a lot of studies have been done on obesity and the influence of obesity or overweight on the foot shape, few articles mention the influence thereof on the length or the width of the foot. Most research focused on the MLA.

In a study conducted by Hills et al. (2002), foot measurements between the different genders were compared while standing. A significantly wider foot was noted in both genders for the overweight group, while there was no significant difference in foot length.

In a study by Mickle et al. (2006b), the researchers observed that the obese individuals in the age groups three to five years and seven to twelve years had larger foot dimensions compared to the healthy weight and underweight individuals.

Cheng et al. (1997) wanted to illustrate the effect of excessive weight bearing on the foot. During their research, they did measurements while non-weight bearing as well as weight bearing. The researchers found a significant increase in the width and the length of the foot on weight bearing when compared to the non-weight bearing foot of children between the ages three to eighteen years.

Another study describing the effect of body weight and height on foot dimensions was conducted in Germany by Bosch et al. (2010). They found that a difference in height (identical weight, identical age of onset of walking, and same gender) of 5 cm

led to a 0.4 cm longer, but a 0.3 cm narrower foot. In addition, a one kilogram (kg) difference in body weight led to a wider foot (± 0.08 cm).

Significant differences in dynamic AI were found between all the categories. The obese children's AI was the highest and the underweight children's AI was the lowest.

Similar to findings in the current study, Dowling et al. (2001; 2004) found the feet of obese children to have a bigger contact area (this would be a high AI). The researchers mentioned the reason for this could be attributed to the long-term bearing of excessive weight that could flatten the medial midfoot region.

Mickle et al. (2006b) also found the obese and overweight children to have a higher AI (flatter feet). Once again, the researchers motivated the reason for this being the foot structure that gets affected by the carrying of excess weight. No difference between the fat pad thicknesses underneath the foot existed. The researchers, therefore, concluded that the reason for the higher arch is because of a lower plantar arch.

Pfeiffer et al. (2006) noted that the probability of a higher AI in obese children is three times higher than those of healthy weight children.

Fritz and Mauch (2013) found that overweight children presented with more robust (27%) and flat feet (22%), compared to the underweight children who had more slender feet (26%).

A study contradicting the research above was done in India. Researchers found that the average BMI for flat-footed children was $14,72 \text{ kg/m}^2$, whereas the BMI for the children with normal feet was $14,61 \text{ kg/m}^2$ (Joseph & Rao, 1992).

G. Research Objectives Five to Eight

To determine the effect of age, gender, race and BMI categories on the shoe fit of school-aged children and adolescents in the Western Cape, South Africa.

There has been an increased concern among researchers and clinicians about the influence of shoes on the growth and development of children's feet. It has been mentioned that ill-fitting shoes can be detrimental to foot health (Janisse, 1992; Frey et al., 1993; Mauch et al., 2009). Limited research is, however, available on shoe fit in children and adolescents with regards to age, gender, race and BMI categories. This is the reason for discussing Objectives Five to Eight under the same heading.

Compromised foot development could affect foot function. In a study by Morio, Lake, Gueguen, Rao and Baly (2009), results show that shoes do not only restrict the natural motion of barefoot, but it also appeared to enforce a specific foot motion pattern during the push-off phase. Results of a study conducted by Hollander, Riebe, Campe, Braumann and Zech (2014) show that running in shoes increased the maximum ground reaction forces and impact ground reaction forces significantly compared to running barefoot. Shoes increased the step length, step width, and the rate of the rear-foot strike when compared to running barefoot.

More questions are raised on the correct shoe fit regarding foot length and width. It has been shown that adult shoe sizes are often adapted for children (Delgado-Abellán et al., 2014). There are numerous shoe size charts used throughout the world. Addendum H displays the different shoe size measurements from different countries.

The "rule-of-thumb" theory, where a parent would use the width of his/her thumb to determine if there is enough space at the front of the shoe, was investigated in a study done by Barisch-Fritz et al. (2016). The researchers found that with the toe allowance (space in the front of the shoe) that is usually used, the average thumb width, 2.54 cm, was far too big. Barisch-Fritz et al. (2016) therefore suggest that the toe allowance should be based on the 90th percentile for German children. The

values recommended were 0.98 cm (9.8 mm) for girls and 1.15 cm (11.5 mm) for boys.

The aforementioned two values were used in the current study to determine if the shoes were too small. The researchers mentioned that despite the toe allowance, the overall shoe fit should also be taken into account (Barisch-Fritz et al., 2016). There are no guidelines in the literature about the shoe fit with regards to width. The study was; however, done on German children and one question that arose was if this can just be used on other countries' children, since other studies have shown, and as reported in the current study, that differences in foot shape exist between different ethnicities.

Age

Results from the current study show that, according to the 90th percentile, a high number of children and adolescents (67%) wore ill-fitting shoes. There were no children under the age of nine that had school shoes that we could measure since in some primary schools children do not have to wear shoes to school. The older age categories wore more ill-fitting shoes (12 – 14 years = 63.38%; older than 15 years = 65.69%).

The most research regarding shoe fit has been done on the elderly population (Janisse, 1992; Menz & Morris, 2005; Schwarzkopf et al., 2011) with no available studies done on the ages six to eighteen years and comparing the ages with one another.

Gender

Several researchers have shown that women tend to wear shoes that are too small for their feet.

In a study involving women only, the researchers found that 88 percent of the women wore ill-fitting shoes. Of those, 76 percent had foot problems. The method of determining ill-fitting shoes was not disclosed (Frey et al., 1993).

Menz et al. (2003) found that women tend to wear more ill-fitting shoes than men when it comes to both the length and width of the shoe.

Burns et al. (2002) conducted a study on a population with an average age of 82 years (range 64 to 93 years). Forty-seven people (72%) were wearing ill-fitting shoes. The researcher defined the shoe as ill-fitting if the difference between the shoe size and the measured foot size was greater than half a standard British shoe size or one width fitting (7 mm). Only 18 participants (28%) had shoes that were both the correct width and length. Four people (6%) wore shoes that were too small (too short or too narrow) and 42 people (65%) wore shoes that were too big (too long or too wide, or both). One person wore a shoe that was both too short and too wide.

In another study conducted on older people, this time by Menz and Morris (2005), results show that 23 subjects (13.7%) wore indoor shoes shorter than their feet. A total of 136 (81.4%) wore indoor shoes narrower than their feet, and 73 (43.7%) wore indoor shoes with a smaller total area than their foot. Similarly, 17 (10.2%) subjects wore outdoor shoes shorter than their feet, 131 (78.4%) wore outdoor shoes narrower than their feet, and 79 (47.3%) wore outdoor shoes with a smaller total area than their foot.

Even in a study done on children (gender was not disclosed), researchers found that 9.6 percent of the children's footwear was too big. Some children (33.4%) wore shoes that were one size too large for their feet and 10.3 percent wore footwear that was two sizes too large for their foot length (Walther et al., 2008).

In a study conducted on Spanish school children, the researchers used a 3D foot digitiser to do a variety of measurements of the foot. The shoe size of the children was documented. The shoe fit was determined based on the French scaling system, and the shoe size was used and compared to the estimated shoe size according to the foot length (D'Aout, Pataky, De Clercq, & Aerts, 2009). Results from the Spanish study showed that girls tend to wear more ill-fitting shoes.

Nonetheless, when looking at the percentage of children and adolescents from the current study, the same percentage (67%) of boys and girls wore ill-fitting shoes.

Boys wore shoes that were on average only 0.57 cm longer than their feet in comparison to the advised 1.15 cm. The girls wore shoes 0.70 cm longer than their feet compared to the 90th percentile of 0.98 cm. This means that the boys had too little toe allowance than the girls.

The opposite was true when looking at the width measurements. Girls wore significantly narrower shoes than the boys when shoe width was compared to foot width. This occurred even though boys had significantly wider feet compared to girls in the same age categories.

Race

Brown children and adolescents had a significantly smaller difference between their foot length and school shoe length when compared to the white children and adolescents. There was also a higher percentage of brown children and adolescents wearing ill-fitting shoes.

A possible reason for this could be that there are possible socio-economic differences between the races in this study population, but since socio-economic status was not determined in the study, this is only a speculation.

BMI Categories

Obese children and adolescents wore the most ill-fitting school shoes. Their shoes were too narrow for their feet and, in comparison to the other children, shorter relative to the length of the feet. In a study conducted on South African children, researchers found that one in five children were overweight or obese. The aerobic capacity and muscle strength, especially leg strength, decreased progressively with an increase in BMI (Truter et al., 2010). Similar results were observed by Corder, van Sluijs, Ekulund, Jones and Griffin (2010) who tracked physical activity of children

over a period of 12 months. There was a statistically significant decrease in physical activity levels in girls with a higher body fat percentage compared to boys with a high body fat percentage and boys and girls with a low body fat percentages (Corder, van Sluijs, Ekelund, Jones, & Griffin, 2010). When looking at the feet of habitual barefoot walkers, the form is different when compared to habitually shod individuals. In a study conducted on habitually barefoot Indians, the feet of the habitually barefoot individuals were wider and they could distribute the peak pressures more equally compared to the shod Indian population. Barefoot walkers also had a lower arch height, in other words, flatter feet (D'Aout et al., 2009).

It, therefore, raises more questions on the generic shoe sizes and suitability of shoes for children and adolescents in these populations. Manufacturers in South Africa, seen as a country with a high number of habitually barefoot citizens, should be made aware of the consequences involved in ill-fitting shoes. Currently, the main guidelines for shoe fit relate to length and not width.

H. Study Limitation

One of the limitations of the study was the limited representation of different races and participants within the brown group. Of the total participants, 13 percent did not disclose their race and this missing data could have had an influence on the results.

Many schools were contacted for possible participation, but not all the schools showed interest in the study. This could be one of the reasons why the race representation was not adequate.

Not all the children remembered to bring either their school shoes or their sports shoes on the day of testing and this also led to incomplete datasets.

The validity of the shoe width measurement was not available.

The possible age and condition of shoes were not documented.

I. Future Research

The author of this thesis suggests that further research is conducted by means of a longitudinal study to track children obliged to wear school shoes, and determining the effect of the school shoe on the development of their feet.

In addition, it is recommended to complete a study where more races are included and enough children of each race are tested to provide a better perspective on the shoe fit between races in South Africa.

J. Practical implications

This research study is a start to document foot metrics of South African children and adolescents and can be expanded upon for the purpose of future studies.

This study can serve as a guideline to shoe manufacturers in South Africa to accommodate South African foot dimensions.

Parents of school children and adolescents should be educated on the importance of well fitting shoes – to always take toe allowance into account and that ill-fitting shoes can influence the development of the growing foot.

This study could potentially aid school authorities to become more flexible with regards to rules on school shoes, whether it is to allow them to attend school barefoot or to wear more foot-friendly shoes.

K. Conclusion

The primary finding of this study is that the school shoes of South African children, independent of gender, race, and BMI category, are ill-fitting. This could be detrimental to the foot. In addition, it was determined that there are differences in foot length and width in South African school children and adolescents when looking at age groups, genders, race, and different BMI categories.

Both hypotheses can, therefore, be rejected.

In conclusion, Dr. Marlene Mauch gave the following advice to parents when asked if she should advise parents to allow their children to be more barefoot if the weather, walking surfaces and society allowed it:

“We definitely should advise this, yes. Shoes, even if the sole is flexible, limit the natural and functional roll-over process of the foot. For this reason, the muscles of the foot cannot work properly and degenerate. This, in turn, can lead to foot deformities like flat feet” (Mauch, personal communication, 12 August 2016).

On a personal level, the author of this thesis dreams of developing an affordable, foot-friendly school shoe for South African children and adolescents.

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ADDENDUM A: INFORMED CONSENT FORMS

- A. English informed consent for parents
- B. Afrikaans informed consent for parents
- C. Xhosa informed consent for parents
- D. English informed consent for older children
- E. Afrikaans informed consent for older children
- F. Xhosa informed consent for older children
- G. English participant information leaflet and assent form
- H. Afrikaans participant information leaflet and assent form
- I. Xhosa participant information leaflet and assent form

A. INFORMED CONSENT FOR PARENTS

Title of the study: Moving feet – a comparative study of school children who normally wear shoes and those who normally walk barefoot

I am Elbé de Villiers (a PhD student in Sport Science) of the Department of Sport Science at Stellenbosch University. I would like to invite your child to participate in my research study. The results of the study will form part of the thesis for my doctoral degree in Sport Science. Your child has been chosen as a possible participant in the study because he/she is in one of the participant schools and also is of the right age.

PURPOSE OF THE STUDY

The main purpose of this study is to determine the effect that shoes have on the developing foot. I will also determine whether shoes influence children's ability to move.

PROCEDURES

If you agree that your child may take part in this study, your child will have to undergo the following tests and measurements:

Anthropometric measurement: Your child's length and weight will be measured.

Complete a questionnaire on physical activity: This is done to determine how active your child is.

Jogging and running for 20 metres: While your child runs, he/she will be recorded on a video camera. The child will be asked to do this three times with and without shoes. The video is just to determine how your child lands with his feet while running.

Balance tests: Your child will be asked to walk backwards on three different sized bars. This will be done twice on each bar with and without shoes.

Jumps: Your child will be asked to jump as far as he/she can with both feet together. The distance will be measured. Your child will do this jump three times with and without shoes.

Next your child will be asked to jump sideways as many times as possible in 15 seconds. They will do it twice with and without shoes.

Foot shape: Your child will be asked to walk over a platform with a pressure plate embedded in it. They will also have to stand on a foot measuring platform, which then will determine the child's foot length and breadth as well as the height of his/her foot bridge while standing and seated.

Grip strength: Your child's grip strength will be determined by using a hand grip calliper.

POTENTIAL RISKS AND DISCOMFORT

Although some of the tests might be unknown to your child, they are simple tests. They should not make your child exceptionally tired or cause any discomfort.

POTENTIAL BENEFITS FOR STUDY PARTICIPANTS AND/OR SOCIETY

Your child will gain no direct benefit from the study.

The study does hold benefits for knowledge in the field of sport science, however, and specifically on the effect of shoes on children's feet and their ability to move. The results could possibly also provide shoe manufacturers with the necessary knowledge in the future to design shoes that are beneficial for the development of children's feet.

REMUNERATION FOR PARTICIPATION

Your child will not be paid for participation in this study.

CONFIDENTIALITY

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. Confidentiality will be maintained by storing the data on

a personal computer with a password. Only the researcher and the supervisor will be able to look at the data. The data will be dealt with anonymously at all times.

If the research should be published, the data will be discussed in general – in other words for the group as a whole.

PARTICIPATION AND WITHDRAWAL

You can decide whether or not your child may participate in this study. If you offer that your child may participate, you may still withdraw him/her from the study at any stage without this holding any negative consequences for your child. The researcher could also decide to remove your child from the study should circumstances require this.

DETAILS OF RESEARCHERS

If you have any questions on the research or if anything about it bothers you, you are welcome to contact us: Elbé de Villiers (cell phone 084 515 7642; e-mail edup@sun.ac.za) or Dr Ranel Venter (cell phone 083 309 2894; e-mail rev@sun.ac.za).

RIGHTS OF RESEARCH PARTICIPANTS

You may withdraw your consent at any stage and discontinue your child's participation, without any negative consequences. Your child will not waive any legal claims or rights by taking part in this research study. For any questions about your child's rights as a study participant, contact Ms Maléne Fouché at the Stellenbosch University Division for Research Development [mfouche@sun.ac.za; 021 808 4622].

SIGNATURE OF PARENT

I was given a copy of the letter with information.

I was given the opportunity to ask questions, and they were answered satisfactorily.

I consent that _____ may participate in this study. I have received a copy of this form.

Name of parent/guardian

Signature of parent/guardian

Date

B. AFRIKAANS INFORMED CONSENT FOR PARENTS

Titel van navorsingsprojek: Bewegende voete – ’n vergelykende studie van skoolkinders wat gewoonlik skoene dra teenoor dié wat gewoonlik kaalvoet loop

Ek is Elbé de Villiers (’n PhD-student in Sportwetenskap) van die Departement Sportwetenskap aan die Universiteit Stellenbosch. Ek nooi u kind om deel te neem aan my navorsingstudie. Die resultate van die studie sal deel uitmaak van die tesis vir my doktorsgraad in Sportwetenskap. U kind 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 hierdie studie is om te bepaal watter effek skoene op die ontwikkelende voet het. Ek sal ook vasstel of skoene kinders se bewegingsvermoë beïnvloed.

PROSEDURES

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

Antropometriese meting: U kind se lengte en gewig sal gemeet word.

Invul van ’n vraelys oor fisiese aktiwiteit: Dit word gedoen om te bepaal hoe aktief u kind is.

Invul van ’n vraelys oor kaalvoetgewoontes: Hiermee wil ons agterkom hoe gereeld u kind kaalvoet is.

Draf en hardloop oor 20 meter: Terwyl u kind draf en hardloop sal hy/sy met ’n videokamera afgeneem word. Die video word geneem om te kyk hoe u kind se voet neergesit word tydens die verskillende situasies. Die tyd wat dit u kind neem om die 20 meter te hardloop sal geneem word en hy/sy sal gevra word om dit twee keer te doen met en sonder skoene.

Balanstoetse: Die kind sal gevra word om agteruit te loop op drie verskillende plankies, elkeen met 'n ander breedte. Dit moet twee keer elk gedoen word met en sonder skoene.

Spronge: U kind sal gevra word om so ver as moontlik met albei voete tegelyk te spring. Die afstand sal gemeet word. U kind sal die sprong drie keer doen, met en sonder skoene.

Na die verspring sal u kind gevra word om so veel keer as moontlik in 15 sekondes sywaarts te spring. Dit sal twee keer herhaal word en die beste een sal gebruik word, met en sonder skoene.

Handgreep: Die krag van albei u kind se hande sal gemeet word met 'n handgreepkaliper.

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

Hoewel van die toetse dalk onbekend sal wees vir u kind, is dit eenvoudige toetse. Dit behoort nie u kind buitengewoon moeg te maak of ongemak te veroorsaak nie.

MOONTLIKE VOORDELE VIR STUDIEDEELNEMERS EN/OF DIE SAMELEWING

U kind sal geen direkte voordeel uit die studie trek nie. Die studie hou egter wel voordele in vir kennis op die gebied van sportwetenskap en veral oor die uitwerking van skoene op kinders se voete en bewegingsvermoë. Die resultate kan skoenvervaardigers ook moontlik in die toekoms die nodige kennis gee om skoene te ontwerp wat voordelig is vir die ontwikkeling van kinders se voete.

VERGOEDING VIR DEELNAME

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

VERTROUOLIKHEID

Enige inligting wat in verband met hierdie studie bekom word en u kind se identiteit verklap, sal vertroulik bly en slegs met u toestemming of ingevolge wetsvereistes bekend gemaak word. Vertroulikheid sal gehandhaaf word deur die data op 'n persoonlike rekenaar met 'n wagwoord te berg. Slegs die navorser en die studieleier sal na die data kan kyk. Die data sal te alle tye anoniem hanteer word. Indien die navorsing gepubliseer word, sal die data in die algemeen – met ander woorde 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 sonder dat dit enige gevolge vir u kind sal inhou. Die navorser kan ook besluit om u kind aan die studie te onttrek indien omstandighede dit vereis.

BESONDERHEDE VAN NAVORSERS

As u enige vrae oor die navorsing het of as enigiets daarvan u pla, kontak ons gerus: Elbé de Villiers (selfoon 084 515 7642; e-pos edup@sun.ac.za) of dr Ranel Venter (selfoon 083 309 2894; e-pos rev@sun.ac.za)

REGTE VAN NAVORSINGSDEELNEMERS

U kan in enige stadium u toestemming terugtrek en u kind se deelname staak, sonder enige nadelige gevolge. U kind doen nie afstand van enige wettige aansprake of regte deur aan hierdie navorsingstudie deel te neem nie. Vir enige vrae oor u kind se regte as studiedeelnemer, skakel met me Maléne Fouché in die Universiteit Stellenbosch se Afdeling Navorsingsontwikkeling [mfouche@sun.ac.za; 021 808 4622].

HANDTEKENING VAN OUER

Ek het geleentheid gekry om vrae te vra, en dit is bevredigend beantwoord.

Ek stem in dat _____ aan hierdie studie kan
deelneem. Ek het 'n afskrif van hierdie vorm ontvang.

Naam van ouer/voog

Handtekening van ouer/voog

Datum

C. XHOSA INFORMED CONSENT FOR PARENTS

lintshukumo zeenyawo – uphando lokuthelekisa abantwana abathanda ukunxiba izihlangu kunye nabo bathanda ukuhamba ngeenyawo

NdinguElbé de Villiers (umfundi owenza izifundo zobugqirha (PhD) kuBunzululwazi beMidlalo kwiSebe leNzululwazi zeMidlalo) kwiYunivesithi yaseStellenbosch. Ndingathanda ukuba umntwana wakho athathe inxaxheba kuphando endilwenzayo. Iziphumo zolu phando ziza kuba yinxalenye yethisisi yam yezifundo zobugqirha zeNzululwazi yeZemidlalo. Umntwana wakho ukhethwe ukuba abe ngomnye wabo baza kuthatha inxaxheba kolu phando kuba isikolo sakhe sithatha inxaxheba nangenxa yokuba enale minyaka yobudala ndiyifunayo.

INJONGO YOPHANDO

Injongo yolu phando kukujonga ifuthe izihlangu ezinalo kwiinyawo ezisakhulayo. Ndiza kujonga nokuba ingaba izihlangu zinefuthe na kwindlela umntwana ahamba ngayo.

IINKQUBO

Ukuba uyavuma ukuba umntwana wakho athathe inxaxheba kolu phando, umntwana wakho siya kuthi simvavanye ezi zinto zilandelayo senze nale milinganiselo ilandelayo:

Umlinganiselo wokuba ungakanani na: Siza kumeta ubude bakhe nobunzima bakhe.

Siza kuzalisa iphepha lemibuzo ngezinto azenzayo ngomzimba wakhe: Oku kwenzelwa ukuba kujongwe ukuba umntwana uwusebenzisa kangakanani na umzimba wakhe (uyadlala na).

Iphepha lemibuzo malunga nokungaxibi izihlangu: Oku kuza kwenzelwa ukuba kujongwe ukuba umntwana wakho uye angaxibi izihlangu kangaphi.

Ukuhamba, ukuncunkca (ukujoga) nokubaleka iimitha ezingama-20: Okokuqala umntwana wakho uza kuhamba, ze ankcunkce ze abaleke kakhulu imitha ezingama-20. Ngeli lixa enza oku uza kurekhodwa kwividiyokhamera. Uza kubaleka kakhulu kabini. Ividiyo ikholo nje ukujonga ukuba iinyawo uzibeka njani emhlabeni ngeli lixa ebaleka.

limvavanyo zokubhalansa: Umntwana wakho uza kucelwa ukuba eme ngomlenze omnye imizuzwana engama-30. Oku kuza kwenziwa kathathu. Emva koko uza kucelwa ukuba ahambe ebuya umva kumaplangwe ama-3, anobubanzi obahlukileyo. Oku kuza kwenziwa kathathu kwiplangwe ngalinye.

Ukutsiba: Umntwana wakho uza kucelwa ukuba atsibele kude kangangoko anako edibanise iinyawo. Kuya kumetwa umgama. Uza kucelwa ukuba utsibe kathathu. Baza kucelwa ukuba batsibele emacaleni kaninzi kangangoko benakho imizuzwana eli-15. Kuza kubalwa ukuba batsibe kangaphi yaye oko baza kukwenza kabini.

Uvavanyo lweentshukumo zomzimba: Olu vavanyo lwenziwa kwiimitha ezi-5 phakathi kweekhowuni ezimbini. Umntwana wakho uza kubaleka phakathi kweekhowuni, emana ebamba phantsi, amatyeli ali-10. Ixesha eliza kuthathwa ngumntwana wakho ukugqiba iigemu ezili-10 liza kubhalwa phantsi. Uza kuluphinda uvavanyo yaye kuya kusetyenziswa elona xesha alenze kakuhle.

Ukumila konyawo: Umntwana wakho uza kucelwa ukuba eme ngemilenze yomibini ephepheni elincinci, kuya kuthi kumetwe ubude benkwali eligophe yonyawo lwakhe, ubude bonyawo nobubanzi balo kusetyenziswa isixhobo sokumeta, icalliper, ngeli lixa emile naxa ehleli phantsi.

IMINGCIPHEKO NOKUNGAZIWA MNANDI OKUNOKUBA KHONA

Noxa ezinye zezi mvavanyo zisenokungaziwa ngumntwana wakho, zimvavanyo ezilula. Azisayi kwenza umntwana wakho ukuba adinwe kakhulu okanye azive engonwabanga.

IINZUZO EZINOKUBA KHONA KWABO BATHATHA INXAXHEBA KOLU PHANDO

Umntwana wakho akasayi kuzuza nto kolu phando. Olu phando lunenzuzo yokufumana ulwazi kwizifundo zemidlalo, nangakumbi kwindlela izihlangu ezinefuthe ngayo ezinyaweni zabantwana nendlela abahamba ngayo. Iziphumo zingancedisa nabavelisi bezihlangu ukuba bafumane ulwazi lokudizayina izihlangu eziya kunceda ekukhuleni kweenyawo zabantwana.

INTLAWULO YOKUTHATHA INXAXHEBA

Umntwana wakho akazi kuhlalulwa ngokuthatha inxaxheba kolu phando.

UBUMFIHLO

Naluphi ulwazi olufunyenwe kolu phando noluya kuveza ukuba ngubani na umntwana wakho, luya kugcinwa luyimfihlo yaye luya kuvezwa kuphela xa kufunyenwe imvume yakho okanye xa lufunwa ngabantu basemthethweni. Izinto ezithethiweyo ziya kugcinwa ziyimfihlo ngokuthi zigcinwe kwikhompyutha enegama eliyimfihlo ekufuneka ulifakile ukuze uyivule. Ngumphandi nomhloli wakhe kuphela abaya kuvumeleka ukuba babone ezi nkukacha. Ngawo onke amaxesha xa kusetyenziswa olu lwazi akuzi kubandakanywa magama abantu.

Ukuba olu phando luyapapashwa, kuza kuthethwa ngalo gabalala – ngamanye amagama kuza kuhlanguaniswa lonke ulwazi olufunyenwe kwiqela.

UKUTHATHA INXAXHEBA NOKURHOXA

Ungathatha isigqibo sokuba umntwana wakho athathe inxaxheba kolu phando. Ukuba uyavuma ukuba umntwana wakho athathe inxaxheba, usenokuphinda umrhoxise nanini kuphando yaye oku akusayi kumchaphazela kakubi umntwana wakho nangayiphi na indlela. Umphandi angathatha nesigqibo sokumkhupha kuphando umntwana wakho ukuba imeko itsho.

IINKCUKACHA ZABAPHANDI

Ukuba unemibuzo onayo ngophando okanye kukho into engakuhlelanga kamnandi, wamkelekile ukuba ungaqhagamshelana nathi: UEIbé de Villiers (kwiselula 084 515 7642; i-imeyili edup@sun.ac.za) okanye uGqr Ranel Venter (kwiselula 083 309 2894; i-imeyili rev@sun.ac.za)

AMALUNGELO ABATHATHI-NXAXHEBA KUPHANDO

Ungarhoxisa imvume yakho nanini na, ungamyekisa umntwana wakho ukuba athathe inxaxheba yaye oku akusayi kuba naziphumo zibi. Umntwana wakho akasayi kuphulukana namalungelo akhe ngokuthatha inxaxheba kolu phando. Ukuba unayo nayiphi na imibuzo emalunga namalungelo omntwana wakho njengomthathi-nxaxheba kolu phando, qhagamshelana noNksz Maléne Fouché kwiCandelo loPhuhliso loPhando leYunivesithi yaseStellenbosch [mfouche@sun.ac.za; 021 808 4622].

ISIGNITSHA YOMZALI / YOMNTU OJONGE UMNTWANA

Ndilini kwe ithuba lokuba ndibuze imibuzo yaye ndiye ndafumana iimpendulo ezanelisayo.

Ndiyavuma ukuba _____ angathatha inxaxheba kuphando. Ndiyifumene ikopi yale fomu.

Igama lomzali/lomntu ojonge umntwana

Isignitsha yomzali/yomntu ojonge umntwana

Umhla

D. INFORMED CONSENT FOR OLDER PARTICIPANTS

Title of the study: Moving feet – a comparative study of school children who normally wear shoes and those who normally walk barefoot

I am Elbé de Villiers (a PhD student in Sport Science) of the Department of Sport Science at Stellenbosch University. I would like to invite you to participate in my research study. The results of the study will form part of the thesis for my doctoral degree in Sport Science. You have been chosen as a possible participant in the study because you are in one of the participant schools and also are of the right age.

PURPOSE OF THE STUDY

The main purpose of this study is to determine the effect that shoes have on the developing foot. I will also determine whether shoes influence children's ability to move.

PROCEDURES

If you agree to take part in this study, you will have to undergo the following tests and measurements:

Anthropometric measurement: Your length and weight will be measured.

Complete a questionnaire on physical activity: This is done to determine how active you are.

Questionnaire on being barefoot: This will be done to determine how often you are barefoot.

Jogging and running for 20 metres: First you will jog and then sprint for 20 metres. While doing this, you will be recorded on a video camera. You will be asked to do the sprinting twice with and without shoes. The video is just to determine how you land with your feet while running.

Balance tests: You will be asked to walk backwards on three different sized bars. This will be done twice on each bar with and without shoes.

Jumping: You will be asked to jump as far as you can with both feet together. The distance will be measured. You will do this jump three times with and without shoes.

With the next jump, you will have to jump sideways as many times as possible in 15 seconds. The jumps will be counted and you will do it twice with and without shoes.

Foot shape: You will be asked to walk over a platform with a pressure plate embedded in it.

You would also have to stand with both legs on a foot measuring platform and your arch height, foot length and foot width will be measured by a calliper while you are standing and being seated.

Grip strength: Your grip strength will be determined by using a hand grip calliper.

POTENTIAL RISKS AND DISCOMFORT

Although some of the tests might be unknown to you, they are simple tests. They should not make you exceptionally tired or cause any discomfort.

POTENTIAL BENEFITS FOR STUDY PARTICIPANTS AND/OR SOCIETY

You will gain no direct benefit from the study.

The study does hold benefits for knowledge in the field of sport science, however, and specifically on the effect of shoes on children's feet and their ability to move. The results could possibly also provide shoe manufacturers with the necessary knowledge in the future to design shoes that are beneficial for the development of children's feet.

REMUNERATION FOR PARTICIPATION

You will not be paid for participation in this study.

CONFIDENTIALITY

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. Confidentiality will be maintained by storing the data on a personal

computer with a password. Only the researcher and the supervisor will be able to look at the data. The data will be dealt with anonymously at all times.

If the research should be published, the data will be discussed in general – in other words for the group as a whole.

PARTICIPATION AND WITHDRAWAL

You can decide whether or not you want to participate in this study. If you offer that you will participate, you may still withdraw from the study at any stage without this holding any negative consequences for you. The researcher could also decide to remove you from the study should circumstances require this.

DETAILS OF RESEARCHERS

If you have any questions on the research or if anything about it bothers you, you are welcome to contact us: Elbé de Villiers (cell phone 084 515 7642; e-mail edup@sun.ac.za) or Dr Ranel Venter (cell phone 083 309 2894; e-mail rev@sun.ac.za).

RIGHTS OF RESEARCH PARTICIPANTS

You may withdraw your consent at any stage and discontinue your participation, without any negative consequences. You will not waive any legal claims or rights by taking part in this research study. For any questions about your rights as a study participant, contact Ms Maléne Fouché at the Stellenbosch University Division for Research Development [mfouche@sun.ac.za; 021 808 4622].

SIGNATURE OF PARTICIPANT

I was given a copy of the letter with information.

I was given the opportunity to ask questions, and they were answered satisfactorily.

I consent that I, _____ will participate in this study.

I have received a copy of this form.

Name of participant

Signature of participant

Date

E. AFRIKAANS INFORMED CONSENT FOR OLDER PARTICIPANTS

Titel van die navorsingsprojek: Bewegende voete – 'n vergelykende studie van skoolkinders wat gewoonlik skoene dra teenoor dié wat gewoonlik kaalvoet loop

Ek is Elbé de Villiers (’n PhD-student in Sportwetenskap) van die Departement Sportwetenskap aan die Universiteit Stellenbosch. Ek nooi jou om deel te neem aan my navorsingstudie. Die resultate van die studie sal deel uitmaak van die tesis vir my doktorsgraad in Sportwetenskap. Jy is as ’n moontlike studiedeelnemer gekies omdat jy in een van die deelnemerskole is en ook die regte ouderdom is.

DOEL VAN DIE STUDIE

Die hoofdoel van hierdie studie is om te bepaal watter effek skoene op die ontwikkelende voet het. Ek sal ook vasstel of skoene kinders se bewegingsvermoë beïnvloed.

PROSEDURES

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

Antropometriese meting: Jou lengte en gewig sal gemeet word.

Invul van ’n vraelys oor fisiese aktiwiteit: Dít word gedoen om te bepaal hoe aktief jy is.

Invul van ’n vraelys oor kaalvoetgewoontes: Hiermee wil ons agterkom hoe gereeld jy kaalvoet is.

Draf en hardloop oor 20 meter: Terwyl jy draf en hardloop sal jy met ’n videokamera afgeneem word. Die video word geneem om te kyk hoe jy jou voet neersit tydens die verskillende situasies. Die tyd wat dit jou neem om die 20 meter te hardloop sal geneem word en jy sal gevra word om dit twee keer te doen, met en sonder skoene.

Balanstoetse: Jy sal gevra word om agteruit te loop op drie verskillende plankies, elkeen met 'n ander breedte. Dit moet ook twee keer elk gedoen word, met en sonder skoene.

Spronge: Jy sal so ver as moontlik met albei voete tegelyk probeer spring. Die afstand sal gemeet word. Jy sal die sprong drie keer doen, met en sonder skoene.

Na die verspring sal jy gevra word om so veel keer as moontlik in 15 sekondes sywaarts te spring. Dit sal twee keer herhaal word en die beste een van die twee sal gebruik word, met en sonder skoene.

Handgreep: Die krag van albei jou hande sal gemeet word met 'n handgreepkaliper.

Voetvorm: Jy sal gevra word om kaalvoet op 'n voetmetingsapparaat te staan terwyl jou voetlengte en -breedte sowel as die hoogte van jou voetbrug bepaal sal word.

MOONTLIKE RISIKO'S EN ONGEMAK

Hoewel van die toetse dalk onbekend sal wees vir jou, is dit eenvoudige toetse. Dit behoort jou nie buitengewoon moeg te maak of ongemak te veroorsaak nie.

MOONTLIKE VOORDELE VIR STUDIEDEELNEMERS EN/OF DIE SAMELEWING

Jy sal geen direkte voordeel uit die studie trek nie.

Die studie hou egter wel voordele in vir kennis op die gebied van sportwetenskap en veral oor die uitwerking van skoene op kinders se voete en bewegingsvermoë. Die resultate kan skoenvervaardigers ook moontlik in die toekoms die nodige kennis gee om skoene te ontwerp wat voordelig is vir die ontwikkeling van kinders se voete.

VERGOEDING VIR DEELNAME

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

VERTROULIKHEID

Enige inligting wat in verband met hierdie studie bekom word en jou identiteit kan verklap, sal vertroulik bly en slegs met jou toestemming of ingevolge wetsvereistes bekend gemaak word. Vertroulikheid sal gehandhaaf word deur die data op 'n

persoonlike rekenaar met 'n wagwoord te berg. Slegs die navorser en die studieleier sal na die data kan kyk. Die data sal te alle tye anoniem hanteer word.

Indien die navorsing gepubliseer word, sal die data in die algemeen – met ander woorde 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 aanbied dat jy kan deelneem, kan jy steeds in enige stadium onttrek sonder dat dit enige gevolge vir jou sal inhou. Die navorser kan ook besluit om jou aan die studie te onttrek indien omstandighede dit vereis.

BESONDERHEDE VAN NAVORSERS

As jy enige vrae oor die navorsing het of as enigiets daarvan jou pla, kontak ons gerus: Elbé de Villiers (selfoon 084 515 7642; e-pos edup@sun.ac.za) of dr Ranel Venter (selfoon 083 309 2894; e-pos rev@sun.ac.za)

REGTE VAN NAVORSINGSDEELNEMERS

Jy kan in enige stadium jou toestemming terugtrek en jou deelname staak, sonder enige nadelige gevolge. Jy doen nie afstand van enige wettige aansprake of regte deur aan hierdie navorsingstudie deel te neem nie. Vir enige vrae oor jou regte as studiedeelnemer, skakel met me Maléne Fouché in die Universiteit Stellenbosch se Afdeling Navorsingsontwikkeling [mfouche@sun.ac.za; 021 808 4622].

HANDTEKENING VAN DEELNEMER

Ek het geleentheid gekry om vrae te vra, en dit is bevredigend beantwoord.

Ek _____stem in om aan hierdie studie deel te neem.

Ek het 'n afskrif van hierdie vorm ontvang.

Naam van deelnemer

Handtekening van deelnemer

Datum

F. XHOSA INFORMED CONSENT FOR OLDER PARTICIPANTS

lintshukumo zeenyawo – uphando lokuthelekisa abantwana abathanda ukunxiba izihlangu kunye nabo bathanda ukuhamba ngeenyawo

NdinguElbé de Villiers (umfundi owenza izifundo zobugqirha (PhD) kuBunzululwazi beMidlalo kwiSebe leNzululwazi zeMidlalo) kwiYunivesithi yaseStellenbosch. Ndingathanda ukuba uthathe inxaxheba kuphando endilwenzayo. Iziphumo zolu phando ziza kuba yinxalenye yethisisi yam yezifundo zobugqirha zeNzululwazi yeZemidlalo. Ukhethwe ukuba ube ngomnye wabo baza kuthatha inxaxheba kolu phando kuba isikolo sakho sithatha inxaxheba nangenxa yokuba unale minyaka yobudala ndiyifunayo.

INJONGO YOPHANDO

Injongo yolu phando kukujonga ifuthe izihlangu ezinalo kwiinyawo ezisakhulayo. Ndiza kujonga nokuba ingaba izihlangu zinefuthe na kwindlela abantwana abahamba ngayo.

IINKQUBO

Ukuba uyavuma ukuba uthathe inxaxheba kolu phando, siya kuthi sikuvavanyele ezi zinto zilandelayo senze nale milinganiselo ilandelayo:

Umlinganiselo wokuba ungakanani na: Siza kumeta ubude bakho nobunzima bakho.

Siza kuzalisa iphepha lemibuzo ngezinto ozenzayo ngomzimba wakho: Oku kwenzelwa ukuba kujongwe ukuba uwusebenzisa kangakanani na umzimba wakho (uyadlala na).

Ukubaleka iimitha ezili-10: Ngeli lixa ubalekayo, uza kurekhodwa ngevidiyo. Uza kucelwa ukuba oku ukwenze kathathu.

Uvavanyo lwebhalansi: Uza kucelwa ukuba ume ngomlenze omnye kumgangatho ozinzileyo nongazinzanga (sponji) imizuzwana engama-20, kuqala uvule amehlo ze uphinde uwavale. Oku kuza kwenziwa kathathu. Emva koko uza kucelwa ukuba ume

ngemilenze yomibini, kumgangatho ozinzileyo nongazinzanga (sponji), kuqala uvule amehlo ze uphinde awavale, imizuzwana engama-20, noku kuza kwenziwa kathathu.

Ilongujampu: Uza kucelwa ukuba utsibe kangangoko unakho udibanise iinyawo zombini. Umgama owutsibileyo uza kumetwa. Oku uza kukwenza kathathu.

Uvavanyo lweentshukumo zomzimba: Ngeli lixa ukwenza oku kumgama weemitha ezili-15, uza kurekhodwa ngevidiyo. Kuya kuthathwa olo vavanyo lungcono kwiimvavanyo ezimbini.

Ubume bonyawo: Uza kucelwa ukuba ume ngomlenze omnye kwipleyiti, ze kujongwe ubude nobubanzi bonyawo lwakho nendlela unyawo olume ngayo.

IMINGCIPHEKO NOKUNGAZIVA MNANDI OKUNOKUBA KHONA

Noxa ezinye zezi mvavanyo usenokungazazi, zimvavanyo ezilula. Azisayi kwenza ukuba udinwe kakhulu okanye uzive engonwabanga.

IINZUZO EZINOKUBA KHONA KWABO BATHATHA INXAXHEBA KOLU PHANDO

Akusayi kuzuza nto kolu phando.

Olu phando lunenzuzo yokufumana ulwazi kwizifundo zemidlalo, nangakumbi kwindlela izihlangu ezinefuthe ngayo ezinyaweni zabantwana nendlela abahamba ngayo. Iziphumo zingancedisa nabavelisi bezihlangu ukuba bafumane ulwazi lokudizayina izihlangu eziya kunceda ekukhuleni kweenyawo zabantwana.

INTLAWULO YOKUTHATHA INXAXHEBA

Awuzi kuhlawulwa ngokuthatha inxaxheba kolu phando.

UBUMFIHLO

Naluphi ulwazi olufunyenwe kolu phando oluchaza ukuba ungubani na, luya kugcinwa luyimfihlo yaye luya kuvezwa kuphela xa kufunyenwe imvume yakho okanye xa lufunwa ngabantu basemthethweni. Izinto ezithethiweyo ziya kugcinwa ziyimfihlo ngokuthi zigcinwe kwikhompyutha enegama eliyimfihlo ekufuneka ulifakile ukuze uyivule. Ngumphandi nomhloli wakhe kuphela abaya kuvumeleka ukuba

babone ezi nkukacha. Ngawo onke amaxesha xa kusetyenziswa olu lwazi akuzi kubandakanywa magama abantu.

Ukuba olu phando luyapapashwa, kuza kuthethwa ngalo gabalala – ngamanye amagama kuza kuhlangukiswa lonke ulwazi olufunyenwe kwiqela.

UKUTHATHA INXAXHEBA NOKURHOXA

Ungathatha isigqibo sokuba uthathe inxaxheba kolu phando. Ukuba uyavuma ukuba uthathe inxaxheba, usenokuphinda urhoxe nanini kuphando yaye oku akusayi kukuchaphazela kakubi nangayiphi na indlela. Umphandi angathatha nesigqibo sokukukhupha kuphando ukuba imeko itsho.

IINKCUKACHA ZABAPHANDI

Ukuba unemibuzo onayo ngophando okanye kukho into engakuhlelanga kamnandi, wamkelekile ukuba ungaqhagamshelana nathi: UEIbé de Villiers (kwiselula 084 515 7642; i-imeyili edup@sun.ac.za) okanye uGqr Ranel Venter (kwiselula 083 309 2894; i-imeyili rev@sun.ac.za)

AMALUNGELO ABATHATHI-NXAXHEBA KUPHANDO

Ungarhoxisa imvume yakho nanini na, ungayeka u ukuthatha inxaxheba yaye oku akusayi kuba naziphumo zibi. Akusayi kuphulukana namalungelo akho ngokuthatha inxaxheba kolu phando. Ukuba unayo nayiphi na imibuzo emalunga namalungelo akho njengomthathi-nxaxheba kolu phando, qhagamshelana noNksz Maléne Fouché kwiCandelo loPhuhliso loPhando leYunivesithi yaseStellenbosch [mfouche@sun.ac.za; 021 808 4622].

ISIGNITSHA YOMZALI / YOMNTU OJONGE UMNTWANA

Ndilinike ithuba lokuba ndibuze imibuzo yaye ndiye ndafumana iimpendulo ezanelisayo.

Ndiyavuma ukuba mna _____ ndingathatha inxaxheba kuphando. Ndiyifumene ikopi yale fomu.

Igama lomzali/lomntu ojonge umntwana

Isignitsha yomzali/yomntu ojonge umntwana

Umhla

G.PARTICIPANT INFORMATION LEAFLET AND ASSENT FORM



TITLE OF THE RESEARCH PROJECT: Moving Feet – A Study where we compare school-aged children who normally walks barefoot to those who normally wear shoes.

RESEARCHER'S NAME: Elbé de Villiers

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 or 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 have on:

The way you walk

The shape of your feet

Your balance

The distance that you can jump

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

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

Who is doing the research?

My name is Elbé de Villiers. I am a Biokineticist working at Stellenbosch University. My job is to help people get better after they had an injury, where in an accident or where 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.

Then we will do a warm-up (light jogging and stretches) to get you ready for the other tests.

We will ask you to walk a few metres over a platform. We will take measurements of your foot while you are standing and sitting

The balance test is next. You will need to walk backwards on three different sized plank, 3 times.

You will be asked to jump forward as far as you can 3 times and jump sideways as many times as possible in 15 seconds. You will do this twice.

Next you will jog and run 20 metres while being recorded by a video camera. We want to see how you put your foot down while running. Only the running will be done twice and the time it takes you to complete this will be taken.

Lastly we will measure your hand grip strength.

Can anything bad happen to me?

Nothing bad can happen to you during the study. You will only run short distances and jump three times. 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 by Elbé.

Who can I talk to about the study?

If you have questions or want to speak to someone about the study you can contact: Elbé de Villiers (cell phone: 084 515 7642; email: edup@sun.ac.za) or Dr 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 just stop being part of it.

Do you understand this research study and are you 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 in the study at any time?

 YES NO

Signature of child

Date

H. AFRIKAANS PARTICIPANT INFORMATION LEAFLET AND ASSENT FORM



NAAM VAN DIE NAVORSINGSPROJEK: Bewegende voete – 'n studie waar ons skoolkinders wat gewoonlik skoene dra vergelyk met dié wat gewoonlik kaalvoet loop

NAVORSER(S) SE NAAM: Elbé de Villiers

ADRES: Departement Sportwetenskap, Universiteit Stellenbosch

KONTAKNOMMER: 021 808 4735 / 084 515 7642

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 navorsing wil ons kyk of die skoene wat jy dra, die volgende doen:

Die manier waarop jy loop verander

Die vorm van jou voet verander

Jou balans beter maak

Jou verder laat spring

Jou vinnig 'n kort entjie laat hardloop en omdraai

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 Elbé de Villiers en ek werk by die Universiteit Stellenbosch. 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 deelneem?

Ons gaan eers kyk hoe lank en hoe swaar jy is.

Daarna gaan ons jou laat opwarm deur liggies te draf en bietjie strekke te doen om jou reg te kry vir die toetse.

Jy gaan 20 meter moet hardloop terwyl jy met 'n videokamera afgeneem word en jou tyd geneem word.

Dan gaan jy 'n op 'n papier moet staan vir 'n paar sekondes, sodat ons jou voet kan meet.

Ons gaan ook jou balans toets. Jy sal tweekeer eenbeentjie moet staan vir 30 sekondes en daarna gaan jy agteruit moet loop op drie verskillende plankies. Dit gaan jy twee keer moet doen.

Volgende gaan ons kyk hoe ver jy met altwee bene gelyktydig kan spring.

Daarna gaan ons kyk hoeveel keer jy sywaarts kan spring in 15 sekondes. Dit moet ook twee keer gedoen word.

Laastens gaan jy moet hardloop van een merker na die ander wat 5 meter uitmekaar is, omdraai en terughardloop terwyl ons jou tyd neem om te kyk hoe vinnig jy dit kan doen.

Is daar enigiets wat kan verkeerd gaan?

Jy gaan kort ente hardloop en driekeer spring en jou spiere kan dalk vreemd voel, maar niks kan jou seermaak of niks kan verkeerd gaan nie. Ons sal ook 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 Elbé, sal weet hoe jy met die toetse gevaar het nie.

Met wie kan ek oor die projek gesels?

As jy enige vrae het oor die projek of as jy met iemand wil gesels kan jy vir Elbé de Villiers (selfoon: 084 515 7642; e-pos: edup@sun.ac.za) of Dr 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 ál jou vrae beantwoord?

JA

NEE

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

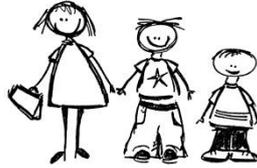
JA

NEE

Kind se handtekening

Datum

I. XHOSA PARTICIPANT INFORMATION LEAFLET AND ASSENT FORM



ISIHLOKO SEPROJEKTHI YOPHANDO: lintshukumo zeenyawo – uphando lokuthelekisa abantwana abathanda ukunxiba izihlangu kunye nabo bathanda ukuhamba ngeenyawo.

IGAMA LOMPHANDI: Elbé de Villiers

IDILESI: Isebe loBunzululwazi bezeMidlalo, kwiYunivesithi yaseStellenbosch

INOMBOLO YOQHAGAMSHELWANO: 021,808 (4735)21 938 4735

Luyintoni uPHANDO?

Uphando yinto esiyenzayo ukukhangela **ULWAZI OLUTSHA** malunga nendlela ezisebenza ngayo izinto (nabantu). Senza iiprojekthi zophando ukufumanisa ngakumbi ngabantwana abancinci kunye nabo sebekhulile kunye nezinto ezichaphazela ubomi babo, izikolo zabo, iintsapho zabo nempilo yabo. Sikwenza oku ukuze senze ihlabathi libe yindawo engcono!

Le projekthi yophando imalunga nantoni?

Ngexesha lokwenza le projekthi sifuna ukubona ukuba izihlangu zakho zemihla ngemihla ezi zinaliphi ifuthe ezinyaweni zakho:

Indlela ohamba ngayo

Ubume beenyawo zakho

Indlela obhalansa ngayo

Umgama onokuxhumela kuwo

Ixesha olithathayo ukubaleka umgama omfutshane nokujika uphinde ubuye umva

Bekutheni ukuze ndicelwe ukuba ndithathe inxaxheba kule projekthi yophando?

Ucelwe kuba ungumfundi kwesinye sezikolo esikhethelwe ukuba kwenziwe kuso uphando. Uphilile, awenzakalanga yaye ubudala bakho bobu sifunayo.

Lwenziwa ngubani olu phando?

Igama lam nguElbé de Villiers. Ndingumoluli womzimba osebenza kwiYunivesithi yaseStellenbosch. Umsebenzi wam kukunceda ukuba abantu babe ngcono emva kokufumana umenzakalo, naxa bebesengozini okanye xa bebegula kakhulu. Sibanceda ngokuthi sibenzise imithambo ethile.

Kuza kwenzeka ntoni kum kolu phando?

Kolu phando siza kwenza iimvavanyo ezimbalwa.

Okokuqala siza kumeta ubude bakho nobunzima bakho.

Emva koko siza kwenza imithambo yokuzilungiselela (ukubaleka kancinci nokolula umzimba) ukuze ulungele ezinye iimvavanyo.

Siza kukucela ukuba uhambe iimitha ezimbalwa ngeli lixa sirekhoda yonke into ngevidiyo. Siza kuthatha imilinganiselo yonyawo lwakho ngeli lixa umile naxa uhleli phantsi. Sakulandela ngokwenza uvavanyo lokubhalansa. Kuza kufuneka ume ngomlenze omnye imizuzwana engama-30. Emva koko kuza kufuneka uzame ukuhamba ubuya umva kumaplangwe amathathu anemilinganiselo eyahlukileyo, ukwenze oku ka-3.

Uza kucelwa ukuba utsibe uye phambili, utsibele kude kangangoko unakho ka-3 ze uphinde utsibele emacaleni kaninzi kangangoko unakho ngemizuzwana eli-15. Oku uza kwenza kabini.

Okulandelayo uza kuhamba, unkcunkce ze ubaleke iimitha ezingama-20 ngeli lixa urekhodwa ngevidiyo. Sifuna ukubona ukuba ulubeka njani unyawo phantsi ngeli lixa

ubaleka. Kukubaleka qha okuya kwenziwa kabini ukanti liya kuthi libhalwe phantsi ixesha olithathileyo ukugqiba oku.

Okokugqibela siya kurekhoda ixesha lakho ngeli lixa ubaleka iimitha ezi-5, ujike uphinde ubaleke amatyeli ali-10.

Ikhona into embi enokundehlela?

Akhonto imbi enokwehlela kolu phando. Uza kubaleka imigama emifutshane ze uxhume kathathu. Into nje enokwehlela kukuba izihlunu zakho zisenokudinwa. Siza kubonisa yonke into ekufuneka uyenze.

Ukhona umntu oza kwazi ukuba ndikolu phononongo?

Liqela elisebenza kule projekthi kuphela eliza kukwazi ukuba uyinxalenye yolu phando. Iziphumo zakho ngqo ziya kwaziwa nguElbé kuphela.

Ndingathetha nabani malunga nolu phononongo?

Ukuba unemibuzo okanye ufuna ukuthetha nomntu malunga nolu phando, ungaqhagamshelana: noElbé de Villiers (kwiselula 084 515 7642; i-imeyili edup@sun.ac.za) okanye noGqr Ranel Venter (kwiselula 083 309 2894; i-imeyili rev@sun.ac.za).

Kuza kwenzeka ntoni xa ndingafuni ukuyenza le nto?

Akukho mntu unokukunyanzela ukuba ube yinxalenye yolu phando Ukuba akufuni kukwenza oku, akunyanzelekanga ukuba ukwenze. Nokuba abazali bakho bakuvumele baze basayina ifomu, awunyanzelekanga ukuba ukwenze oku.

Ukuba uthe ufuna ukuba yinxalenye yophando, ze kamva ugqibe kwelokuba awusafuni, akukho iza kwenzeka kuwe, ungavele nje uyeke ukuba yinxalenye yalo.

Uyaluqonda olu phononongo lophando yaye uzimisele ukuthatha inxaxheba kulo?

EWE

HAYI

Ngaba umphandi uyiphendule yonke imibuzo yakho?

EWE

HAYI

Uyaqonda ukuba ungarhoxa kolu phononongo nanini na?

EWE

HAYI

Utyikityo lomntwana

Umhla

ADDENDUM B: ETHICAL CLEARANCE FROM STELLENBOSCH UNIVERSITY

Approval Notice

Stipulated documents/requirements

18-Feb-2015

De Villiers, Johanna JE

Proposal #: HS1153/2014

Title: Moving Feet – A Comparative Study between Habitually Barefoot And Shod School-Aged Children.

Dear Ms. Johanna De Villiers,

Your Stipulated documents/requirements received on 18-Feb-2015, was reviewed by members of the Research Ethics Committee: Human Research (Humanities) via Expedited review procedures on 17-Feb-2015 and was approved. Sincerely,

Clarissa Graham

REC Coordinator

Research Ethics Committee: Human Research (Humanities)

ADDENDUM C: LETTER OF APPROVAL FROM THE WESTERN CAPE DEPARTMENT OF EDUCATION 2015

Audrey.wyngaard@westerncape.gov.za

tel: +27 021 467 9272

Fax: 0865902282

Private Bag x9114, Cape Town, 8000

wced.wcape.gov.za

REFERENCE: **20141023-38716**

ENQUIRIES: Dr A T Wyngaard

Mrs Johanna De Villiers

PO Box 1551

Stellenbosch

7599

Dear Mrs Johanna De Villiers

RESEARCH PROPOSAL: MOVING FEET – A COMPARATIVE STUDY BETWEEN
HABITUALLY BAREFOOT AND SHOD SCHOOL-AGED CHILDREN

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

- Principals, educators and learners are under no obligation to assist you in your investigation.

- Principals, educators, learners and schools should not be identifiable in any way from the results of the investigation.
- You make all the arrangements concerning your investigation.
- Educators' programmes are not to be interrupted.
- The Study is to be conducted from **02 February 2015 till 30 September 2015**
- No research can be conducted during the fourth term as schools are preparing and finalizing syllabi for examinations (October to December).
- 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?
- A photocopy of this letter is submitted to the principal where the intended research is to be conducted.
- Your research will be limited to the list of schools as forwarded to the Western Cape Education Department.
- A brief summary of the content, findings and recommendations is provided to the Director: Research Services.
- 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: **24 October 2014**

ADDENDUM D: LETTER OF APPROVAL FROM THE WESTERN CAPE DEPARTMENT OF EDUCATION 2016

Audrey.wyngaard@westerncape.gov.za

tel: +27 021 467 9272

Fax: 0865902282

Private Bag x9114, Cape Town, 8000

wced.wcape.gov.za

REFERENCE: **20160128-7123**

ENQUIRIES: Dr A T Wyngaard

Mrs Johanna De Villiers

PO Box 1551

Stellenbosch

7599

Dear Mrs Johanna De Villiers

RESEARCH PROPOSAL: MOVING FEET – A COMPARATIVE STUDY BETWEEN
HABITUALLY BAREFOOT AND SHOD SCHOOL-AGED CHILDREN

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

- Principals, educators and learners are under no obligation to assist you in your investigation.

- Principals, educators, learners and schools should not be identifiable in any way from the results of the investigation.
- You make all the arrangements concerning your investigation.
- Educators' programmes are not to be interrupted.
- The Study is to be conducted from **01 February 2016 till 24 June 2016**
- No research can be conducted during the fourth term as schools are preparing and finalizing syllabi for examinations (October to December).
- 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?
- A photocopy of this letter is submitted to the principal where the intended research is to be conducted.
- Your research will be limited to the list of schools as forwarded to the Western Cape Education Department.
- A brief summary of the content, findings and recommendations is provided to the Director: Research Services.
- 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: **28 January 2016**

ADDENDUM E: BMI FOR 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: EXTRACT OF SCHOOL RULES

An extract of the “Example of a Code of Conduct for a School” as presented by the South African Department of Education:

School Uniform and General Appearance:

Learners are expected to wear the official School uniform and appear neat and tidy at all times.

1. No additions to the uniform that are not in accordance with the regulations will be allowed (e.g. beanies).
2. No earrings, jewellery, accessories, coloured contact lenses or visible tattoos are allowed.
3. Only learners that have applied, submitted relevant supporting documents and received the necessary permission from the School Governing Body, may deviate from official School uniform for religious and cultural reasons as contemplated in Part 1 paragraph I of this Code of Conduct

<http://www.education.gov.za/Portals/0/Example%20of%20a%20Code%20of%20Conduct%20for%20a%20school.pdf?ver=2009-10-13-121912-523> (Department of Education, 2008)

An extract of the Uniform rules of two High schools

XXXXX High School Uniform

Boys – Summer and winter

Brown chino's with embroidered badge and brown anklet socks, or shorts with embroidered badge and long brown socks

Official dark brown shoes (not suede)

Girls – Summer and winter

White socks (summer)

Official dark brown socks can be worn in addition to the stockings (optional, from school shop) (winter)

Dark brown shoes with laces or with bar

(School-laws, 2016a)

XXXXX High School Uniform

Boys

Only black, school-type shoes are allowed, and they are to be kept polished.

Girls

Only black regulation school shoes of the lace-up or bar type are allowed and they are to be kept polished.

(School-laws, 2016b)

Xxxxx Primary School

Uniform: All learners must wear the prescribed uniform at all times. This applies, not only, to uniform worn from day to day, but also to uniform worn during extramural activities. Learners found wearing partial or incorrect uniform, whether at school or not, will be subject to disciplinary action. Failure to adhere to the school's dress code will result in the item of clothing, footwear or jewellery being confiscated. A fine of R300.00 will be paid for the release of the item.

Only plain black lace-up or T-bar shoes may be worn. Boots, suede-type shoes and track shoes are unacceptable. Shoes must be in good repair and polished.

(School-laws, 2016c)

Xxxx Primary School

School Uniform - Summer

Boys

Blue open-necked, short-sleeved shirt

Grey shorts

Grey school socks

Dark brown lace-up shoes

Girls

Blue open-necked, short-sleeved shirt

School gym

Short white socks

Black school shoes

(School-laws, 2016d)

ADDENDUM G: PERMISSION LETTER TO USE FIGURES AND TABLES

ELSEVIER LICENSE

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Jan 28, 2017

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Expected completion date	Feb 2017
Estimated size (number of pages)	190

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Elbe de Villiers
Stellenbosch Biokinetics Centre
Department of Sport Science
Coetzenburg
Stellenbosch, Western Cape 7600
South Africa
Elbe de Villiers
0.00 EUR

Attn:
Total

From: Hylton Menz [<mailto:H.Menz@latrobe.edu.au>]
Sent: 25 January 2017 03:09 AM
To: De Villiers, JE, Me edup@sun.ac.za
Subject: RE: Permission to use pictures from your publications

Dear Elbe,

Yes, please feel free to reproduce these images.

Good luck with your thesis!

Kind regards,

Hylton

Professor Hylton B. Menz, PhD, DSc
NHMRC Senior Research Fellow
La Trobe Sport and Exercise Medicine Research Centre
School of Allied Health
College of Science, Health and Engineering
La Trobe University
Bundoora, Victoria, 3086, Australia
Office location: Level 2, Room 215, Health Sciences 3
T: +61 3 9479 5801, F: +61 3 9479 5415
www.latrobe.edu.au/health/about/staff/profile?uname=HMenz
ResearcherID: www.researcherid.com/rid/B-4508-2013
ORCID: <http://orcid.org/0000-0002-2045-3846>
Editor-in-Chief, Journal of Foot and Ankle Research, www.jfootankleres.com

From: De Villiers, JE, Me <edup@sun.ac.za> [<mailto:edup@sun.ac.za>]
Sent: Friday, 20 January 2017 7:16 PM
To: Hylton Menz <H.Menz@latrobe.edu.au>
Subject: Permission to use pictures from your publications

Good morning Prof. Menz,

I hereby ask permission to use the following picture from the publication: "A protocol for classifying normal- and flat-arched foot posture for research studies using clinical and radiographic measurements", in my doctoral dissertation: Arch Index

As well as:

Calcaneal inclination and calcaneal first metatarsal angle from: "Plantar calcaneal spurs in older people: longitudinal traction or vertical compression?"

The necessary acknowledgements and referencing will be used.

Kind regards

Elbé de Villiers

ELSEVIER ORDER DETAILS

Feb 20, 2017

Order Number:	501237707
Order date:	Feb 20, 2017
Licensed Content Publisher:	Elsevier
Licensed Content Publication:	Elsevier Books
Licensed Content Title:	Handbook of Footwear Design and Manufacture
Licensed Content Author:	B. Fritz,M. Mauch
Licensed Content Date:	2013
Licensed Content Volume Number:	n/a
Licensed Content Issue Number:	n/a
Licensed Content Pages:	23
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Original figure numbers:	Figure 3.8,
Title of your thesis/dissertation:	Growing feet – foot metrics and shoe fit in South African school-aged children and adolescents
Expected completion date:	Feb 2017
Estimated size (number of pages):	190
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- **Elbe de Villiers**

Jan 20, 2017

Good morning Dr.,

I hereby ask permission to use the following graph from the publication: "Handbook of Footwear Design and Materials", in my doctoral dissertation:
Profiles of the five foot types

The necessary acknowledgements and referencing will be used.

Kind regards
Elbé de Villiers

-

Bettina Barisch-Fritz to you

Jan 25, 2017

with pleasure.
Bettina

Dear Elbe de Villiers

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Dear Mrs de Villiers,

Thank you for your request.

The details are summarized below:

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Type of Publication: Book

Book Title: Kinesiology of the Musculoskeletal system
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ADDENDUM H: DIFFERENT SHOE SIZES

M/W indicates Men's or Women's Sizes. Other systems are for either gender.

System	Sizes																System		
Europe	35	35½	36	37	37½	38	38½	39	40	41	42	43	44	45	46½	48½	Europe		
Mexico						4.5	5	5.5	6	6.5	7	7.5	9	10	11	12.5	Mexico		
Japan	M	21.5	22	22.5	23	23.5	24	24.5	25	25.5	26	26.5	27.5	28.5	29.5	30.5	31.5	Japan	M
	W	21	21.5	22	22.5	23	23.5	24	24.5	25	25.5	26	27	28	29	30	31	Japan	W
U.K.	M	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	10	11	12	13½	U.K.	M
	W	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8	9½	10½	11½	13	U.K.	W
Australia	M	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	10	11	12	13½	Australia	M
	W	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	10½	11½	12½	14	Australia	W
U.S. & Canada	M	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	10½	11½	12½	14	U.S. & Canada	M
	W	5	5½	6	6½	7	7½	8	8½	9	9½	10	10.5	12	13	14	15.5	U.S. & Canada	W
Russia & Ukraine *	W	33½	34		35		36		37		38		39				Russia & Ukraine	W	
Korea (mm.)		228	231	235	238	241	245	248	251	254	257	260	267	273	279	286	292	Korea	
Inches		9	9⅛	9¼	9⅜	9½	9⅝	9¾	9⅞	10	10⅛	10¼	10½	10¾	11	11¼	11½	Inches	
Centimeters		22.8	23.1	23.5	23.8	24.1	24.5	24.8	25.1	25.4	25.7	26	26.7	27.3	27.9	28.6	29.2	Centimeters	
Mondopoint		228	231	235	238	241	245	248	251	254	257	260	267	273	279	286	292	Mondopoint	