Lower limb development and gait kinematics of back-carried Setswana children

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DECLARATION

This study is made possible through the collective work of a group of researchers and academia. Contributions by academia were kept within reasonable limits, to allow the candidate to submit the thesis for examination purposes. This thesis serves as the fulfilment of the requirements for the degree Doctor of Philosophy, Human Movement Science, within the Research Focus Area, Physical Activity, Sport and Recreation (PhASRec), in the Faculty of Health Sciences at the North-West University (NWU), Potchefstroom.

The contribution of each of the researchers is depicted in the table below and includes a statement from the co-authors confirming their individual roles in this study, providing their permission that the articles may be included within the thesis.

Responsible person	**Role in the study**
Mrs. M van Aswegen MSc (Med) in Biokinetics Ph.D. student	Responsible for the execution of the total study, data collection, management, and the complete thesis. The main author of the thesis, including articles one to four. Responsible for ethical application. Statistical analysis of article one.
Prof SH Czyz Ph.D. (Physical culture sciences) Promoter	Project coordinator and co-author of all articles. Significant contribution towards the writing of the thesis. A critical reviewer of the content. Significant assistance and responsible person for submission and ammendments of ethics documents to HREC. Statistical analysis of article four.
Prof SJ Moss Ph.D. (Biokinetics) Co-Promoter	Co-author of all articles. Significant contribution towards the technical editing of the thesis and critical reviewer of the content.
Prof F Steffens Ph.D. (Statistics) Statistical consultant	Statistical analysis for articles two and three. Co-author of articles two and three.

The first two articles of this thesis were presented at two separate international conferences. Article two, entitled; *Back-carrying in black Setswana-speaking children related to lower limb development*, was presented at the 30th FIEP World Congress (Sport, Physical Education, and Performing Arts as tools of social transformation), held in Barcelona, Spain, 27-29 June 2019. I was selected as a Future New Leader at the FIEP congress, communication in this regard is included in APPENDIX J. The abstract for the oral presentation is available in APPENDIX K and the oral presentation certificate is available in APPENDIX L.

Article one, entitled; *The profile and development of the lower limb in black Setswana-speaking children between the ages of two- to nine years*, was presented at the European College of Sport Science (ECSS). Congress held in Prague, 3-6 July 2019. The abstract submitted for this conference was chosen as a Young Investigator Award (YIA) Finalist and received the YIA travel grant award (500 EUR). The correspondence for these awards is included in APPENDIX J.

The last article, article four, entitled; *Kinematic gait comparisons of the tibiofemoral joint between back-carried and non-back-carried black Setswana-speaking children*, was presented on 7-9 November 2019, at the 12th International Conference on Kinanthropology, at the Masaryk University, Brno, the Czech Republic. Prof SH Czyz presented the article and the abstract for the oral presentation is available in APPENDIX K.

I declare that I have approved the above-mentioned articles and that my role in the study as indicated is representative of my actual contribution and that I hereby provide my consent that it may be published as part of the Ph.D. thesis of M van Aswegen.

Prof SH Czyz	Prof SJ Moss	Prof F Steffens

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ABSTRACT

Back-carrying (BC) of children is a common phenomenon among African mothers. Children are often back-carried (BC) by their mothers for long durations, well into their toddler years. Positive relationships between BC and hip development, particularly in the prevention of developmental hip dysplasia have been shown, but it is unknown how knee and lower limb (LL) development will be impacted. This study aimed to determine what possible relationships exist between static- and kinematic LL development in BC children, compared to their non-back-carried (non-BC) counterparts.

Five objectives, of a cross-sectional design, were developed to address the aim. Firstly, LL development, in terms of the tibiofemoral angle (TFA), quadriceps-angle (Q-angle), hip anteversion angle (AVA) and the tibial torsion angle (TTA) of two- to nine-year-old Setswana-speaking children, were profiled. Goniometry was applied to determine LL angles. The second objective was to determine the relationships between BC and LL development in the frontal plane (objective two) and the transverse plane (objective three). A questionnaire was developed to determine whether children were BC, swaddled and/or pushed in a pram or stroller and the frequencies and durations they were BC or the alternative methods of carrying. A *Classification and Regression Tree* (CART) analysis was applied, grouping the participants according to their LL development and BC information, age and sex. The fourth objective aimed to determine the predictor factors for LL deviation in BC children. Predictor factors were obtained by applying the data from the first three objectives, in an *Automatic Linear Modelling* (ALM) analysis. The last objective aimed to determine what possible kinematic differences exist, specifically at the tibiofemoral joint (TFJ), between BC and non-BC children. Bayesian analysis of TFJ angles, observed in all three cardinal planes at heel-strike, mid-stance and toe-off was applied.

General LL development progressions are similar in comparison to children of other ethnicities (Americans, Europeans, Asians and Nigerians), in terms of increases and decreases in angles with age. The TFA and Q-angles compares closest with those found in American- and Indian children respectively. Hip AVAs are far greater and greater internal TTAs are observed in Setswana-children, than in European children. The CART reveals children BC more frequently present with greater genu valgum, greater TTA and smaller AVA, than less frequently BC or non-BC children. Overall 11 significant predictors of LL alignment exist of which age is consistently the greatest predictor. For the TFA, longer swaddling durations and earlier independent walking age contributes to greater valgus TFAs. In the transverse plane, increased BC durations predicts lower AVAs. Due to the aforementioned relationships between static LL measures and BC, we expected dynamic, kinematic differences. Bayesian comparison of angles of the TFJ during kinematic gait of BC with non-BC children, do not render any conclusive results.

Based on all the results, BC of children do not seem to impact the development of the LL in a detrimental manner. Previously, other researchers hypothesised that BC prevents developmental hip dysplasia, thus we recommend mothers or primary caregivers to continue back-carry (BC) their young, but in moderate frequencies and durations, based on our LL development findings. Moderation is recommended based on the detrimental impact of long duration BC on cognitive function, as found by other researchers previously.

Keywords: Back-carrying, swaddling, lower limb development, tibiofemoral joint, genu valgum, tibial torsion

OPSOMMING

Rug-dra (Pépa) van kinders is ’n algemene verskynsel in moeders in Afrika. Kinders word gereeld tot diep in hul peuterjare deur hul moeders op die rug gedra. Positiewe verhoudings tussen pépa en heupontwikkeling, spesifiek in die voorkoming van heupdisplasie, is voorheen bevestig, maar dit is onbekend hoe knie- en beenontwikkeling (BO) beinvloed kan word. Hierdie studie het gepoog om te bepaal of verhoudings tussen statiese- en dinamiese BO in pépa kinders bestaan in vergelyking met hul nie-pépa eweknieë.

Vyf doelstellings, van ’n deursnit studieontwerp, is ontwikkel om die doelwit te ondersoek. Eerstens is profiele van BO, in terme van die tibiofemoralehoek (TFH), kwadriseps-hoek (K-hoek), heupanteversiehoek (HAH) en die tibiale torsiehoek (TTH) van twee- tot negejarige Setswana-sprekende kinders, saamgestel. Metings van die onderste ledemate is met behulp van goniometrie verkry. Die tweede doelwit was om te bepaal of verhoudings tussen pépa en BO in die frontalevlak (doelwit twee) en in die transversalevlak (doelwit drie), bestaan. ’n Vraelys is ontwikkel om pépa, “swaddling” en stootwaentjie gebruik, asook die frekwensies en duur van die gebruike, van die deelnemers te bepaal. ’n *Klassifikasie En Regressie Boom* (KERB) analise is toegepas, wat deelnemers volgens hul BO, pépa informasie, ouderdom en geslag gegroepeer het. Die vierde doelwit het gepoog om voorspellerfaktore vir BO afwyking in pépa kinders te bepaal. Die data wat vir die eerste drie doelwitte verkry is, is analiseer deur middel van ’n *Outomatiese Lineêre Model* (OLM) analise. Die laaste doelwit het gepoog om te bepaal of kinematiese verskille bestaan, spesifiek in die tibiofemoralegewrig (TFG), tussen pépa kinders en hul nie-pépa eweknieë. ’n Bayes analise van die TFG hoeke, waargeneem in al drie kardinalevlakke tydens hak-landing, mid-staanfase en aftree-fase is toegepas.

Algemene BO volg soortgelyke progessies as in kinders van ander etniese herkoms (Amerikaners, Europese, Asiate en Nigeriërs), in terme van vergroting of vermindering in hoeke met ouderdom. Die TFH en K-hoek vergelyk respektief goed met die bevindings vir Amerikaanse- en Indiese kinders. Die HAH en (interne) TTH is albei egter hoër in Setswana-sprekende kinders as in Europese kinders. Die KERB wys dat kinders wat meer gereeld ge-pépa was, groter genu valgum-, groter TTH en kleiner HAHe, in vergelyking met kinders wat minder gereeld ge-pépa was, toon. Elf betekenisvolle voorspellers van BO is gevind, waarvan ouderdom deurlopend die grootste voorspellende faktor is. Vir die TFH, voorspel langer durasie “swaddling” en ’n jonger onafhanklike loopmylpaal groter valgus TFHe. In die transversalevlak voorspel langer duur pépa laer HAHs. Weens die bogenoemde verhoudingsbevindinge tussen statiese BO en pépa, het ons kinematiese verskille verwag. Die Bayes vergelyking van hoeke van die TFG tydens kinematiese stapanalise van pépa kinders met nie-pépa kinders, het egter nie enige bevestigde bevindings getoon nie.

Gebaseer op al die resultate, blyk dit nie of pépa van kinders BO nadelig beinvloed nie. Vorige navorsing hipotetiseer dat pépa heup displasie voorkom, daarom moedig ons moeders aan om voort te gaan om hul kinders te pépa, maar in moderasie, gebaseer op ons BO bevindinge. Moderasie word aanbeveel weens die negatiewe inpak van langdurige pépa op kognitiewe funksie, wat voorheen deur ander navorsers gevind is.

Sleutelwoorde: Rug-dra, pépa, “swaddling”, onderste ledemaat ontwikkeling, tibiofemoralegewrig, genu valgum, tibiale torsie

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LIST OF ABBREVIATIONS AND SYMBOLS

ABD	Abduction (table 2-11 in Chapter 2)
ACL	Anterior cruciate ligament
ADD	Adduction (table 2-11 in Chapter 2)
ANOVA	Analysis of variance
AP axis	Anterior-posterior axis
ASIS	Anterior superior iliac spine
AV	Anteversion
AVA	Anteversion angle of the hip
BC	Back-carried, back-carry, back-carrying
BC-LS	Back-carried with the legs spread around the mother's waist
BMI	Body Mass Index
CART analysis	Classification and Regression Tree analysis
CAST protocol	Calibrated Anatomical Systems Technique protocol
cm	Centimetre
dorsiflx	Dorsiflexion (table 2-10 in Chapter 2)
DDH	Developmental dysplasia of the hip
DOF	Degrees-of-freedom
DUDU wrap	Down-Up-Down-Up wrap technique (used in swaddling)
EMG	Electromyography
ER	External rotation
flx	Flexion (table 2-10 in Chapter 2)
FP	Frontal plane
HREC	Health research ethics committee
H-S	Heel-strike
Hz	Hertz
ICC	Interclass coefficient
ICD	Intercondylar distance
IMD	Intermalleolar distance
IR	Internal Rotation
kg	Kilogram
LL	Lower limb
m	meter
MAA	Mechanical axis angle

ML axis	Medial-lateral axis
mLDFA	Mechanical lateral distal femoral angle
mm	millimetre
MRI	Magnetic resonance imaging
M-S	Mid-stance
N-m/kg	Newton-meter per kilogram
non-BC	Non-back-carried
NWU	North-West University
PAF	Project automation framework package (of Qualisys motion capture systems)
PVF	Planovalgus foot
PPVF	Pediatric planovalgus foot
plt flx	Plantar flexion (Table 2-10 in Chapter 2)
Q-angle	Quadriceps-angle
QTM	Qualisys track manager
RD	*Rug-dra (Afrikaans)*
ROM	Range of motion
RV	Retroversion
SD	Standard Deviation
SCFE	Slipped capital femoral epiphysis
SEGO test	"*Skoolgereedheidsevaluering deur Gekwalifiseerde Onderwyseresse*" / (School readiness Evaluation by Qualified Teachers)
SIDS	Sudden infant death syndrome
TFA	Tibiofemoral angle
T-O	Toe-off
TP	Transverse plane
TT	Tibial torsion
TTA	Tibial torsion angle
USA	United States of America
yr	year(s) (used in tables)
3D	Three-dimensional

SYMBOLS:

β	Beta
°	Degree
H_0	Null-hypothesis

H_1	Alternative-hypothesis
η^2	Partial eta-squared
%	Percentage
R^2	R squared

CHAPTER 1 : INTRODUCTION

1.1. INTRODUCTION

In South Africa, mothers in rural communities prefer to back-carry (BC) their infants or toddlers. Setswana speaking mothers regularly BC, or “pépa”, their children as this is the cultural method of keeping their children safe (Pretorius & Naudé, 2002:586; Pretorius *et al.*, 2002:175; Graham *et al.*, 2015:59). The infant or toddler is carried in a semi-seated position with the legs wrapped around the mother’s waist and secured with a blanket or towel or a traditional “thari” sling. The back-carrying (BC) position restricts limb movements and the vision of the child (Pretorius *et al.*, 2002:175). Regardless, the tradition of BC is socially valued and accepted among the African society, other than in the Western society (Golding, 1994:181; Pretorius *et al.*, 2002:175; Stroebel *et al.*, 2009:306). Children are often back-carried (BC) for extensive periods (up to six- to eight hours per day) to keep the child safe while the mother works or travels on foot (Pretorius & Naudé, 2002:586; Pretorius *et al.*, 2002:175). This chapter aims to state the problem for children being BC, by presenting background information with regards to the developmental effects of BC. The various benefits and detriments of BC, posed to both the mother and the child, will be outlined, from which future research will be identified by highlighting the objectives derived for this study.

Based on the objectives, the various orthopaedic tests that can be used to measure lower limb (LL) alignment will be discussed and reference will be made to LL malalignments such as genu varum (bow legs) and –valgum (knock knees). The various orthopaedic measures will be briefly discussed in this chapter, to indicate their relevance in answering the proposed research questions and showing why it is important to consider the entire lower kinetic chain,instead of focusing on a specific single joint. The orthopaedic measures of the LL, are solely performed in static positions and whilst the entire kinetic chain is included, this investigation would not be complete without kinematic analysis. The motor development skills linked to walking gait and kinematic gait patterns observed in children will be outlined. The objectives and their hypotheses are presented and a conceptual framework is used to abridge the research question, before providing the outline of the structure of the thesis.

1.2. PROBLEM STATEMENT

Most mothers will BC their child for the benefit of safe-keeping of the child, and freeing the mother’s arms to allow her to perform work. The relationships between BC children and their school readiness (Pretorius & Naudé, 2002:586), along with the impact of BC on visual integration pathways (Pretorius *et al.*, 2002:175), have been studied. The two studies mention potential benefits and potential detriments to child development in BC children. BC children are disadvantaged in terms of school readiness (Pretorius & Naudé, 2002:592), and exhibited deficits in physical and motor development and fine motor skills (Pretorius & Naudé, 2002:592). BC children, however, demonstrate strong emotional and social bonds with their mother (Pretorius & Naudé, 2002:593).

The highly significant benefit of BC, namely the possible prevention of developmental dysplasia of the hip (DDH) in BC children, is reasoned to be attributed to the resemblance between the BC position and the Pavlik harness or spica cast used to treat DDH (Griffiths, 1970:91; van Meerdervoort, 1974:2436-2437; Roper, 1976:157). Graham *et al.* (2015:60) conclude that the BC of infants with their legs in a flexed and abducted position is the reason why a low incidence of DDH was found in Malawian children. Many researchers find DDH to be very rare or of a low occurrence in African populations (Griffiths, 1970:90-91; van Meerdervoort, 1974:2436; Roper, 1976:157; Graham *et al.*, 2015:59). Loder and Shafer (2015:95) reported a 4% incidence of DDH in black American children from their sample of 424 children. Unfortunately, BC practices were not investigated in their research, but they report that black American children are not likely to be BC, but are more likely transported in strollers and car seats, explaining the higher incidence of DDH found in the black children from their sample (Loder & Shafer, 2015:95). These very significant results on the effect of BC on hip development of Malawian children; raises the question of whether BC would also have an effect on LL development at the ankle, knee, and hip. The aim of the current study is to investigate the possible LL developmental effects of BC, especially the knee and specifically the development of the tibiofemoral angle (TFA) of the knee.

The TFA is often used to investigate knee alignment (Cheng *et al.*, 1991:155; Heath *et al.*, 1992:260; Cahuzac *et al.*, 1995:729; Arazi *et al.*, 2001:264; Saini *et al.*, 2010:580-581; Kaspiris *et al.*, 2013:297; Oyewole *et al.*, 2013:168; Baruah *et al.*, 2017:343). The TFA is measured in degrees as the acute angle formed by the juncture of the femoral- and tibial axes. The intercondylar distance (ICD) for genu varum or the intermalleolar distance (IMD) is often used in support of the TFA (Cheng *et al.*, 1991:154; Heath & Staheli, 1992:259; Cahuzac *et al.*, 1995:729; Arazi *et al.*, 2001:264; Omololu *et al.*, 2003:301; Saini *et al.*, 2010:580; Bafor *et al.*, 2012:1249; Kaspiris *et al.*, 2013:297; Oyewole *et al.*, 2013:167). The use of TFA, ICD or IMD are the preferred methods to determine genu varum or genu valgum in the frontal plane (FP) (Cheng *et al.*, 1991:154; Heath & Staheli, 1992:259; Cahuzac *et al.*, 1995:729; Arazi *et al.*, 2001:264; Omololu *et al.*, 2003:301; Saini *et al.*, 2010:580; Bafor *et al.*, 2012:1249; Kaspiris *et al.*, 2013:297; Oyewole *et al.*, 2013:167). Other clinical measurements often included along with the TFA, ICD and IMD comprise of measurements to determine rotational profiles of the femur, tibia and the foot (Cheng *et al.*, 1991:155).

In healthy children there is a progression of the knee angle, from varus angles in infants, which changes to a valgus angle in early childhood, but these angles vary between children of different ethnicities (Cheng *et al.*, 1991:154; Heath & Staheli, 1992:259; Arazi *et al.*, 2001:264; Yoo *et al.*, 2008:714; Saini *et al.*, 2010:579; Kaspiris *et al.*, 2013:296). The development of the TFA is not known for the black, Setswana-speaking child population, which is necessary to determine if knee malignments such as genu varum, are exacerbated by BC practices or not. Developmental profile knowledge of the TFA is required before it can be established whether BC practices could contribute to the development of knee malalignments such as genu varum or genu valgum. Health care providers such as paediatricians, physiotherapists, occupational therapists, and biokineticists, require developmental profile knowledge, to allow diagnosis of malalignments, sound advice, and treatment of knee alignment issues (Cheng *et al.*, 1991:154; Saini *et al.*, 2010:579; Farr *et al.*, 2014:1362). In adolescent children, overuse injuries are often associated with knee malalignments such as genu varum or genu valgum (Krivickas, 1997:135).

Genu varum is characterised by the separation of the knees while the feet are placed together (Peterson-Kendall *et al.*, 2005:96-97; Espandar *et al.*, 2010:47). The presence of genu varum in newborns and infants is normal and also called physiologic genu varum. Physiologic genu varum resolves under normal conditions, when the toddler starts walking (Espandar *et al.*, 2010:47). Intrinsic-, extrinsic- and environmental factors such as diet, injuries, infections, and poor chair-, desk- and bed ergonomics affecting postural alignment, may affect normal angular development (Peterson-Kendall *et al.*, 2005:96-97; Espandar *et al.*, 2010:47).

An early study by Golding (1994:184) mentions the effect of BC practices on knee-alignment. Constant knee-valgus- and external torsion pressures on the LL during BC are reported (Golding, 1994:182). Leveau and Bernhardt (1984:1879) contrast these findings in their review on the effects of forces on growth and development stating; "*Both double diapering and straddle carrying can force persistence of normal varus positioning*". This statement is based on an earlier study by Knight (1954:522-523), who had an interest in LL deformities arising from long-duration sitting and sleeping postures. Knight (1954:523) postulated, but never investigated, that long-duration thick diaper carrying and straddle carrying, would lead to the development of genu varum. Both of these opposing statements by Golding (1994:182) and Knight (1954:523) amplified the interest to further determine whether a relationship exists between LL development, -malalignments and BC. Once it is established whether this relationship between genu varum and BC practices exist, one could investigate the factors which contribute to the development and severity of these malalignments, since this is also unknown.

The knee forms part of the lower kinetic chain and therefore, genu varum does not occur in isolation. Correlated motions such as tibia vara, medial tibial torsion (TT), and femoral retroversion (RV) often accompany genu varum, (Riegger-Krugh & Keysor, 1996:166) along with compensatory movements such as forefoot valgus, excessive subtalar pronation and pelvic internal rotation (Riegger-Krugh & Keysor, 1996:166). These findings are the rationale for including transverse plane (TP) measures at the hip, namely femoral anteversion (AV) (Magee, 2006:621) and at the leg, namely TT (Magee, 2006:801). The quadriceps-angle (Q-angle), a FP measure, determines the muscular lateral pull of the quadriceps musculature, and may be indicative of femoral AV, associated with increased Q-angles, greater than 20°, or femoral RV which is associated with a decreased Q-angle of less than 15° (Magee, 2006:729). Cheng *et al.* (1991:155) were the only TFA investigators, to also assess the rotational profile of the hip (femoral AV) and the tibia (tibial torsion), in the establishment of tibiofemoral development in children. Unfortunately, measures of the foot progression angle revealed considerable variability and unreliability, and it was excluded (Cheng *et al.*, 1991:155). The lack of reliable foot progression angles in children is a gap in the literature that warrants further investigation.

There is no research available on the South African child population which specifically investigate healthy knee development, and therefore the development of the TFA, ICD, and IMD in black Setswana-speaking children, nor has differences of these angles of infants or children who were BC, been compared to those who were not BC in this way. Data on the development of the TFA was found for including, but not limited to; American- (Heath & Staheli, 1992), Chinese- (Cheng *et al.*, 1991), Greek- (Kaspiris *et al.*, 2013), Indian- (Saini *et al.*, 2010), Korean- (Yoo *et al.*, 2008), Nigerian- (Omololu *et al.*, 2003; Oyewole *et al.*, 2013), and Turkish cohorts (Arazi *et al.*, 2001; Kurtoglu *et al.*, 2011).

Independent walking, a significantly important motor development task which children should master within the first two years of life (Malina, 2004:53), has been linked to the progression of the TFA from genu varum to genu valgum (Espandar *et al.*, 2010:47). The genu valgum angle in toddlers is initially exaggerated, and veers toward normal TFA when the child turns seven years of age. It is therefore important to investigate both static (TFA) and dynamic variables (kinematic gaits) of BC children. Once the child starts walking, their walking ability develops exponentially (Malina, 2004:53), but to learn how to walk, the child needs to experiment freely and unrestricted in various environments, such as at home, on playgrounds in the community, the crèche or preschool, to best contribute to their skill development and ability (Malina, 2004:54). BC of children has been shown to affect the child's cross-patterning skills due to the restrictions of their upper- and LL and head (Pretorius *et al.*, 2002:175). The affected cross-patterning skills have a direct impact on the child's neuromuscular maturation status (Malina, 2004:54) and hence the researcher for this study questioned whether this will, in turn, affect their kinematic gait. The research question to be answered with this study is: What are the relationships of BC with regards to gait kinematics in BC Setswana-speaking children at different ages compared to their non-BC peers?

This research is warranted as it divulges important lacking information about the development of the TFA of black Setswana-speaking children. Very little information is available on the biomechanical consequences of LL development in BC children. Treatment of LL malalignments poses high burdens on the health system, and for the intended population with a low socioeconomic status, children with excessive genu varum might not receive any treatment due to financial constraints (Omololu *et al.*, 2003:301). Furthermore, Saini *et al.* (2010:579) and Cheng *et al.* (1991:154) establish that due to the diverse findings with regards to TFA during childhood, children are often subjected to therapeutic interventions (braces, corrective shoe inserts, etc.) which are possibly not required, some of which, causing more harm. The answer to the research questions will generate new knowledge with regards to the role of BC practices on the development of the LL in children. Researchers will gain a better understanding of the LL developmental effects of BC practices. The new knowledge will be disseminated to other researchers and clinicians interested in paediatric LL development, in the form of peer-reviewed articles. Others have found some positive relationships between the low incidence of DDH and BC (van Meerdervoort, 1974:2437; Roper, 1976:155; Graham *et al.*, 2015:60) as well as positive relationships with emotional intelligence (Pretorius & Naudé, 2002:591; Pretorius *et al.*, 2002:177). Mothers will be educated regarding the best BC practices in terms of methods, or perhaps maximal time limits that children should be BC on a daily basis, should large discrepancies be found between BC and non-BC children in terms of LL development.

1.3. OBJECTIVES OF THE STUDY

The specific objectives of this study are to:

1. Determine the profile and development of the tibiofemoral angle and rotational angles affecting the femur and tibia in, black Setswana-speaking children between the ages of two- to nine years.

2. Determine the relationship between frontal plane lower limb angle measures (tibiofemoral angle and the quadriceps-angle) in black Setswana-speaking children between the ages of two to nine years, who were back-carried during infancy and toddler ages and their black non-back-carried Setswana-speaking counterparts.
3. Determine the relationship between transverse plane lower limb angle measures (femoral retroversion and medial tibial torsion), in black Setswana-speaking children between the ages of two to nine years, who were back-carried during infancy and toddler ages and their black non-back-carried Setswana-speaking counterparts.
4. Determine the predictor factors contributing to the development of, and severity of deviation in lower limb alignments in the frontal-, and transverse planes, in back-carried black Setswana-speaking children between the ages of two to nine years.
5. Compare the kinematic gait pattern differences between black back-carried Setswana children with black non-back-carried Setswana-speaking children between seven years to nine years of age.

1.4. HYPOTHESES

The study is based on the following hypotheses:

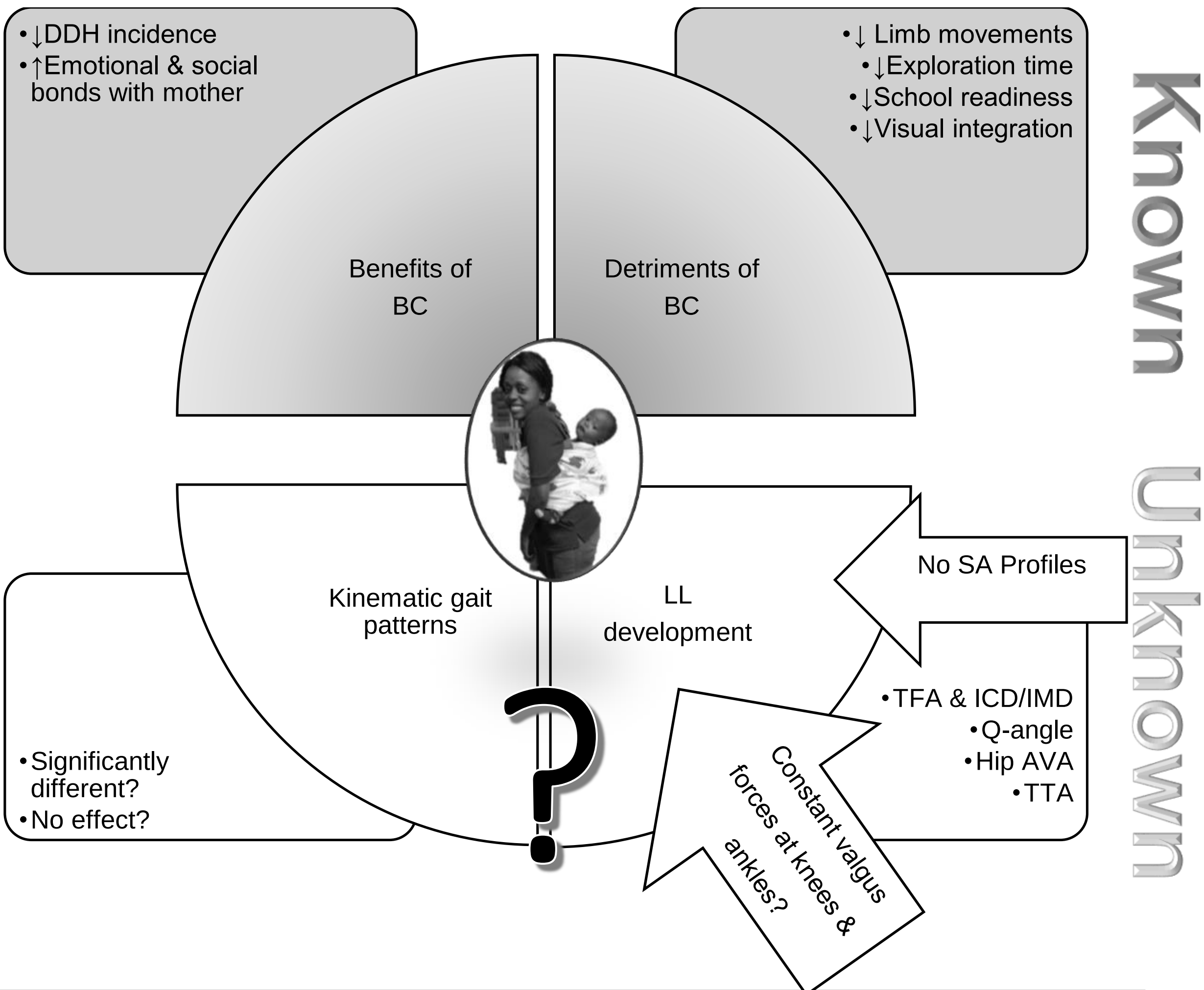
1. The first objective does not have a hypothesis, as the lower limb development is profiled.
2. In terms of the tibiofemoral- and quadriceps-angles, significantly greater genu varum angles will be observed in black two- to nine-year-old Setswana-speaking children who were back-carried during infancy and toddler ages than in their non-back-carried black Setswana-speaking peers.
3. Both femoral retroversion- and medial tibial torsion angles, will be significantly greater in two- to nine-year-old black Setswana-speaking children who were back-carried between infancy and toddler ages than in their non-back-carried black Setswana-speaking peers.
4. Certain factors will yield statistically significant ($p<0.05$) correlations with deviations of lower limb development, in back-carried black Setswana-speaking children between the ages of two- to nine years.
5. There will be conclusive evidence for differences between the kinematic gait patterns of seven- to nine-year-old black Setswana-speaking children that were back-carried, compared to their black Setswana-speaking not back-carried peers.

1.5. CONCEPTUAL FRAMEWORK

This study was derived from the framework depicted in Figure 1-1 below. A pertinent number of benefits and detriments, to both mother and child, were reported previously by other researchers for BC From a detrimental perspective, the limb movements of BC children are restricted (Pretorius *et al.*, 2002:175), they exhibit shortfalls in physical- and motor development (Pretorius & Naudé, 2002:592) and are hampered in terms of school readiness, as compared to non-BC children (Pretorius & Naudé, 2002:586). The most significant benefit of BC toward the child's orthopaedic development being the possible prevention of DDH (Griffiths, 1970:91; van Meerdervoort, 1974:2436-2437; Roper, 1976:157; Graham *et al.*, 2015:60). To the knowledge of the researcher, at the time of this study, only one study indicated constant knee-valgus pressures at the knee and external torsion pressures at the lower leg, in BC children (Golding, 1994:182). The unsubstantiated secondary statement by Knight (1954:523) and the Golding (1994:182) finding increased interest in investigating the relationship between BC practices and LL development, but specifically genu varum. The TFA can be used to determine genu varum, but due to the knee forming part of the LL kinetic chain, other measures such as hip anteversion angles (AVA) and tibial torsion angles (TTA) should accompany the TFA. Various authors have investigated the development of the TFA and found variance in children from different ethnicities (Cheng *et al.*, 1991:154; Heath & Staheli, 1992:259; Arazi *et al.*, 2001:264; Yoo *et al.*, 2008:714; Saini *et al.*, 2010:579; Kaspiris *et al.*, 2013:296), yet no profiles exist for South African children, less so for black Setswana-speaking children. These profiles are required to determine whether a relationship exists between BC and LL development. These measures are all static measures, and a kinematic investigation into the gait patterns of BC- versus non-BC children will contribute to the current knowledge base. It is not yet known whether the kinematic gait patterns of BC children will resemble those of non-BC children, or if there will be significant differences between the two groups.

1.6. STRUCTURE OF THE THESIS

The thesis consists of seven chapters. Four chapters are research papers presenting the findings of the study. The structure, as set out below, follows an article format, as approved by the North-West University (NWU). Each research paper presents the methods and results relevant to that paper, which will not be discussed in another chapter. The research papers are presented in agreement with the requirements of the intended scientific journal that it is prepared for. These requirements are incorporated in the appendixes for perusal. The research papers will be submitted or have been submitted to the journals as indicated. The authors' guidelines for the mentioned journals are in the relevant appendices (sub-sections presented in APPENDIX E).



Legend: AVA = anteversion angle, BC = back-carrying, DDH = developmental hip dysplasia, ICD = intercondylar distance, IMD = intermalleolar distance, LL = lower limb, Q-angle = quadriceps-angle, SA = South Africa, TFA = tibiofemoral angle, TTA = tibial torsion angle

Figure 1-1: Conceptual framework for investigating back-carrying (BC) and lower limb (LL) development

Chapter one serves as the introduction to the thesis and presents the problem statement, the objectives, and hypotheses of the study as well as the structure of the thesis. Structurally, the chapter is written according to the guidelines and requirements of the NWU, conforming to the NWU Harvard referencing system.

Chapter two is a review of the literature, entitled *"An overview of carrying techniques, lower limb development and gait kinematics of children"*. Chapter two is also written according to NWU guidelines and the NWU Harvard referencing system. It presents a review of the most relevant- and current literature.

Chapter three contains the first research paper that presents the findings of the first objective and is entitled *"The profile and development of the lower limb in black Setswana-speaking children, between the ages of two- to nine years"*. This chapter is written according to the guidelines of *Frontiers in Pediatrics Journal,* but the font was changed to Arial to comply with the rest of the thesis. The structural guidelines to authors are in APPENDIX E.

The fourth chapter is written according to the guidelines of the *Gait and Posture* journal and is entitled: *"Back-carrying in black Setswana-speaking children related to lower limb development".* This paper addreses objectives two and three. Author instructions for paper structure are available in APPENDIX E.

Chapter five is called *"Factors and their contribution to the severity of the lower limb malalignments of black Setswana-speaking children",* addressing objective four. The guidelines of the *Early Human Development* journal are followed for this paper. Here the relationships the from Chapter four, are investigated further in terms of durations spent on the mother's back or the age until which the child was BC, and compared to LL development. The author's guidelines are in APPENDIX E.

The last research paper addresses the last objective, objective five, and is presented in Chapter six entitled *"Kinematic gait comparison between back-carried- and non-back-carried black Setswana-speaking children"*. The *Gait and Posture Journal*'s guidelines are utilised for this paper's structure and are available in APPENDIX E.

The summary of the study, the conclusions, limitations, and recommendations are presented in the final chapter, Chapter seven. This chapter presents the concluding findings of the study and direction for future research.

1.7. SUMMARY

Several benefits and detriments have been reported for back-carried children, at various levels, and in different ethnic groups. Limited information with regards to LL development in Setswana-speaking children is available, who have a strong culture of back-carrying. Should BC pose detrimental to LL development, this lack of information could carry negative long term consequences. The thesis will investigate the problems identified in the problem statement by a thorough, and critical analysis of the current literature available on LL development in children, which is presented in Chapter two.

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CHAPTER 2 : LITERATURE REVIEW:

AN OVERVIEW OF CARRYING TECHNIQUES, LOWER LIMB DEVELOPMENT AND GAIT KINEMATICS OF CHILDREN

2.1. INTRODUCTION

In the South African culture, back-carrying (BC) of infants (defined as under 12-months-old) (Stedman, 2001:495) , toddlers (between one- to four years old) (Kahf *et al.*, 2019:99; Pretorius et al., 2002b, 176) and often older children, is a widely accepted and common practice (Pretorius *et al.*, 2002a; Pretorius *et al.*, 2002b; Graham *et al.*, 2015). Some developmental effects in terms of cognition, peripheral vision, and hip development were found in children who were back-carried (BC) (Pretorius *et al.*, 2002a; Pretorius *et al.*, 2002b; Graham *et al.*, 2015). Various researchers have postulated that BC positively contributes toward the prevention of developmental dysplasia of the hip (DDH) (Griffiths, 1970:90-91; van Meerdervoort, 1974:2436; Roper, 1976:157; Graham *et al.*, 2015:59), which raises the question of whether the practice of BC may affect the rest of the lower limb (LL) in the BC child in terms of development as well. During LL assessment, child history, such as their birth, attainment of developmental milestones and familial deformity history is taken into account (Kahf *et al.*, 2019:100). Asencio *et al.* (2019:32) found a significant relationship between age of independent walking milestone attainment and risk for the development of paediatric planovalgus foot (PPVF), where an older (thus later than normal) independent walking age was a significant risk factor for PPVF development, along with overweight and obesity. Their work highlights the fact that psychomotor factors or milestone attainment (e.g. crawling and independent walking age attainment) have possible impacts on LL development, which forms part of this thesis.

This chapter starts with a discussion of the preferred BC methods employed by Setswana-speaking mothers. The traditional African manner of BC is discussed broadly, by referring to the method of carrying, the age until which and the duration which children are typically BC, as well as the benefits and detriments of BC. Thereafter, the different carrying methods employed by mothers world-wide are explored. The specifics on how mothers from different cultures choose to carry their children, and the devices they use to carry them in, carry them on their body, or devices they place the children into travel long distances, are obtained from literature, interpreted and integrated into this chapter. Both Western, modern carrier devices and methods, as well as traditional cultural carrier devices and methods of the Inuit and various Asian cultures, are considered. The benefits and detriments to both the mother and child of a variety of carrying and swaddling methods are discussed.

The development of the LL at the hip, knee, and ankle is broadly discussed, including the various measuring instruments and methods employed for their respective assessments. Development of the femoral anteversion angle (AVA), tibiofemoral angle (TFA), quadriceps-angle (Q-angle), and tibial torsion angle (TTA) are each addressed. The tibiofemoral malalignments, genu varum, and genu valgum are discussed along with their aetiology and how the presence of either genu varum and –valgum could have an effect on the LL kinetic chain in affecting rotation at the hip and tibia.

Child gait is discussed, starting with normal motor development in terms of independent walking, how normal walking patterns develop, the five factors that could impact motor development and age-related differences in kinematic gait patterns. Typical temporal-spatial differences in terms of walking speed, cadence, step length and cycle times that are observed in child gait, is discussed along with the joint angle patterns which are normally observed. Before summarising and explaining the gap and how this research study will address it, the gait characteristics of children with genu valgum are discussed.

2.2. BACK-CARRYING (BC) AS AN AFRICAN TRADITION

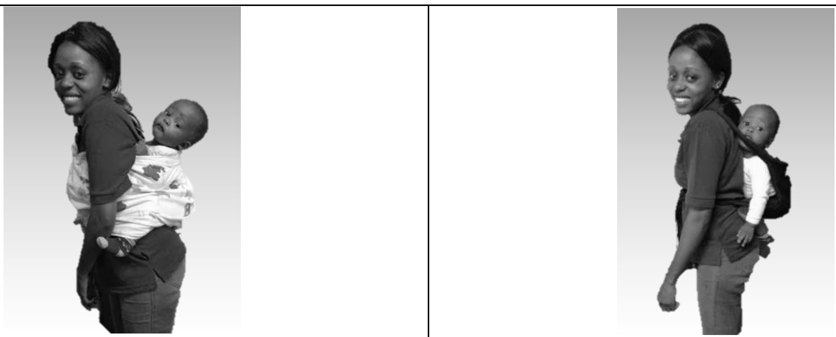
Mothers from rural communities in Southern Africa often employ the preferred traditional and cultural method of transporting their children, by BC them (Pretorius *et al.*, 2002b:175). Graham *et al.* (2015:59) mention that it is highly uncommon for mothers in Central and Southern Africa to utilize prams or other infant carriers, due to not only economic reasons but also due to cultural and other environmental reasons. To back-carry (BC) infants is part of the African culture, especially Central- and Southern Africa, and is socially accepted amongst the African society and valued in terms of kinship (Pretorius *et al.*, 2002b:175; Graham *et al.*, 2015:59). It is a normal rearing practice in the, to name just a few, Batswana, Basotho, Zulu, Ndebele and Xhosa cultures (Pretorius *et al.*, 2002b:175).

Rural mothers will, for the sake of convenience to themselves and safety to the child, carry their infants or toddlers on their backs with the aid of Western blankets or towels (Pretorius *et al.*, 2002a:586; Pretorius *et al.*, 2002b:175; Graham *et al.*, 2015:59). The child is usually BC whilst the mother goes about her daily work duties around the house/rural community, or when the mother needs to travel by foot to her workplace. This often results in the child being BC intermittendly for up to six- or eight hours per day in total (Pretorius *et al.*, 2002a:586).

Kenyan mothers use a “kanga”, which is a large rectangular shaped cloth, to tie their baby to their back by wrapping the kanga around both baby and mother (Gross-Loh, 2010:48). Mozambican and South African Tsongas are also known to BC their young. The “ntehe” or blanket that is used to BC the child is normally an antelope skin, and not the skin of a sheep or other domestic animal, that is prepared by the maternal uncle of the expecting mother (Pretorius *et al.*, 2002b:175). Setswana-speaking mothers employ a sling, called the “thari”, which is used to BC their infant, toddler or child and the act of BC children is called to “pépa” (Pretorius *et al.*, 2002a:592).

2.2.1. Method of carrying

The traditional custom was to use a goat- or animal skin for this purpose, but the more modern mothers utilise Western blankets or towels as a method of carrying (Pretorius *et al.*, 2002a:586; Pretorius *et al.*, 2002b:175; Graham *et al.*, 2015:59). The infant or toddler is placed in an upright, semi-seated position on the mother’s back, with the legs wrapped around the mother’s back. The blanket or towel is then secured around the child and mother and fastened or tied at the mother’s front (Figure 2-1a) (Pretorius *et al.*, 2002b:175). In Figure 2-1 the most typical BC methods are depicted. Figure 2-1a, shows how the infant or toddler is tied on the back, with the legs spread around the mother’s hips, using either a blanket or towel. Another preferred BC method is shown in Figuer 2-1b, where the infant or toddler’s legs are dangling down.

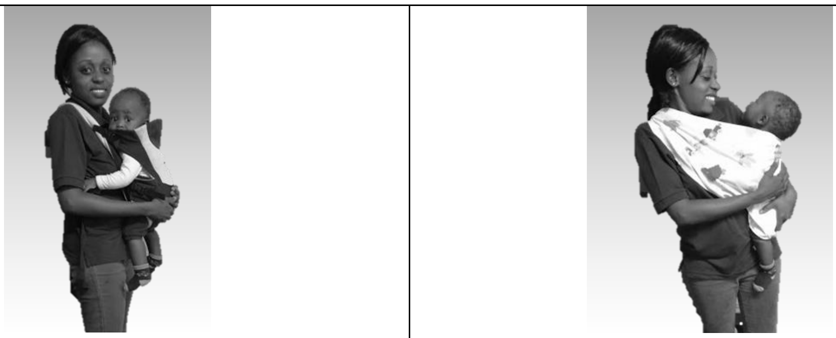


a b

Figure 2-1: Preferred typical back-carrying methods: (a) Carrying method using a towel or blanket, (b) Carrying method using a “thari”[1]

This carrying method is preferred for newborns (synonym of neonate, and younger than a month old) (Stedman, 2001:662)) or very young infants. A child is carried in either a baby carrier (Figure 2-1b) or wrapped in a blanket or towel (Figure 2-1a). Alternative traditional carrying methods are shown in Figure 2-2a, where a modern baby carrier or sling is used and the child is carried on the front. Infants are carried with the child facing the mother, whilst older children may be carried facing away from the mother (not shown).

[1] Photos demonstrated and published with permission – Photo by M. van Aswegen



a b

Figure 2-2: Alternative carrying methods: (a) Front carrying with a modern carrier device, (b) Side carrying with a blanket[2]

Another alternative, less predominant method of carrying is to fasten the child on the side Figure 2-2b, with the child facing the mother. This method is not as popular as the other discussed carrying methods. Most mothers will rather just carry their child on the hip without securing a blanket on the side (not shown) (Pretorius *et al.*, 2002b:175, Gross-Loh, 2010:50).

2.3. WESTERN OR MODERN BABY CARRY DEVICES AND METHODS

2.3.1. Babywearing and baby carrier devices

Mostly grey literature is available on the use of baby gear such as baby carrier devices, prams, strollers, and car seats. Most of the peer-reviewed work published addresses factors beyond the scope of this thesis, such as the risk for sudden infant death syndrome (SIDS) and reviews on child risks linked to baby gear use (Batra *et al.*, 2015:184).

Babywearing is the term clinched by parenting consultants on the internet network, introducing new mothers to the different carrying methods. Babywearing is especially popular with mothers who prefer attachment parenting styles (Flaskerud, 2013:210; Russell, 2015:1130-1131). Attachment parenting style advocates breastfeeding, especially extended breastfeeding, co-sleeping, babywearing in a sling or baby wrapping device, not leaving an infant to cry and shuns spanking and time-outs (Flaskerud, 2013:210).

An overabundance of babywearing carrier devices to choose from exist, depending on the need of the parent in terms of carrying distances and reasons, and the age of the infant or child. Four general categories of babywearing devices include pouch slings, ring slings, soft-structured carriers or wraps. There is a great amount of grey literature and very limited peer reviewed scientific literature available on the process of mothering and baby carrying methods, thus popular literature is used in sections of this literature review to describe different carrying methods.

[2] Photos demonstrated and published with permission – Photo by M. van Aswegen

The pouch sling (Figure 2-3a) is normally made of material of either a fixed size or adjustable pouch size. Ring slings (Figure 2-3b) were most probably inspired by the *mei tai* from China, the Korean *podaegi* and the Japanese *onbuhimo*, as they are adjustable slings with one end strung through two rings (Gross-Loh, 2010:50). Western ring slings are either padded or unpadded with either open or closed ends. With the use of the ring sling, a child can be carried in a cradle hold on the hip or facing in, or they can be carried high up on the body (Gross-Loh, 2010:50). In both the ring- and pouch sling, there is an added advantage of easy transfer of the infant into and out of the device. Soft-structured carriers (Figure 2-3c) resemble modified back-packs as they have two straps that the mother wears over each shoulder and the child is worn either at the front or the back. They offer an added advantage to the babywearer in that weight is also supported at the wearer's hips, reducing pressure to the shoulders and back (Gross-Loh, 2010:50; Wu *et al.*, 2017:116). Lastly, wraps (Figure 2-3d) are made of long sections of cloth varying from stretch to woven materials. The cloth is draped around the mother and child and quite a few methods of draping exist, but mothers can experiment with the technique that suits her and baby best (Gross-Loh, 2010:50).

Russell (2015:1131) explored the informational resources new mothers would utilise to decide on which babywearing method or device, in the form of slings, wraps or other carriers to use, how to use it and which would be best for their baby's safety, health and development in relation to expenses, fashion, and lifestyle. Russell (2015:1131) describes babywearing as a non-traditional, non-Western carrying method, although not a new method utilized by Californian mothers, since baby body carrying devices have been available in the United States of America (USA) since the 1960s, but that its use has vastly increased in the past decade with multiple new options available on the market. Gross-Loh (2010:44), on the other hand, describes the use of slings and babywearing as a *"simple manifestation of a biological norm for human infants"* after the practice was previously seen as an alternative option, but later became more familiar. Babywearing is said to promote bonding between mother and infant (Gross-Loh, 2010:46; Flaskerud, 2013:210), but is also associated with the risk for suffocation, especially if the infant falls into a foetal C-position, there is potential of positional asphyxia whereby the infant's head position restricts their airway and breathing (Gross-Loh, 2010:44, 55; Flaskerud, 2013:210; Bergounioux *et al.*, 2015:1668). Bag-style slings were recalled in the USA after their Safety Commission issued warnings on the use of these slings in 2010 (Gross-Loh, 2010:46). Antunovic (2008:10) advocates that when using the soft baby carrier, the mother should rather carry the infant facing toward her (as depicted in Figure 2-3c) as opposed to the infant facing outward. Carrying the infant in a soft carrier that lacks proper support for the LL, facing forward away from the mother cause an anterior pelvic tilt and places the lower back in a lordotic position ("hollow-back") which, according to Antunovic (2008:10), is both harmful and unsafe. Furthermore, not all babywearing devices are made equal and some like the papooses of the Inuit Eskimos do not adequately support the infants' legs and similarly as described as above, place their lower back in hyperextension which along with the infants immature abdominal musculature leads to the possible development of spondylolisthesis (slippage of vertebral bodies) (Antunovic, 2008:12).

a[3]	**b**[4]	**c**[5]	**d**[6]

Figure 2-3: Various babywearing devices: (a) Pouch sling, (b) Ring sling, (c) Soft baby carrier, (d) Baby wrap

2.3.2. Other baby gear: Prams or strollers and car seats

Similar to the previous section, a fair amount of grey literature is available on pram- and stroller usage, which were excluded from this section. Most of the peer-reviewed articles available for this section are beyond the scope of this thesis, and the discussion hereafter focuses on the benefits and detriments associated with prams, strollers and car seats usages. The development of plagiocephaly is the closest developmental factor linked to prams, strollers and car seats usages, which is discussed here.

Prams are designed for newborns and younger infants to transport the infant in a supine position which limits time for playing in prone positions (Zachry *et al.*, 2017:2234). The average modern Western parent prefer to use a pram or stroller whilst walking around in town, whilst shopping, some even whilst jogging (Currie *et al.*, 2002:885; Antunovic, 2008:23). The use of a pram or stroller is less stresfull on the mother’s back as she does not have to carry the weight of the child, and although at least one hand needs to push the pram or stroller, most mothers report this to be their preferred mode of transport for their infant. Antunovic (2008:23) claims that lying the infant flat on their back for extended periods, in the pram or stroller, is not desirable as it negates the normal reflexive “frog position” and C-spine of the infant, pulling the vertebrae into a straight line which is stressful for the infant. Furthermore, the pram or stroller cannot provide the warmth a mother’s arms could (Antunovic, 2008:23).

[3] Image adapted and reproduced with permission from: Baby Slings & Carriers: http://www.babyslingsandcarriers.com/product/PS-PS-R-redyoko
[4] Image adapted from: https://upload.wikimedia.org/wikipedia/commons/b/ba/Ringsling-closed-up.png
[5] Image adapted and reproduced with permission from Ubuntu Baba - https://ubuntubaba.com/product/the-stage-2/
[6] Image adapted and reproduced with permission from Osha Slings - https://www.oschaslings.com/shop/category/babywearing/baby-wrap/

Gross-Loh (2010:47) mentions that extensive use of car seats or any other seating device in which the head is supported, the infant could develop positional plagiocephaly where their head becomes flat or misshapen due to extended periods (longer than two hours) of lying on the back (Antunovic, 2008:5; Zachry *et al.*, 2017:2230). Zachry *et al.* (2017:2230) hypothesised that children diagnosed with cranial asymmetry (which includes positional plagiocephaly), would have spent longer durations in baby gear devices such as car seats, high chairs, swings or bouncer seats. No significant correlation was found between baby gear and cranial asymmetry, but did those diagnosed with cranial asymmetry spent less time in alternative positions (to lying on their back) such as on their tummy or side-lying (Zachry *et al.*, 2017:2233). The car seat should only be used for intended traveling and not as a temporary bassinet once they arrive at their destination, as the extended (longer than two hours) time spent in the car seat is associated with oxygen desaturation in infants (Gross-Loh, 2010:47). Other injuries could also arise if the car seat falls off an elevated surface that it is placed on (Gross-Loh, 2010:47). Furthermore, extended car seat use could prolong the time taken for the infant to properly develop head and neck control, as they are not stimulated to use the neck musculature as they would have in a semi-upright position as when carried in a sling or baby carrier devise (Gross-Loh, 2010:47).

2.3.3. Swaddling

Swaddling, as depicted in Figure 2-4, is an almost universal maternal caring method, employed to soothe a baby by replicating the womb environment (Mahan *et al.*, 2008:177). The infant is wrapped tightly with a blanket, cloth or muslin wrap, with their arms normally folded across their chest, or extended at their sides and their hips in full extension and adduction, although some variation exists in the specific technique (Mahan *et al.*, 2008:177; Clarke, 2014:5; Nelson, 2017:217). Nelson (2017:222) performed an integrative review of the risks and benefits of infant swaddling practices. From the final 44 studies included in her review, she was able to make suggestions toward best swaddling practices. Firstly, swaddling can be utilized as an effective approach toward calming and soothing infants and promoting sleep. Secondly, it should be ensured that the infant is swaddled using a weather-appropriate blanket to prevent hyperthermia and being cautious swaddling an infant who has a fever. Thirdly, swaddling should be alternated with periods of skin-to-skin contact. Fourth, the infant should not be swaddled too tightly and the wrapping technique should allow for hip abduction to take place (Mahan *et al.*, 2008:177; Nelson, 2017:223). Should an infant be diagnosed with DDH, it may resolve without any special treatment, provided the child’s legs are not restrained through tight swaddling, and rather allows for hip flexion and abduction to take place (Mahan *et al.*, 2008:177-178).

Nelson (2017:223) prescribes the *Down-Up-Down-Up* or “DUDU” wrap technique as developed by paediatrician, Dr Harvey Karp. Fifth, should the swaddled infant sleep for longer intervals, he or she may need to be woken to allow for appropriate feeding intervals. Sixth, Nelson (2017:222) suggests that the sleep recommendations for infants, as prescribed by the American Academy of Paediatrics, be followed for all infants and lastly, that swaddling should be discontinued as soon as an infant is able to roll over by themselves.

Figure 2-4: Baby swaddled in a light blanket[7]

2.4. CULTURAL BABY CARRYING METHODS FROM AROUND THE WORLD

The Inuit Eskimo from Northern Canada uses the "*amauti"* (Figure 2-5a), which is a carrier within their coat, lined with fur for warmth. The baby is carried, high up on the mother's back, in a back pouch, which is formed with a drawstring cord at her waist (Gross-Loh, 2010:48). In Northern America, some of the indigenous cultures use cradleboards or papoose (actually meaning "baby") (Figure 2-5b), in which the infant is first swaddled and then strapped to the papoose or cradleboard, which is then either carried on the back or fixed to sledges which are pulled over the snow. The cradleboard of the Kiowa or Comanche people (Figure 2-5c) is similar to the papoose, in that the infant's legs are placed together and swaddled before wrapping within the carrier device (Antunovic, 2008:13).

a[8]	**b**[9]	**c**[10]

Figure 2-5: Various cultural carrier devices: (a) Inuit mother carrying her baby in her *amauti* coat, (b) Navajo baby in a papoose, (c) Cradleboard of the Kiowa or Comanche

[7] Photo demonstrated and published with permission – Photo by M. van Aswegen
[8] Image by: Ansgar Walk from: https://commons.wikimedia.org/wiki/File:Iglulik_Clothing_2_1999-07-18.jpg
[9] Image by: H. Armstrong Roberts from: https://commons.wikimedia.org/wiki/File:Navajo_papoose_on_a_cradleboard_with_a_lamb_approaching,_Window_Rock,_Arizona,_1936_-_NARA_-_519160.tif
[10] Image by: Sean Pathasema from: https://commons.wikimedia.org/wiki/File:Cradleboard_of_the_Kiowa_or_Comanche_people.jpg

The Asian countries have a variety of carrier devices, most notably the following. The Japanese *Dakkohimo* or *Onbuhimo* or *Obui-himo* (Figure 2-6a) is meant to allow the baby being carried on the front or the back, with the legs either hanging straight down or wrapped around the mother' waist. Many modifications of this traditional *Onbuhimo* has been made, as babywearing is very popular in Japan (Gross-Loh, 2010:48). The Chinese fashion a square panel with four straps at each corner, called the *Mei tai* (Figure 2-6b), which is used to carry a baby, either at the front or back. The bottom two straps are tied around the mother's waist, whilst the two upper straps are used as shoulder straps can either cross at the front (when the baby is BC) or cross at the back (when the baby is front-carried). In the BC position, the child's legs wrap around the mothers' waist as indicated in Figure 2-6b. Babywearing is just as popular in the Chinese culture and they too have derived modern versions thereof (Gross-Loh, 2010:48). The Korean *Podaegi* (Figure 2-6c) resembles a blanket with straps which is wrapped around mother and baby to carry them snugly on either the back or front, mostly with the child's legs spread around the mother' waist (Gross-Loh, 2010:48).

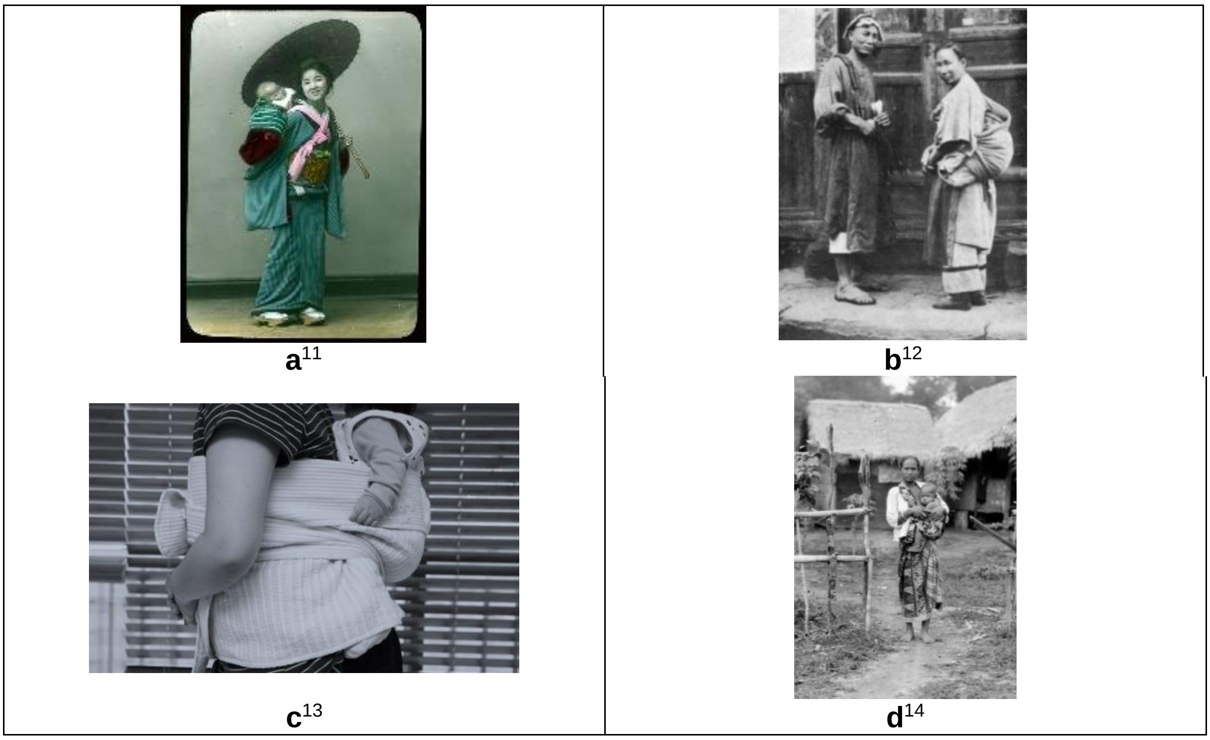


Figure 2-6: Various cultural carrier devices: (a) Japanese *onbuhimo*, (b) Chinese *mei tai*, (c) Korean *podaegi*, (d) Indonesian *selendang*

[11] Image by: University of Victoria Libraries from Victoria, Canada, from: https://commons.wikimedia.org/wiki/File:Woman_in_traditional_dress_holding_open_parasol_and_carrying_baby_on_her_back._(19949880145).jpg

[12] Image by: Isabella Lucy Bird (J.F. Bishop), from: https://commons.wikimedia.org/wiki/File:Mode_of_Carrying_Cash_and_Babies_(J.F._Bishop).png

[13] Image by: National Institute of Korean Language from: https://upload.wikimedia.org/wikipedia/commons/e/ef/Podaegi_%28baby_sling%29_2.jpg - color changed to black and white

[14] Image by: Dr. W.G.N. (Wicher Gosen Nicolaas) van der Sleen (Fotograaf/photographer) from: https://commons.wikimedia.org/w/index.php?search=indonesian+baby+carrying&title=Special:Search&go=Go&ns0=1&ns6=1&ns12=1&ns14=1&ns100=1&ns106=1&searchToken=f4kty783vk2o4i4kebyf5mgkw#%2Fmedia%2FFile%3ACOLLECTIE_TROPENMUSEUM_Portret_van_een_vrouw_met_kind_op_de_arm_voor_de_kampong_bij_de_koprafabriek_van_plantage_Sawarna_TMnr_10027502.jpg – image cropped for improved visual

The Indonesian *Selendang* (Figure 2-6d) is a large rectangular batik cloth that is used to form a sling in which the child is carried either at the mother's front or as shown on her side. When carried at the side, the child's legs are not spread apart as wide as during BC (Gross-Loh, 2010:48). The Vietnamese Hmong people have the *Nyias* is a strapped panel of embroidered material, used to fasten the baby to the mother's back, with the child's legs spread (Gross-Loh, 2010:48).

2.5. EFFECT OF BACK-CARRYING (BC) ON MOTHER AND CHILD

As previously mentioned BC is popular in African cultures, (Pretorius *et al.*, 2002a:586; Pretorius *et al.*, 2002b:175). Infants are commonly BC from their second week of life and often the child will be BC until their second birthday or even later (Graham *et al.*, 2015:59). Rural and urban mothers of lower socioeconomic status will BC their child for extended periods of time whilst working. It is evident that BC has potential benefits and potential detriments to child development (Pretorius *et al.*, 2002a).

2.5.1. General benefits of back-carrying (BC) to the mother and child

Mothers will BC their children to allow them to continue with their daily work duties, or for convenient on foot travelling (Graham *et al.*, 2015:59). BC keeps the child out of harm's way and is often used to soothe the child (Pretorius *et al.*, 2002b:175-176). BC and babywearing for that matter allows the mother to develop a stronger bond with her baby and benefits her to continue with work hands-free (Russell, 2015:1130-1131). In the case of frontal babywearing, the mother can also breastfeed her baby, whilst babywearing (Russell, 2015:1135). Hunziker *et al.* (1986:645-646) concluded that newborns tend to fuss and cry less when their parents carried them more often throughout the day. They reasoned that soothing actions such as picking a crying baby up, rocking or hugging or swaddling a crying baby are all similar in bringing about postural change, having a rhythm, being repetitive and promoting mother-child closeness. Excessive crying of a baby could potentially wear a mother down and possibly disrupt her coping skills, thus a happy baby is equal to a happy mother (Hunziker *et al.,* 1986:646).

Probably the most positive orthopaedic outcome of BC infants and toddlers is the possible prevention of DDH in children or contribution thereof to the rarity of DDH. Many researchers found DDH to be very rare or of a low occurrence in the African population (Griffiths, 1970:90-91; van Meerdervoort, 1974:2436; Roper, 1976:157; Graham *et al.*, 2015:59). One study by Loder *et al.* (2015:95) indicate that the incidence of DDH in black children residing in Indiana, in the USA, to be higher than expected. From their sample of 424 children diagnosed with DDH, a total of 4% were of black ethnicity. Although this is still a low incidence when compared to the 80.8% incidence in white children from the sample, it is higher than incidence rates reported by Griffiths (1970) and Roper (1976). Unfortunately, BC practices was not analysed in their research, but they mentioned that black children residing in Indiana are not likely to be carried in this way and would much more likely be transported in other means such as in strollers and car seats (Loder *et al.*, 2015:95). Therefore, although they found a slightly higher incidence of DDH amongst the black participants in their study, their results are not in contradiction of the studies reporting low occurrence of DDH in the African population (Griffiths, 1970:90-91; van Meerdervoort, 1974:2436; Roper, 1976:157; Graham *et al.*, 2015:59).

The DDH is treated by placing the LL in a flexed and abducted position, often this position is achieved by placing the child in a brace (Pavlik harness) or hip spica cast, post-surgery (van Meerdervoort, 1974:2436; Clarke, 2014:5). The position obtained by the Pavlik harness or spica cast resembles the position attained when infants are BC. Hence, researchers have postulated that BC practices of African mothers contribute to the low incidence of DDH in African populations (Griffiths, 1970:91; van Meerdervoort, 1974:2437; Roper, 1976:157). However, most of the researchers agree that further research is required to confirm this hypothesis, as the development of DDH is multifactorial with genetics and environmental factors such as swaddling or BC practices playing a role (Griffiths, 1970:91; van Meerdervoort, 1974:2437-2438; Roper, 1976:155).

Graham *et al.* (2015:57) postulate that the fact that Malawi mothers BC their infants and children, is a contributing factor why DDH is not regularly seen in the African population. Graham *et al.* (2015:57-61) conducted a retrospective review in Malawi, to investigate the role of BC infants and the possible effect thereof on the prevention of the development of DDH. Their investigation included a total of 40 683 children under the age of 16 years and found zero infant patients who presented with, or were treated for symptomatic DDH. Graham *et al.* (2015:60) concluded that BC of infants with their legs in a flexed and abducted position, was the reason why a low incidence of DDH was found in Malawi. They proposed a clinical trial to investigate the effect of BC infants by other population groups (non-African) and the subsequent prevention of DDH. Graham *et al.* (2015:59) mention that surgeons in Kenya have acknowledged higher incidences of DDH amongst black African children and the orthopaedic surgeons believed it to be due to urbanization and greater utilization of prams in the place of BC practices.

Graham *et al.* (2015:59) compared the ratio of hip replacements to knee replacements that were recorded by the Malawi National Joint Registry against those recorded by the British National Joint Registry, in the United Kingdom (UK) in 2012. The number of hip replacements performed for osteoarthritis in Malawi was only 28 versus 93 which were performed in the UK, whilst knee replacements recorded in Malawi were 93 versus 97 in the UK. They concluded that further research is required to investigate if the implementation of BC could reduce the incidence of DDH in high-income countries and if it would possibly contribute to reduce the number of adult hip replacement surgeries required per annum too (Graham *et al.*, 2015:59). Swaddling, which in essence consists of the opposite limb arrangement as described above, is recognized as a risk factor contributing to DDH according to Mahan *et al.* (2008:177) and Nelson (2017:221).

Another benefit of BC is that the child is in constant contact with their mother or caregiver and this closeness may contribute positively to the emotional development of the child (Pretorius *et al.*, 2002b:177). The child's physical safety is also ensured whilst safely tucked away on his or her mother's back (Pretorius *et al.*, 2002b:176).

2.5.2. General detriments of back-carrying (BC) to the mother and child

Unfortunately, BC may also have detrimental effects on both the mother, who needs to carry her child, as well as to the child, who is being carried's development. Wu *et al.* (2017:112) compare the use of three different babywearing devices and the effect on the carrier (mother), in terms of muscle activation (surface electromyography (EMG)) body tactile pressure at the shoulders (pressure sensor sheet), skin temperature and heart rate. They compared two soft carriers, one with two shoulder straps, another with two shoulder straps and a waistband and a ring sling with only one shoulder strap, with each other. All were used to carry the infant at the front. The three carriers' results were very similar, but most of the participants still preferred the ring sling as opposed to the two soft carriers. Their results indicated that muscle activation increases with the load of the baby, higher EMG activity was found for the 10 kg dummy baby than for the 7.0 kg dummy baby. The ring sling had a broad adjustable shoulder strap and showed the lowest shoulder pressure than the two soft carriers. Heart rate responses indicated moderate workloads in females (mothers) when front carrying the 10 kg baby. Wu *et al.* (2017:116) recommend the use of prams or strollers when parents need to carry their heavier infant for longer durations.

The act of BC a child restricts the child's vision and peripheral vision, upper- and LL movement and the head is restricted in rotation to the left or right (Pretorius *et al.*, 2002b:175). Pretorius *et al.* (2002a:586) aimed to identify if school readiness would be negatively impacted due to insufficient sensorimotor development owing to mothers carrying their infants on their backs for extended periods of time (as long as six- to eight hours per day). They postulated that the extended BC would limit the infant's view, head-turning ability, would limit crawling as well as any arm and hand movements. These movement limitations obstructs the peripheral visual field and cause an impairment in visual scanning and integration which hinders the child's school readiness later in life (Pretorius *et al.*, 2002a:586). They utilised the "*Skoolgereedheidsevaluering deur Gekwalifiseerde Onderwyseresse (SEGO)*" (Direct English translation: School readiness Evaluation by Qualified Teachers) test battery, to determine school readiness. The SEGO test measures language and general development, physical motor development and emotional and social development (Pretorius *et al.*, 2002a:588). Results indicated that BC children are hampered in terms of school readiness. In BC children, linguistic invariance, visual analysis and synthesis with regards to language and general development was observed (Pretorius *et al.*, 2002a:591). In terms of physical- and motor development, BC children struggled with fine motor skills specifically integrating movement with observational ques. The researchers suggested that fine motor skills and observational skills were compromised due to the inhibiting nature of BC, limiting head- and neck rotation and arm movements. This, in turn, limits the child's ability to discover their surroundings in the crucial development period and that the child's ability to notice distances between objects and himself are limited as well. This further leads to diminished sensorimotor development which in turn affects handwriting skills, ability to copy gestures or letters or patterns. There was one positive outcome for BC children, which was that they developed a strong emotional- and social bond with their mother (or the person carrying them), however a small sample of the children had difficulty with unfamiliar situations which the researchers linked to their limited discovery or exploration ability whilst being BC (Pretorius *et al.*, 2002a:593).

The *Obui-himo* is a carrier device or band used by Japanese mothers in which the child's weight is mainly supported under the arms and the perineum (Imanishi *et al.*, 1998:1249). Long duration BC with the use of this *Obui-himo* band causes compression of the axillary veins, in the child, which in turn could lead to swelling of the arm in children lacking the cephalic vein (Imanishi *et al.*, 1998:1248-1249). Under normal circumstances, venous blood returning from the hand and arm would travel through the axillary vein to the subclavian vein and the cephalic veins. The latter runs into the subclavian vein over the axilla. Thus, in the absence of the cephalic vein, venous blood cannot return to central circulation since the axillary vein is compressed, causing the limb to swell and become cyanotic. This is known as "*Obui-himo syndrome*" (Imanishi *et al.*, 1998:1249).

In terms of LL development and BC, Golding (1994:181) analysed the mechanical factors that might influence bone growth in children and observed a low incidence of tibia vara, yet a high incidence of genu valgum in practice at the Ibadan University Hospital in West Africa. Her hypotheses were that this low incidence of tibia vara was due to the BC practices of the West African mothers. She postulated that the fastening method of BC produces a constant valgus force and external torsion pressure upon the LL and feet. Further, the higher incidence of internal tibial torsion (TT) in West African children contributes to the development of genu valgum. This reasoning was based upon the treatment of a daughter of a Ghanaian lecturer whose older daughters had normal limb alignment, but the youngest presented with tibia vara. The youngest had grown up in Australia, whilst her older siblings grew up in Ghana. The youngest was not BC, whilst the older siblings were both BC (Golding, 1994:181). Many years prior to the argument of (Golding, 1994:181), another medical doctor reasoned that long-duration wearing of thick cloth nappies and regular continuous straddle carrying of a child, would lead to the development of genu varum (Knight, 1954:522-523). Leveau *et al.* (1984:1879) states in their review on the effects of forces on growth and development that "*Both double diapering and straddle carrying can force persistence of normal varus positioning*". The statement is based on work by Knight (1954:522-523), a medical doctor, who was interested in the effects of long-duration sitting and sleeping postures of infants, leading to LL deformities such as genu-varum and internal TT. He postulated, but never investigated, that mothers carrying their young with their legs wrapped around their waist (straddle carrying positions, similar to those attained in a BC position) would lead to genu varum. The 1954's did not yet have the benefits of modern nappies, and mothers would use cloth nappies along with plastic diaper covers. Knight (1954:523) reasoned the thick diaper forced the child's legs into hip abduction, flexion and knee flexion, which would contribute to the development of genu varum in the child. Both these statements were made without empirical research and were based upon their observations in clinical practice.

In order to determine the effects of BC on LL development at the hip, knee, and ankle, LL development profile data is required. Information on BC will be collected during a clinical investigation for the first objective. Data from BC children will be compared to the data from non-BC children to allow the determination of the second objective. The second objective is to determine the relationship between frontal plane (FP) LL angle measures (TFA and the Q-angle) in Setswana-speaking children between the ages of two- to nine years, who were BC during infancy and toddler ages and their non-BC Setswana counterparts. The hypothesis is that greater genu varum will be observed in the BC sample compared to the non-BC sample. The reasoning for the interest in determining genu varum in BC children is based on the carrying angle, with the legs in flexion and abduction around the mother's waist. Other than the unverified observational hypothesis of Golding (1994:181), that a low incidence of tibia vara and hence genu varum was due to BC practices of West African mothers, no other research has been done on knee development of children who were BC. A similar gap in the research exists for BC and its rotational effects on the LL, which will be addressed by the third objective, where the relationship between femoral retroversion (RV) and medial TT, in Setswana-speaking children between the ages of two to nine years, who were BC during infancy and toddler ages and their non-BC Setswana counterparts will be determined. Both objectives two and three will be addressed in Chapter four.

The section above introduced a gap in the literature, warranting further investigation. The TFA can be used to determine the presence and severity of either genu varum or genu valgum. The following section describes how the TFA develops throughout infancy to childhood, as well as the methods that can be employed to measure the angle as well as other methods to determine genu valgum or genu varum.

2.6. PROFILE AND DEVELOPMENT OF THE TIBIOFEMORAL ANGLE (TFA)

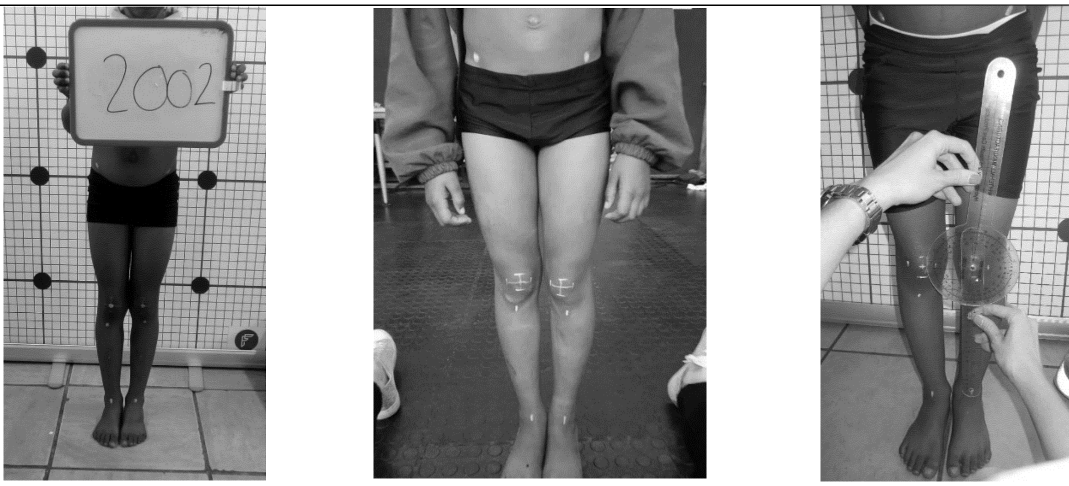
According to the Stedman (2001:803) medical dictionary, when investigating the profile of an object or joint, the outline or contour of the joint from a particular point of reference view or cardinal plane is investigated. The cardinal planes include the frontal- (dividing the body in anterior and posterior sections), sagittal- (dividing the body into a left and a right side) or transverse (dividing the body into an upper and lower part) planes (Stedman, 2001:803). Thus, in order to investigate the profile and development of the TFA, this thesis will describe it in terms of the FP and the TP. The tibiofemoral joint (TFJ) is not static and its profile in the FP and TP develops and changes from birth, depending on various factors which will be discussed later, throughout the child's life. Various methods exist to investigate tibiofemoral profile development in the FP, of which the TFA is most popular.

2.6.1. Measurement techniques of the tibiofemoral angle (TFA)

The TFA is the angle formed by the juncture between the mechanical axis of the femur and tibia (Saini *et al.*, 2010:579). Various techniques exist to determine this angle, including clinical, radiologic and photographic techniques (Saini *et al.*, 2010:579-580). When working with children one wants to limit unnecessary radian exposure, thus photographic and clinical techniques are preferred as they associate well with radiological procedures and are also cheaper than radiological investigations (Omololu *et al.*, 2003; Saini *et al.*, 2010:580; Bafor *et al.*, 2012:1249).

Cheng *et al.* (1991:155) aimed to establish norms for Chinese children between the ages of two- to 12 years. They investigated the development of the LL in 2 630 children, and their clinical method is often employed by other researchers (Arazi *et al.*, 2001:264; Saini *et al.*, 2010:580; Bafor *et al.*, 2012:1249; Kaspiris *et al.*, 2013:297; Oyewole *et al.*, 2013:168). Cheng *et al.* (1991:155) measured the clinical TFA by placing the standing child's lower legs carefully with the knees or ankles in close touching approximation. The measurer must ensure that the knees are in neutral rotation, with the hips and knees in full extension. The anterior superior iliac spines (ASIS) and the centre of the patella as well as the midpoint of the ankle joints are marked with skin dots. Both the femoral and tibial axes are palpated and marked (Figure 2-a-b). As shown in Figure 2-7c, a goniometer is used to measure the varus- (positive) or valgus angle (negative) in degrees, using the centre of the patella as the point of origin (Cheng *et al.*, 1991:155).

Measuring the intercondylar distances (ICD) between the medial epicondyles of the knees (Figure 2-8b) is an alternative clinical method that can be employed to determine the presence of genu varum in children and adults (Cahuzac *et al.*, 1995:730; Arazi *et al.*, 2001:265; Omololu *et al.*, 2003:301; Magee, 2006:667; Saini *et al.*, 2010:581; Bafor *et al.*, 2012:1249; Kaspiris *et al.*, 2013:297; Oyewole *et al.*, 2013:168). Magee (2006:667) states that a distance of 4.0 cm between the epicondyles is considered excessive and indicative of genu varum.



a **b** **c**

Figure 2-7: (a & b) Landmarks, top to bottom: Anterior superior iliac spine (ASIS), centre of patella, tibial tuberosity & tibial axes, centre of malleoli (c) Measurement of the tibiofemoral angle (TFA) using a goniometer*[15]*

Measurement of the intermalleolar distances (IMD) (Figure 2-8a) is similarly used to determine the presence of genu valgum in children and adults (Magee, 2006:667). This distance between the medial malleoli at the ankles is measured with the knees placed together and is seen as positive when the distance exceeds 9.0 cm (Magee, 2006:667). As mentioned above, both the TFA and IMD or ICD change with an increase in age (Cheng *et al.*, 1991:155), these developments will now be discussed.

a **b**

Figure 2-8: (a) Measurement of the intermalleolar distance (IMD) and (b) Measurement of the intercondylar distance (ICD)*[16]*

[15] Photos demonstrated and published with permission – photos by M. van Aswegen
[16] Photos demonstrated and published with permission – photos by M. van Aswegen

2.6.2. Development of the tibiofemoral angle (TFA)

TFA and ICD or IMD measurements, as found by various authors, are presented in Table 2-1 to Table 2-6, reported in positive degrees for varum angles and negative degrees for valgus angles.

2.6.3. Normal progression of the tibiofemoral angle (TFA) with age

In normal healthy children, there is a natural progression of the knee angle. Infants present with knee varus angles (bowlegs) shortly after birth, which changes to a valgus angle (knock knees) in early childhood and later deviates back to a 0° angle (straight) (Salenius *et al.*, 1975:261; Magee, 2006:666; Ginesin *et al.*, 2018:109). A widening of the pelvis may be the reason for the change in the knee angle from a varus- to valgus angle (Sass *et al.*, 2003:468). On the other hand, Salenius *et al.* (1975:261) argue the change from varus to valgus is attributed to walking. In early walking (regardless of the child's age), the child lacks stability and walks with the feet wide apart, to improve stability (Malina, 2004:53). This gait increases lateral pressure in the knee, allowing faster growth of the medial knee compartment, ultimately leading to tibial valgus positions (Salenius *et al.*, 1975:261). In general, the ages by which the different knee alignments (genu varum, -valgum and neutral) are attained differ depending on the ethnicity of the population. In general, children tend to present with genu varum until 18 months, before the knee angle straightens (Sass *et al.*, 2003:468). Thereafter, children present with genu valgum until their third or fourth birthday (Sass *et al.*, 2003:468). By the age of six years, most children present with no knee angle deformity, whilst the adult knee tends to present with a genu valgum angle of approximately 6.0° (Magee, 2006:666-667). These angles vary mildly (-14.1° valgum to 4.3° varum) between children from different ethnicities, as described below (Table 2-1 to Table 2-6).

Three separate studies investigated the TFA of Nigerian children (Table 2-1), Bafor *et al.* (2012:1248) found a maximum valgus knee angle of -7.9° in three-year-olds, which then steadily decreased to -1.0° by the age of ten years. No significant differences were noted between males and females and a negative correlation between TFA and body mass (Bafor *et al.*, 2012:1250). Omololu *et al.* (2003:303), on the other hand, reported maximal varum angles in one- to three-year-olds, which changed to neutral or 0° for females at five years of age, and for males at seven years. ICD values of 0.8 cm ±1.5 cm was obtained at one year of age by both Omololu *et al.* (2003:303) and Oyewole *et al.* (2013:171), whilst IMD values reported by all three Nigerian studies vary, but are in close agreement with another (Table 2-2). After the age of seven years, no genu varum angles greater than 0° were observed (Omololu *et al.*, 2003:303).

In terms of genu valgum, researchers found that in one to ten-year-olds all presented with an angle of approximately -11°, which did not differ significantly between males and females (Table 2-1). Maximal valgus seems to occur at age of three years, at -14.1° ±5.8° for the left knee and -14.2° ±5.6° for the right knee (Omololu *et al.*, 2003:Table 3), although the authors did not make any mention of this (Omololu *et al.*, 2003:304). The participant numbers reported for valgus- and varus angles by Omololu *et al.* (2003:303) seem as if a minor error occurred when these values were reported. However, the rest of their data is still valuable to use. Unfortunately, the authors did not respond to the communication sent to them, to solve the matter.

Oyewole *et al.* (2013:168) performed a longitudinal study of the TFA in Nigerian children from birth until three years of age and found no significant differences between left and right limb angles nor between genders. Results were consequently pooled as one mean value per age. Maximal genu varum of 13.2° ±3.8° was reported at birth to age three weeks. By ten- to 12 months, the varus angle had significantly decreased to 6.6° ±0.1° and by 16 to 18 months it had further decreased to 1.99°. Genu varum disappeared completely after 18 months and a valgus of -3.8° ±0.3° was found. A maximal valgus angle of -8.38° ±0.3° was observed shortly after the participants' second birthday (between 25 to 27 months), by three years of age, the valgus angle had increased to -6.6° ±0.2° (Oyewole *et al.*, 2013:171). All three these researchers found maximal valgum at ages two to three years in their separate investigations, with Bafor *et al.* (2012:1248) and Oyewole *et al.* (2013:171) reporting similar values of -7.87° ±0.36° and -6.62° ±0.21° respectively, whilst Omololu *et al.* (2003:303) found a greater valgus of -14.1° ±5.7° (Table 2-1). This might be attributed to individual measurement technique differences. It should be noted that the values reported here for Omololu *et al.* (2003:303) are measurements that were performed in a standing position, while measurements that were performed in supine, were significantly lower than those in a standing position (Table 2-7).

Cheng *et al.* (1991:157) found a decrease in the TFA from birth (-4°±8°) to a maximum of -8° ±8.0° valgus at 3.5 years in Chinese children (Table 2-3). No significant differences were reported between males and females. Cheng *et al.* (1991:157) were the only researchers (reported here), who did not find any genu varum at birth in terms of TFA, but found an ICD of 3.0 cm ±3.0 cm in newborns, which decreased to 0.0 cm ±3.0 cm by one-year of age (Table 2-2 and Table 2-3). The maximal IMD was observed in three-year-old children (-2.8 cm ±3 cm) (Cheng *et al.*, 1991:158).

Table 2-1: A summary of studies reporting on the tibiofemoral angle (TFA) measurements in degrees for Nigerian children, per gender

Demographical region		Measurements of the Tibiofemoral Angle (TFA) TFA **means in** degrees ±Standard deviation (number of participants), positive = varum, negative = valgus									
Age (years)		**1 yr**	**2 yr**	**3 yr**	**4 yr**	**5 yr**	**6 yr**	**7 yr**	**8 yr**	**9 yr**	**10 yr**
Nigerian children[17] (N=471)	**Males**	-	-	-8.24±0.48 (n=25)	-6.09±0.32 (n=32)	-5.63±0.27 (n=28)	-4.66±0.21 (n=32)	-4.63±0.20 (n=32)	-3.10±0.20 (n=31)	-1.81±0.19 (n=34)	-1.20±0.19 (n=33)
	Females	-	-	-7.4±0.53 (n=20)	-5.76±0.26 (n=25)	-5.28±0.39 (n=27)	-4.91±0.22 (n=28)	-4.5±0.24 (n=28)	-3.43±0.29 (n=29)	-1.28±0.12 (n=34)	-0.74±0.02 (n=33)
	Total (N=471)	-	-	-7.87±0.26 (n=45)	-5.95±0.21 (n=57)	-5.45±0.23 (n=55)	-4.78±0.15 (n=60)	-4.57±0.15 (n=60)	-3.26±0.17 (n=60)	-1.54±0.11 (n=68)	-0.97±0.12 (n=66)
Nigerian children[18] N=2166	**Left varum**	1.4±5.0 n=108	1.6±4.1 n=163	0.6±2.4 n=200	0.2±1.1 n=250	0.1±1.2 n=227	0.3±1.9 n=270	0.1±0.7 n=222	0.0±0.0 n=242	0.0±0.3 n=260	0.0±.05 n=224
	Right varum	1.5±5.3 n=108	1.7±4.0 n=163	0.6±2.3 n=200	0.2±1.0 n=250	0.2±1.4 n=227	0.2±1.9 n=270	0.0±0.5 n=222	0.0±0.0 n=242	0.0±0.3 n=260	0.0±0.0 n=224
	Left valgum	-11.1±5.8 n=108	-12.5±7.1 n=163	-14.1±5.8 n=200	-11.1±5.5 n=250	-10.0±4.9 n=227	-9.2±3.9 n=270	-10.9±3.0 n=222	-10.1±3.0 n=242	-10.5±3.1 n=260	-10.5±2.9 n=224
	Right valgum	-11.3±5.9 n=108	-12.5±7.0 n=163	-14.2±5.6 n=200	-11.0±6.0 n=250	-9.7±5.3 n=227	-9.0±3.9 n=270	-11.0±2.9 n=222	-10.1±2.9 n=242	-10.4±3.0 n=260	-10.5±2.9 n=224
Nigerian children[19] (N=152)	**Total**	6.64±0.11 (n=152)	-6.03±0.33 (n=138)	-6.62±0.21 (n=113)	-	-	-	-	-	-	-

Legend: n = number of participants per age, N = total number of participants, SD = standard deviation, TFA = tibiofemoral angle (valgus = negative values, varus = positive values), yr = year(s)

Maximal valgus Maximal varus Neutral angle

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[17] Bafor *et al.* (2012:1248) bilateral mean varum or valgus angles for males and females individually and combined, ±2SD. No significance based on sex (p=0.088)

[18] Omololu *et al.* (2003:302-303) analysis showed only significant covariance for age, not sex, thus means and ±2SD for sexes reported combined. Measures in standing. Max varus at ages 1 to 3, neutral for females at 5 yrs and for males at 7 yrs. Valgus angle remained the same throughout 1 to 10yrs.

[19] Oyewole *et al.* (2013:171) longitudinal study (N=152), attrition of 25.7%, (N=113 at 3 years). Reported means and ±2SD for males and females combined. High correlation for limbs (r=0.992, p=0.01), no significant differences according to sex (t=0.88, p=0.38).

Table 2-2: Intercondylar distance (ICD) and intermalleolar distance (IMD) measurements in centimetre for Nigerian, Chinese, and Turkish children

Demographical region		Measurements of intercondylar- (ICD) and intermalleolar distances (IMD) ICD or IMD means in centimetre ±Standard deviation (number of participants), positive = ICD, negative = IMD									
Age (years)		1 yr	2 yr	3 yr	4 yr	5 yr	6 yr	7 yr	8 yr	9 yr	10 yr
Nigerian children[20] (N=471)	Males	-	-	-1.74±0.248 (n=25)	-1.38±0.199 (n=32)	-0.64±0.117 (n=28)	-0.297±0.084 (n=32)	-0.203±0.100 (n=32)	-0.194±0.076 (n=31)	-0.132±0.090 (n=34)	-0.015±0.015 (n=33)
	Females	-	-	-1.81±0.192 (n=20)	-0.68±0.181 (n=25)	-0.43±0.143 (n=27)	-0.161±0.052 (n=28)	-0.143±0.067 (n=28)	-0.241±0.101 (n=29)	-0.061±0.047 (n=34)	-0.030±0.021 (n=33)
	Total (N=471)	-	-	-1.77±0.161 (n=45)	1.07±0.144 (n=57)	-0.54±0.093 (n=55)	-0.233±0.51 (n=60)	-0.175±0.062 (n=60)	-0.217±0.062 (n=60)	-0.097±0.051 (n=68)	-0.023±0.013 (n=66)
Nigerian children[21] N=2166	ICD	0.78±1.45 N=108	0.25±1.00 N=163	0.11±0.60 N=200	0.15±0.71 N=250	0.22±0.59 N=227	0.34±1.09 N=270	0.10±0.43 N=222	0.22±0.61 N=242	0.16±0.64 N=260	0.10±0.43 N=224
	IMD	-1.47±1.51 N=108	-2.33±1.68 N=163	-2.12±1.65 N=200	-2.02±1.75 N=250	-1.45±1.62 N=227	-1.63±1.86 N=270	-0.86±1.29 N=222	-0.73±1.14 N=242	-0.81±1.17 N=260	-1.00±1.38 N=224
Nigerian children[22] (N=152)	Total	0.80±0.04 (n=152)	-1.65±0.18 (n=138)	-1.69±0.17 (n=113)	-	-	-	-	-	-	-
Chinese children[23] N=2500	Total (N=2323)	0±3 (n=29)	-2±3 (n=38)	-2.8±3 (n=180)	-2.2±3 (n=400)	-1.2±3 (n=450)	-0.6±3 (n=487)	-0.1±3 (n=189)	0.2±3 (n=175)	0.1±3 (n=180)	0±3 (n=195)
Turkish Children[24] (N=590)	Males (n=148)	-	-	-2.2±1.7 (n=12)	-1.7±1.1 (n=20)	-2.2±2.0 (n=16)	-1.0±1.1 (n=20)	-1.1±0.9 (n=19)	-0.2±1.0 (n=26)	-0.2±1.1 (n=20)	0.1±0.9 (n=15)
	Females (n=122)	-	-	-2.1±1.2 (n=14)	-2.0±1.0 (n=13)	-2.2±1.1 (n=11)	-1.3±1.4 (n=18)	-1.3±1.5 (n=16)	-0.9±1.5 (n=19)	-0.6±1.1 (n=14)	-0.3±0.5 (n=17)

Legend: ICD = intercondylar distance (positive values), IMD = intermallealoar distance (negative values), n = number of participants per age group, N = total number of participants, SD = standard deviation, TFA = tibiofemoral angle, yr = year(s)

Maximal valgus   Maximal varus   Neutral angle

[20] Bafor *et al.* (2012:1248) bilateral mean varum or valgus angles for males and females individually and combined, ±2SD. No significance based on sex (p=0.088)
[21] Omololu *et al.* (2003:302-303) significant covariance for age, not sex, thus means and ±2SD for sexes reported combined. Measures in standing. Max ICD until age 1, max IMD ages 2 to 4 years,
[22] Oyewole *et al.* (2013:171) longitudinal study (N=152), attrition of 25.7%, (N=113 at 3 years). Reported means and ±2SD for males and females combined. No significant differences according to sex (t=0.88, p=0.38).
[23] Cheng *et al.* (1991:157) mean totals for males and females combined, although females had slightly greater ICD values than males (p=0.0156) and a normal range of ±3 cm. Read from figures.
[24] Arazi *et al.* (2001:265-266) measured 3- to 17-year-olds. Reported means and ±2SDs for males and females (3-10 yr olds only), read from figures. Significant differences found in 6- and 10-year-olds and older ages, between genders.

Yoo *et al.* (2008:715-716) investigated TFA development in Korean children radiographically and found varus alignment (4.1° ± 6.1°) in children younger than one year which changed to neutral alignment by 1.5 years and then turned into a valgus (-2.6° ± 5.9°) alignment by two years (Table 2-3). They found a maximal valgus of -7.8° ±3.9° in four-year-old children which decreased to -5.8° ±2.5° at an age of seven years and then plateaued until age 15 years. Male and female TFAs showed similarity and only differed significantly at ages three (males: -6.3°±3.5°; females: -4.5°±2.3°) and age 12 (males: -4.9±2.1°, females: -6.6°±1.2°) (Yoo *et al.*, 2008:716).

In Turkish kids, (Table 2-3), Arazi *et al.* (2001:265-266) reported significant differences in TFA between gender in older children from the ages of 13 years (p=0.014), 14 years (p=0.000) and 16 years (p=0.004). They observed a maximal valgus (-9.8° ±1.4°) in six-year-old females, which did not differ significantly from the valgus in six-year-old males (-9.6° ±1.5°). After the age of six, the TFA gradually increased in both sexes to -6.6° ±1.8° in females and -7.5° ±2.0° in males at the age of 17 years (Arazi *et al.*, 2001:265). Significant differences in IMD between genders were observed at six-year-olds (p=0.015), 10-year-olds (p=0.044), 12-year-olds (p=0.016), 13-year-olds (p=0.016) and 15-year-olds (p=0.001) (Table 2-2).

Valgus angles increased dramatically between two- and three-year-old Malay children (Table 2-3), thereafter the valgus angle steadily decreased until age five years (Mohd-Karim *et al.*, 2015:10). A total of 160 children between two- and six years old were tested in this study, because the authors argued that the most change in the TFA occurs between these ages. Left and right measures were pooled, and no comparison between limbs was made. Statistically significant differences between males and females were only observed in the five-year-olds (p=0.037), where females presented with greater valgus than the males (Table 2-3) (Mohd-Karim *et al.*, 2015:11).

Table 2-4 summarises the findings of three different studies on TFA development in Indian children. Saini *et al.* (2010:581-582) did not find any varus angles in children older than two years old and reported statistically significant differences between Indian males and females at three-, five and six years of age. Left and right limb measurements did not differ significantly. They measured both ICD and IMDs but did not report their findings per age, instead stated that they found a negative correlation between TFA and ICD with r = -0.247 (p=0.000) and a positive correlation between TFA and IMD with r = 0.162 (p=0.018). ICD was found to increase with an increase in TFA, whilst IMD values decreased (become negative) with a decrease in TFA. The maximal valgus TFA of -7.5° ±2.2° in five-year-old males, whilst the maximal valgus angle for females was -9.0° ±1.9° at the age of six years old. The valgus angle increased to a range of -5.8° ±1.5° to -5.3° ±2.3° in seven- to ten-year-old males and -4.6° ±2.1° in 15-year-old males, whilst the valgus angle remained slightly higher in females and ranged between -6.4° ±2.0°

to -5.6° ±1.9° in seven- to ten-year-old females and -5.0° ±0.8° in the 15-year-old females (Saini *et al.*, 2010:582). In tribal Indians Kumar *et al.* (2016:77) found similar results to those of Saini *et al.* (2010) with no significant differences between the left and right limb measurements and also did not note any varus angles in children older than two years.

The maximal valgus (-7.6°±2.9°) was similarly noted in six-year-old females whilst the males from this age category had a significantly lower valgus angle of -5.5°±1.7°, but differently to Saini *et al.* (2010:582) the maximal valgus (-6.5°±2.2°) in males were only observed in seven-year-old males. Mathew *et al.* (2013:158) also did not observe varus angles in children older than two years of age in their study performed on South Indian children and only ten children from their total sample of 360 presented with genu varum. They combined the measurement angles of children between two to three years old, five to six years, eight to nine years (reported in Table 2-4 above), 11- to 12 years, 14- to 15 years and lastly 17- to 18 years.

Table 2-3: A summary of studies reporting on the tibiofemoral angle (TFA) measurements in degrees for Asian, Turkish, and Malay children, per gender

Demographical region		Measurements of Tibiofemoral Angles (TFA) TFA means in degrees ±Standard deviation (number of participants), positive = varum, negative = valgus									
Age (years)		1 yr	2 yr	3 yr	4 yr	5 yr	6 yr	7 yr	8 yr	9 yr	10 yr
Chinese children[25] N=2500	Total (N=2323)	-4±8 (n=29)	-7±8 (n=38)	-7.5±8 (n=180)	-7.8±8 (n=400)	-6±8 (n=450)	-5±8 (n=487)	-2.5±8 (n=189)	-1±8 (n=175)	-0.8±8 (n=180)	-0.5±8 (n=195)
Korean children[26] N=452	Males (n=318)	3.8±5.9 (n=22)	-3.8±6.2 (n=63)	-6.3±3.5 (n=63)	-8.3±3.8 (n=31)	-7.6±1.9 (n=28)	-7.2±2.4 (n=20)	-5.5±2.4 (n=12)	-6.1±2.8 (n=28)	-5.5±2.4 (n=22)	-5.2±2.3 (n=29)
	Females (n=307)	4.3±6.2 (n=32)	-2.1±5.5 (n=52)	-4.5±2.3 (n=48)	-7.4±4.0 (n=31)	-6.3± 2.8 (n=29)	-5.6±3.8 (n=22)	-6.0±2.7 (n=27)	-5.0±3.4 (n=26)	-4.3±2.9 (n=24)	-5.7±1.4 (n=16)
	Total (n=625)	4.1±6.1 (n=54)	-2.6±5.9 (n=115)	-5.5±3.2 (n=111)	-7.8±3.9 (n=62)	-7.0±2.5 (n=57)	-6.4±3.3 (n=42)	-5.8±2.5 (n=39)	-5.6±3.2 (n=54)	-4.9±2.7 (n=46)	-5.4±2.9 (45)
Turkish Children[27] (N=590)	Males (n=148)	-	-	-9.6±1.5 (n=12)	-9.6±1.0 (n=20)	-9.5±1.5 (n=16)	-9.6±1.5 (n=20)	-9.6±1.1 (n=19)	-8.2±1.9 (n=26)	-8.4±1.9 (n=20)	-7.9±1.8 (n=15)
	Females (n=122)	-	-	-9.7±1.4 (n=14)	-9.3±1.1 (n=13)	-9.3±1 (n=11)	-9.8±1.4 (n=18)	-9.3±1.6 (n=16)	-7.7±1.8 (n=19)	-9.6±1.9 (n=14)	-8.5±1.4 (n=17)
Malay Children[28] (N=160)	Males (N=80)	-	-2.16±0.51 (n=16)	-8.91±1.17 (n=16)	-7.22±1.41 (n=16)	-6.97±1.26 (n=16)	-6.84±0.99 (n=16)	-	-	-	-
	Females (N=80)	-	-2.34±0.55 (n=16)	-8.56±0.62 (n=16)	-7.84±1.35 (n=16)	-7.56±0.95 (n=16)	-6.59±0.98 (n=16)	-	-	-	-
	p-value	-	0.162	0.148	0.074	**0.037**	0.313	-	-	-	-
	Total	-	-2.25±0.53	-8.73±0.95	-7.53±1.40	-7.27±1.14	-6.72±0.98	-	-	-	-

Legend: n = number of participants per group, N = total number of participants, SD = Standard deviation TFA = Tibiofemoral angle (valgus = negative values, varus = positive values), yr = year(s)

Maximal valgus Maximal varus Neutral angle

[25] Cheng *et al.* (1991:157) reported mean totals for males and females combined (p=0.7979) and a normal range of ±8°. Read from figures.
[26] Yoo *et al.* (2008:714) reported mean TFA for males and females between 1 to 15 years old. TFA measured from radiographs. (N=number of children) (n=number of limbs measured)
[27] Arazi *et al.* (2001:265-266) measured children between 3- to 17years old. Reported means and ±2SDs for males and females (3-10 yr olds only), read from figures. Significant differences found in older ages between males and females.
[28] Mohd-Karim *et al.* (2015:10) measured children between 2- to 6 years old. Reported means and ±SD for males andfemales.

Table 2-4: A summary of studies reporting on the tibiofemoral angle (TFA) measurements in degrees for Indian children, per gender

Demographical region		Measurements of Tibiofemoral Angles (TFA) TFA means in degrees ±Standard deviation (number of participants), positive = varum, negative = valgus									
Age (years)		**1 yr**	**2 yr**	**3 yr**	**4 yr**	**5 yr**	**6 yr**	**7 yr**	**8 yr**	**9 yr**	**10 yr**
Indian children[29] (N=215)	**Males (N=92)**	-	-1.0±3.1 (n=12)	-1.6±3.6 (n=13)	-3.9±1.4 (n=8)	-7.5±2.2 (n=10)	-7.2±2.6 (n=9)	-5.8±1.5 (n=7)	-5.7±2.5 (n=10)	-5.3±2.2 (n=9)	-5.3±2.3 (n=14)
	Females (N=61)	-	-1.0±3.6 (n=5)	-3.4±1.5 (n=8)	-4.8±1.3 (n=7)	-5.9±1.8 (n=9)	-9.0±1.9 (n=6)	-6.4±2.0 (n=6)	-6.7±1.8 (n=8)	-5.9±1.0 (n=4)	-5.6±1.9 (n=8)
	p-value	-	1.00	0.033*	0.077	0.022*	0.038*	0.379	0.198	0.395	0.601
Indian children[30] (N=360)	**Males (N=150)**	-	-1.2±0.79 (n=15)	-2.65±1.70 (n=15)	-4.3±2.57 (n=15)	-5.16±2.08 (n=15)	-5.50±1.74 (n=15)	-6.46±2.22 (n=15)	-5.30±1.80 (n=15)	-5.26±2.11 (n=15)	-5.13±1.82 (n=15)
	Females (N=150)	-	-1.78±1.36 (n=15)	-3.73±2.42 (n=15)	-4.70±2.66 (n=15)	-5.53±2.09 (n=15)	-7.60±2.91 (n=15)	-6.73±2.65 (n=15)	-6.33±1.82 (n=15)	-5.46±1.63 (n=15)	-5.93±1.66 (n=15)
	p-value	-	0.162	0.167	0.678	0.635	0.023*	0.768	0.130	0.774	0.221
South Indian children[31] (N=360)	**Females**	-	-2.45±0.87		-	-7.25±0.64		-	-5.76±2.23		-
	Males	-	-1.80±0.65		-	-6.70±1.30		-	-4.86±1.06		-
	Mean difference	-	-0.65(-1.0 to -0.21) p=0.003		-	-0.55(-1.1 to 0.03) p=0.06		-	-0.9(-1.8 to 0.003) p=0.05		-
North-East Indian children[32] (N=1020)	**Females (N=504)**	-	-1.49	-3.53	-4.50	-5.14	-6.44	-8.81	-6.85	-6.30	-6.00
	Males (N=516)	-	-0.19	-3.01	-3.80	-5.40	-6.42	-8.38	-7.48	-6.57	-5.90
	Total	-	-0.82±2.70	-3.26±1.10	-4.15±2.25	-5.28±2.16	-6.43±1.33	-8.55±1.06	-7.16±1.35	-6.44±1.17	5.95±1.59

Legend: n = number of participants per group, N = total number of participants, SD = Standard deviation, TFA = Tibiofemoral angle (valgus = negative values, varus = positive values), yr = year(s)

Maximal valgus Maximal varus Neutral angle

[29] Saini *et al.* (2010:582) reported means for males and females, ±2SD and P-value. Tested 2- to 15-year-olds.
[30] Kumar *et al.* (2016:77) measured children between 2-14 years of age. Reported means and ±SDs for 2- to 10-year-old males and females.
[31] Mathew *et al.* (2013:158) measured children between 2-18 years of age, grouped their results per ages, ±SDs and mean difference values (95% CI) of TFA and p-values. Reported means and ±SDs for 2-10 yr old males and females.
[32] Baruah *et al.* (2017:343) measured right limb of male and female children, between 2 to 18 years of age, ±SDs of TFA. Reported means and ±SDs for 2- to10 year-old males and females

Table 2-5: Intercondylar distance (ICD) and intermalleolar distance (IMD) measurements in centimetre for Indian, European, and American children

Demographical region		Measurements of intercondylar- (ICD) and intermalleolar distances (IMD) ICD or IMD means in centimetre ±Standard deviation (number of children per age group), positive = ICD, negative = IMD									
Age (years)		**1 yr**	**2 yr**	**3 yr**	**4 yr**	**5 yr**	**6 yr**	**7 yr**	**8 yr**	**9 yr**	**10 yr**
South Indian children[33] (N=360)		-	-	-	-	-3.3	-3.3	-	-	-	-
North East Indian children[34] (N=1020)	**Total (N=?)**	-	-0.78±0.71	-1.21±0.46	-1.83±0.68	-1.79±1.04	-1.80±0.70	-2.17±0.47	-1.94±0.67	-1.87±0.61	-1.95±0.75
European children[35] (N=427)	**Males (N=212)**	-	-	-	-	-	-	-	-	-	0.0±0.5 (n=37)
	Females (N=215)	-	-	-	-	-	-	-	--	-	-1.9±0.7 (n=25)
European (Czech) children[36] (N=282)	**Males (N=156)**	-	-	-	-1.1±1.4 (n=15)	-1.1±2.2 (n=24)	0.5±0.9 (n=51)	0.3±0.7 (n=22)	-	0.2±0.6 (n=22)	-
	Females (N=126)	-	-	-	-1.1±1.2 (n=16)	-0.5±1.1 (n=29)	0.4±1.0 (n=15)	0.3±0.6 (n=22)	-	0.6±1.3 (n=22)	-
American White children[37]	**Males & Females (N=196)**	2.6±1.5 at 6 months 0 at 1 yr	not disclosed	-3.5±1.3	-3.5±2.0	> -2	> -2	-2.1±2.2	> -2	> -2	> -2

Legend: n = number of participants per age group, N = total number of participants, SD = standard deviation, ICD = intercondylar distance (positive values), IMD = intermalleolar distance (negative values)

Maximal valgus   Maximal varus   Neutral angle

[33] Mathew *et al.* (2013:158) did not tabulate results. Mean IMD -1.58 cm (±0.89). Only 10 children from whole sample presented with varus ICD
[34] Baruah *et al.* (2017:343) measured 2- to 18-year-olds. Reported ±1SD for 2- to 10-year-olds only. (N = ?) Number participants per age group is unknown
[35] Cahuzac *et al.* (1995:730) measured males and females between 10 and 16 years old. Only reported means for males and females from their group for 10- to 11-year-olds, read from figures.
[36] Petrášová *et al.* (2012:66) measured males and females between 4- to 7.99 years, 9- to 9.99 yrs and 11- to 11.99 years. Reported means and ±SDs for males and females.
[37] (Heath *et al.*, 1993) photographic measurement of TFA of children between 1- to 11 years. Reported mean totals for males and females combined. Read from figures.

Similar to both Saini *et al.* (2010:582) and Kumar *et al.* (2016:77) peak valgus angles were observed in five to six-year-olds with males -6.7° ±1.3° and females -7.3° ±0.6° ($p=0.06$). Mathew *et al.* (2013:158) reported a mean IMD of 1.6 cm (±0.9) and similarly to Saini *et al.* (2010) did not report the ICD or IMD values obtained per age group. They found that even the slightest deviation in the posture of the participants, it would impact the accuracy of the ICD or IMD obtained and reasoned that the measurement and use of TFA are far more reliable and accurate (Mathew *et al.*, 2013:160). Baruah *et al.* (2017:340) conducted a large study on 1020 children between two- to 18-year-old North-East Indians. They measured both the TFA and ICD or IMD in standing. Two-year-olds presented with the closest to neutral TFAs of -0.8° ±2.7°, yet the majority of the group had valgus TFAs. The researcher reported varus TFAs in 15 of the 60 two-year-old children, of which a maximum of +5.0° was found. None of the three-year-olds presented with varus (Baruah *et al.*, 2017:344). The maximum valgus angle of -8.6° ±1.1° was found in seven-year-olds. No statistically significant differences were found between males and females in any of the reported age groups. A significant moderate correlation was reported between the TFA and IMD measures, whereby the IMD (Table 2-5) followed a similar progression to that of the TFA with respect to age (Baruah *et al.*, 2017:345).

TFA development in European and American children are summarised in Table 2-6. Cahuzac *et al.* (1995:730) investigated the development of the TFA in European adolescent children between ten and 16 years of age, and although their study population is older than those investigated in this study, it is significant to mention. Females between ten and 16 years presented with a stable valgus angle of -5.6° to -5.5° and significant gender differences were only noted at 14 years. Other than the females, males started to show a significant decrease of the valgus angle after 14 years of age and 16-year-old males presented with greater bowing than their age-matched female counterparts (males: -4.4° versus females: -5.5°). In another European radiographical investigation of TFA development, Salenius *et al.* (1975:260) observed substantial genu varum in infants to 18-month-olds (+9.7°) where the angle changed closer to neutral by two years (-1.3°) and a maximal valgus angle (-11.3°) was observed in three-year-olds. The valgus angle steadily decreased from the age of four years (-8.8°) to seven years of age (-3.8°), then remained relatively steady from between eight years of age (-6.0°) to ten years of age (-5.1°). In terms of ICD and IMDs (Table 2-5) no significant changes were found in females with maturation, whilst the ICD increased in males from the age of 14 years (-2.0 cm) to -1.5 cm at the age of 16 years (Cahuzac *et al.*, 1995:730). The greatest IMDs were observed in overweight children, but this could probably be attributed to greater adipose tissue deposits at the knees, causing an overestimation of the IMD (Cahuzac *et al.*, 1995:732).

Petrášová *et al.* (2012:70-71) found no statistically significant differences between male and female participants, in their four- to 12-year-old cohort Czechian children (Table 2-6). They reported slightly greater valgus angles when compared to other European reports. The reported greater TFAs measured, could be due to the use of a new anthropometric measurement of the TFA. In this method, vertical and horizontal distances between landmarks such as the greater trochanter, the knee centres and the centre of the ankle joint are used to calculate the TFA mathematically. They performed a secondary photographic protractor measurement of the TFA by connecting lines from the iliospinale anterius to the patellar apex and from the patellar apex to the mid-ankle (Petrášová *et al.*, 2012:67). They suggest that most practitioners rather use IMD or ICD measures (Table 2-5) to determine genu valgum or genu varum, due to the time-consuming process of measuring the TFA. Instead, they recommend the use of the new anthropometric measure, since they find it more accurate than IMD measures, due to postural sway and limb correction, leading to changes in IMD measures (as also mentioned by Mathew *et al.* (2013:160).

Heath *et al.* (1993:260-261) pooled their data for both genders as they did not find any significant differences in their six-month to 11-year-old American participants (Table 2-6). Similar to Salenius *et al.* (1975:260), although not as pronounced, the American one-year-olds also presented with a varus angle of +5.0° (Heath *et al.*, 1993:260) and maximal valgus angles (-8.0°) were found at four years of age which steadily decreased to a valgus of -5.8° at the age of ten years.

In Table 2-7 to Table 2-9, the demographics of each study in terms of ages and races studied, methodological approaches, as well the findings such as the varus, valgus, peak valgus and final valgus values, and whether or not gender variation was observed, per study represented, are summarised. It is evident from the work reported by the researchers mentioned above, that the TFA develops differently in various population groups. However, all follow a similar general progression, from varus angles at birth toward a maximal valgus in toddlerhood and then back toward neutral. Varus angles found in children after two years of age is deemed abnormal and would require further investigation (Heath *et al.*, 1993:262; Baruah *et al.*, 2017:344). Some find statistically significant differences between males and females (Heath *et al.*, 1993; Cahuzac *et al.*, 1995; Arazi *et al.*, 2001; Saini *et al.*, 2010; Mathew *et al.*, 2013; Mohd-Karim *et al.*, 2015; Kumar *et al.*, 2016), while others do not (Salenius *et al.*, 1975; Cheng *et al.*, 1991; Omololu *et al.*, 2003; Yoo *et al.*, 2008; Bafor *et al.*, 2012; Petrášová *et al.*, 2012; Oyewole *et al.*, 2013; Baruah *et al.*, 2017). Radiological measures naturally render the most accurate TFAs, but they are costly and expose the participant to radiation, which should preferably be avoided (Salenius *et al.*, 1975:260; Omololu *et al.*, 2003:301; Yoo *et al.*, 2008:715-716; Saini *et al.*, 2010:580; Bafor *et al.*, 2012:1249).

Table 2-6: A summary of studies reporting on the tibiofemoral angle (TFA) measurements in degrees for European and American children, per gender

Demographical region		Measurements of Tibiofemoral angles (TFA) TFA means in degrees ±Standard deviation (number of participants per age group), positive = varum, negative = valgus									
Age (years)		**1 yr**	**2 yr**	**3 yr**	**4 yr**	**5 yr**	**6 yr**	**7 yr**	**8 yr**	**9 yr**	**10 yr**
European children[1] (N=427)	**Males (N=212)**	-	-	-	-	-	-	-	-	-	5.6±2.13 (n=37)
	Females (N=215)	-	-	-	-	-	-	-	-	-	-5.49±1.4 (n=25)
European children[2]	**Males & Females**	9.70±8.00	-1.25±8.00	-11.25±8.00	-8.75±8.00	-6.9±8.00	-5.6±8.00	-3.75±8.00	-6±8.00	-6.25±8.00	-5.1±8.00
European (Czech) children[3]	**Females (N=126)**	-	-	-	-7.54±2.30 (n=16)	-6.78±2.54 (n=29)	-7.00±2.68 (n=15)	-7.86±2.91 (n=16)	-	-8.00±2.15 (n=22)	-
	Males (N=156)	-	-	-	-6.99±1.64 (n=15)	-6.83±2.59 (n=24)	-5.92±2.27 (n=51)	-6.84±2.56 (n=22)	-	-7.49±2.15 (n=22)	-
American White children[4]	**Males & Females (N=196)**	5±4	-4.5±5	-7.5±2.5	-8±2	-7.1±2	-7.3±2.2	-6.25±2.3	-7±2.4	-6±2.4	-5.8±2.4

Legend: n = number of participants per age, N = total number of participants, TFA = tibiofemoral angle (valgum = negative values, varum = positive values), yr = year(s)

Maximal valgus | Maximal varus | Neutral angle

[1] Cahuzac *et al.* (1995:730) measured males and females between 10 and 16 years old. Only reported means for males and females from their group for 10- to 11-year-olds.
[2] Salenius *et al.* (1975:260) radiographic measurement of interception angle between femoral and tibial longitudinal axes. Read from figures.
[3] Petrášová et al. (2012:66) photographic measurement of TFA of children between 4- to 7.99 years old and 9 years old and 11 years old.
[4] Heath *et al.* (1993) photographic measurement of TFA of children between 1- to 11 years. Reported mean totals for males and females combined. Read from figures.

Table 2-7: A summary of the methods used to obtain the tibiofemoral measures of Nigerian, Asian, Turkish, and Malay children from various age groups

Authors	Children (N) total	Race	Age (years)	Technique	Main findings							
					Varus	Valgus	Peak valgus	Final valgus	Neutral	Gender Variation	Notes
Bafor *et al.* (2012)	471	Nigerian	3 to 10	Clinical TFA measures in standing IMD	-	-	-7.9° in 3 yr olds	1° in 10 yr olds	-	No (p=0.088)	
Omololu *et al.* (2003)	2166	Nigerian	1 to 10	Clinical measures in standing & supine IMD or ICD	Max at 1 to 3 yr No varum after 7 yr	11° in 1 to 10 yr	- Max IMD of -2.5 cm & -2.2 cm at ages 2 & 4 yr	Remain 11° in 1 to 10 yr	Females at 5 yr Males at 7 yr	No, Significant covariance for ages 3 to 7 yr	
Oyewole *et al.* (2013)	152	Nigerian	0 to 3	Clinical measures in supine IMD or ICD	13.2° at birth to 3 wk 6.7° at 3 mo 0.3° at 18 mo	-2.4±2.5° at 19 mo	-8.5±2.5° at 27 mo	-7.7±2.2° at 36 mo	0° at 18 mo	No (p=0.38)	Longitudinal study
Cheng *et al.* (1991)	2630	Chinese	0 to 12	Clinical measures in standing IMD or ICD	- 3 cm ICD in newborns 0 cm ICD at 1 yr	-	-7.5° to -7.8° at 3 & 4 yr Max -2.8 cm IMD at 3 yr	-	-0.8° at 9 yr 0 cm ICD at 8 yr	No	Aimed to also measure the foot-progression angle, but results were unreliable.
Yoo *et al.* (2008)	452	Korean	0 to 16	Radiological; either weight bearing or supine, patella forward to ensure neutral lower limb	<1yr	-	-7.8° at 4 yr	5° to 6° at 7 & 8 yr	At 1.5 yr, then changed to valgus	No	Retrospective radiographical review
Arazi *et al.* (2001)	590	Turkish	3 to 17	Clinical measures in standing IMD or ICD	-		-9.8° in 6 yr females -9.6° in 7 yr males	-7.5° in females -6.6° in males at 17 yr	-	Yes, at 13 yr (p=0.014), 14 yr (p=0.000) & 16 yr (p=0.004)	
Mohd-Karim *et al.* (2015)	160	Malay	2 to 6	Clinical measures in standing	-	-	-8.9 at 3 yr	-	-	Yes, at 5 yr (p=0.037)	

Legend: cm = centimetre, ICD = intercondylar distance (positive values), IMD = intermalleolar distance (negative values), Max = maximum, mo = month(s), SD = standard deviation, SEM = standard error of the mean, TFA = tibiofemoral angle (valgum = negative values, varum = positive values), wk = week(s), yr = year, yr = year(s), < = younger than, > = older than

Table was adapted from Mathew et al. (2013:159), Findings: Reported as TFA means in degrees ± SD

Table 2-8: A summary of the methods used to obtain the tibiofemoral measures of Indian children from various age groups

Authors	Children (N) total	Race	Age (years)	Technique	Main findings						
					Varus	Valgus	Peak valgus	Final valgus	Neutral	Gender Variation	Notes
Saini *et al.* (2010)	215	Indian	2 to 15	Clinical measures in standing IMD or ICD (results not tableted)	< 2yr	> 2yr	-8° at 6 yr Max -4.5 cm IMD at 5yr	4° to 5° at 10yr	-	Yes at 3 yr (p=0.033), 5 yr (p=0.022), 6 yr (p=0.038)	
Kumar *et al.* (2016)	360	Tribal Indian	2 to 14	Clinical measures in standing	-	>2 yr	-6.5°±2.2° (males) at 7 yr -7.6°±2.9° (females) at 6 yr	±6° from 8 yr onwards	-	Only 6 yr olds (p=0.023) Females higher valgus than males in general	
Mathew *et al.* (2013)	360	South Indian	2 to 18	Clinical measures in standing IMD or ICD (results not tableted)	-	2 yr	-6.7°±1.3° (males) -7.3°±0.6° (females) Both at 5 to 6 yr Peak IMD of -3.3 cm in 5 to 6 yr group	-3.2°±1.7° (males) -4.4°±0.7° (females) Both at 17 to 18 yr	-	Yes, females > valgus than males (p=0.0004)	-
Baruah *et al.* (2017)	1020	North-East Indian	2 to 18	Clinical measures in standing IMD or ICD	-	2 yr	-8.6° at 7 yr	-3.18° at 18 yr	-	No significant differences	

Legend: cm = centimetre, ICD = intercondylar distance (positive values), IMD = intermalleolar distance (negative values), Max = maximum, SD = standard deviation, SEM = standard error of the mean, TFA = tibiofemoral angle (valgum = negative values, varum = positive values, yr = year(s), < = younger than, > = older than
Table was adapted from Mathew et al. (2013:159), Findings: Reported as TFA in degrees ± SD

Table 2-9: A summary of the methods used to obtain the tibiofemoral measures of European and American children from various ethnicities and age groups

Authors	Children (N) total	Race	Age (years)	Technique	Main findings						
					Varus	**Valgus**	**Peak valgus**	**Final valgus**	**Neutral**	**Gender Variation**	**Notes**
Cahuzac *et al.* (1995)	427	European	10 to 16	Clinical measures in standing IMD or ICD	-	-	-	-5.6° stable valgus in females 10 to 16 yr < 8 cm IMD (females) < 4 cm IMD (males)	-	Yes, after 14yr Females constant valgus, males progress toward varus 14-16yr	
Salenius *et al.* (1975)	1480 (limbs) from 1279 patients	European	0 to 16	Radiological, in supine, patella upright. Angle between interception of longitudinal axes of the femur and tibia (newborns = estimate of femoral axis due to curvature of the femur)	< 1yr	-5° to -6°	Between 2 to 3 yr	-5° to -6° until age 6 or 7 yr	18 mo, changed to valgus between 2 & 3 yr	Not reported as such. Both: SD = ±8° SEM = ±4.4° Females: SD = ±7° SEM = ±4° Males: SD = ±10° SEM = ±4.8°	Longitudinal study, participants from two hospitals in Helsinki. Means of left and right leg angles combined. Clinical values excluded as direct correlation was found with the radiographic values.
Petrášová *et al.* (2012)	282	European (Czech)	4 to 11.9	New anthropometric method, mathematically calculated angle	-	-5.9° to -8.0°	9 yr olds -8.0° in females -7.5° in males	11 yr olds -6.9° in females -7.5° in males	-	None reported in the angle itself	Mathematically calculated angle from vertical and horizontal distances between landmarks
Heath *et al.* (1993)	196	White	0.5 to 11	Photographic IMD or ICD	6 mo		-8°±2° (both genders)		By 18 mo, but changed to valgus	Only 4 yr olds ($p<0.05$) Rest no differences	Children < 2 yr photographed in supine

Legend: cm = centimetre, ICD = intercondylar distance, IMD = intermalleolar distance, Max = maximum, mo = month(s), SD = standard deviation, SEM = standard error of the mean, TFA = tibiofemoral angle, yr = year(s), < = younger than, > = older than

Table was adapted from Mathew et al. (2013:159), Findings: Reported as TFA in degrees ± SD

Most researchers seem to agree that the normal, clinical goniometric assessment of the TFA is the best and lowest risk to the participant, measure of FP knee development (Cheng *et al.*, 1991:155; Saini *et al.*, 2010:580) with the IMD or ICD used as a supportive measure, rather than a standalone measure (Mathew *et al.*, 2013:160). What is apparent from all these studies, is that whatever the measurement method employed, the researcher must ensure rigorous protocol during measurement, to ensure measurement reliability and validity. For instance, measuring the TFA in standing versus in supine while using the same landmarks and methodology, renders different values, where standing values were consistently higher than those measured in supine (Omololu *et al.*, 2003:303). Ginesin *et al.* (2018:110) concluded in their editorial that a number of factors contribute to the final TFA that is established in adulthood. Factors such as socio-demographics, a person's physical stature or somatotype, as well as the sport they participate in, may bear an effect on the TFA (Ginesin *et al.*, 2018:110). As evident by the different findings of the various researchers depicted in Table 2-1 and, socio-demographics indeed play a significant role.

Knowledge of normal knee development in children is vital to health care providers such as paediatricians, physiotherapists, occupational therapists, and biokineticists, since parents most often consult these clinical health care providers when they have concerns about their child's knee alignment (Cheng *et al.*, 1991; Farr *et al.*, 2014). Therefore, knowledge of normal knee development in children is vital to these clinical health care providers, in order to reassure concerned parents about their child's development. Saini *et al.* (2010:579) find that due to the diverse findings with regards to TFA during childhood, children are often subjected to therapeutic interventions (such as braces and corrective shoe inserts) that are unnecessary, and sometimes result in more harm (Cheng *et al.*, 1991:154; Jacquemier *et al.*, 2008:192; Saini *et al.*, 2010:579).

Due to the knee forming part of the kinetic chain and the TFA acting as an indicator of pelvic to LL alignment, Pefanis *et al.* (2009:271-272) were interested to understand whether the TFA would affect ankle sprain injury risk, in 45 male adult basketball, soccer and volleyball players. The TFA did not show any statistical significance ($p=0.24$) in ankle sprain occurrence, but previous ankle sprain injury and body mass index (BMI) did show clear correlations (Pefanis *et al.*, 2009:273). The authors suggest that the relationship between the TFA and ankle sprain injury be investigated further, due to their small sample and cross-sectional design. They suggested a comparison between males and females along with the inclusion of normally aligned TFAs and abnormally aligned TFAs, since their sample did not include abnormal TFAs (Pefanis *et al.*, 2009:275). The following sections discuss genu varum (greatly increased TFAs), and genu valgum (greatly decreased TFAs), and refer to their risk of injury.

2.6.4. Genu varum

Genu varum is faulty alignment, commonly known as bow legs, which is characterised by the separation of the knees while the feet are placed together (Cooke *et al.*, 2000:101). As mentioned earlier, the presence of some genu varum and medial TT is normal in newborns and infants and rectifies under normal conditions when the toddler starts to walk, normally between ages 18 and 24 months (Salenius *et al.*, 1975:260; Heath *et al.*, 1993:260; Omololu *et al.*, 2003:303; Scherl, 2004:55; Yoo *et al.*, 2008:714; Oyewole *et al.*, 2013:171). The presence of bowed legs during the first two years is known as physiologic genu varum. Espandar *et al.* (2010:47) mentioned in their review on angular deformities of the LL in children, that normal angular alignment of LL may be perturbed by both intrinsic- and extrinsic factors. Factors such as dietary and vitamin intake, physical trauma, infections as well as high intakes of exogenous metals such as lead and fluoride could all contribute to the development of genu varum (Espandar *et al.*, 2010:47). Peterson-Kendall *et al.* (2005:96-97) also list these factors but include environmental factors such as the chair, desk, and bed that the child use could affect postural alignment.

Witvrouw *et al.* (2009:426) described the development of genu varum as multifactorial with the above mentioned contributing biological factors as well as biomechanical overload placed on the medial tibial physis during sport participation, later in life. Witvrouw *et al.* (2009:423) performed a retrospective cohort study in which they compared knee angles of 336 male, eight to 18-year-old soccer players, to the knee angles in 458 male non-soccer players. Statistically significant genu varum was observed in both soccer players and non-soccer players from the age of 14, whilst a significant ($p=0.028$) increase in genu varum in soccer players only, from the age of 16 to 18 years, was noted (Witvrouw *et al.*, 2009:425). Males undergo a growth spurt from the ages of 16- to 18 years and the observed increase in genu varum in soccer players supports the hypothesis of Witvrouw *et al.* (2009:425) that soccer imposed stress and strain on the knee joint contributes to the development of a growth deformity (genu varum). Their study purely highlighted the statistically significant presence of genu varum in soccer players and discussed the possible association between kicking in soccer, especially kicking following an angled or diagonal run-up, which increases varus forces at the medial tibial physis. They suggested that future researchers investigate the exact movements linked to genu varum development in soccer players, and that if a positive correlation is found between kicking and genu varum development, that limits be set to the allowable number of kicks made by young soccer players, similar to the limitation set for throws by young baseball pitchers (Witvrouw *et al.*, 2009:426).

Cooke *et al.* (2000:101) state that sporadically an exaggerated lateral-to-medial downward inclination accompanies genu varum alignment which is possibly a developmental malalignment. This inclination causes the tibia to project proximally and laterally and also gait patterns present a lateral thrust of the knee which over time causes the development of osteoarthritis of the medial compartment. In addition, due to the malrotation of the distal femur or proximal tibia, the patella may be displaced laterally (Cooke *et al.*, 2000:101; Goldman *et al.*, 2010:47). Furthermore, Goldman *et al.* (2010:47) note that medial meniscus tears are commonly associated with genu varum. Growth plate damage can occur with longstanding LL malalignment (either varus or valgus) which leads to knee degeneration and eventually osteoarthritis. According to Goldman *et al.* (2010:47), the malalignment threshold responsible for these degenerative changes is unknown, but in children, the Hueter-Volkman law prescribes deformity progression especially in severe angular malalignments. According to this law, growth will be stunted where mechanical compression is increased, and oppositely where compression or loading is reduced, growth will be augmented (Cooke *et al*., 2000:101; Goldman *et al*., 2010:47; Villemure *et al*., 2009:1794). Genu varum may be increased in the presence of obesity, ligament instability and lateral thrusting of the knee during gait. (Goldman *et al.*, 2010:47-48). Based on the preceding literature, it would be important for researchers to investigate whether being carried on the mother's back would also contribute to the development of an excessive genu varum angle in children older than two years.

Knee malalignment could be due to a postural- or structural fault (Peterson-Kendall *et al.*, 2005:99). Postural bowing will decrease when knee hyperextension and hip medial rotation decreases. Knee hyperextension can be decreased through the strengthening and tightening of the posterior ligaments. If poor postural habits persist, the child should be encouraged to correct the faulty alignment, as correction of faulty alignment becomes more challenging with maturation. Structural bowing can be distinguished from postural bowing by noting if the bowing disappears when moving from standing to recumbent. If it is a structural fault the bowing will not disappear in the recumbent position, whilst postural bowing will (Peterson-Kendall *et al.*, 2005:99).

Güven *et al.* (2014:539) investigated the relationship between infantile Blount's disease and obesity. Blount's disease is the inward bowing of the tibia due to the cessation of growth of the medial tibial epiphysis and physis, which presents as bow legs (Salter, 1999:308). Blount's disease typically manifests by two years of age and females are affected more than males (Salter, 1999:308). Scherl (2004:56) mentions in their review that Blount's disease is especially common in overweight African-American females. Güven *et al.* (2014:541) found a relationship between increasing body weight and Blount's disease in children. The precise aetiology of Blount's disease is not well understood but can be explained somewhat by the Hueter-Volkmann principle (Güven *et al.*, 2014:541), which states that growth is inhibited by an increased pressure load. Ossification is disrupted by the increased pressures on the medial epiphyseal plate causing chondrocyte dysfunction, while normal bone growth is seen on the lateral epiphyseal plate, leading to the bowing of the leg (Salter, 1999:309; Güven *et al.*, 2014:542). Increased body mass, leads to increased pressure on the medial compartment and thus exacerbates the development of

Blount's disease. It is also important to mention that all but one of the children in their sample started walking before the age of 12 months (Scherl, 2004:56; Güven *et al.*, 2014:542).

Genu varum is more common than genu valgum (Cooke *et al.*, 2000:101; Shohat *et al.*, 2018:77), and prolonged and severe genu varum was associated with increased risk for the development of overuse injuries in adolescent children and osteoarthritis due to altered forces shifting further away from the knee joint centre and presenting a greater load on the medial compartment of the knee (Krivickas, 1997:135; Scherl, 2004; Witvrouw *et al.*, 2009:422; Espandar *et al.*, 2010:46). Overuse injuries such as patellofemoral stress syndrome (PFSS), iliotibial band syndrome (ITB) and stress fractures of the tibia are often caused by an anatomical genu varum malalignment (Krivickas, 1997:136-142; Witvrouw *et al.*, 2009:423; Espandar *et al.*, 2010:47). Should the young adult individual present with an anterior cruciate ligament (ACL) deficiency, in addition to genu varum, knee instability could arise due to the lateral thrust of the knee in gait and the inability of the ACL to control medial tibial displacement associated with internal rotation of the tibia during extension (Cooke *et al.*, 2000:101). Surgical correction of either the ACL or tibial osteotomy might be necessary to prevent the condition from worsening (Cooke *et al.*, 2000:101).

Samaei *et al.* (2012:469) investigated the effects of genu valgum and genu varum on both dynamic and static balance. They selected 90 female university students, not participating in sport. Participants were divided into three groups, 30 with genu valgum, 30 with genu varum and 30 neutral or normal. An IMD larger than 3.0 cm was deemed genu valgum, whilst an ICD of 3.0 cm was deemed genu varum. They utilised the *Biodex Balance System* which is capable of measuring anterior-posterior stability, mediolateral stability and overall stability (Samaei *et al.*, 2012:470). Higher scores indicating postural sway in either direction are indicative of poor balance. No significant differences were found between groups in terms of their overall stability or anterior-posterior stability (Samaei *et al.*, 2012:471). Both the genu valgum and genu varum groups showed higher mediolateral stability scores (thus poor balance), but only the genu varum group showed a statistically significant difference in comparison to the control group (neutral alignment). Similarly, the genu varum group also showed statistically significant poorer dynamic balance indices for mediolateral stability when compared to the normal group (Samaei *et al.*, 2012:471). Samaei *et al.* (2012:472) conclude that persons with genu varum have a higher risk for falling due to a deficit in mediolateral balance, which is most likely brought about by increased pronation at the foot which has been proven to alter balance control and consequently results in poor mediolateral balance. The study was performed on young adult university students, the expectation is that in young children with genu varum, balance will be poorer, due to the development stage and immature gait combined with genu varum, increasing the risk of falling and subsequent injury.

Sharrard (1976:827) recommends that whenever the ICD measures greater than 5.0 cm at any developmental age, the child should be clinically examined to rule out the presence of rickets and also be sent for a radiological examination. Rickets is a nutritional deficiency, affecting bone growth and development. Self-correction of the malalignment is most probable should the radiological findings be negative. Proper diet and exercise should be prescribed for overweight children with excessive genu varum (Sharrard, 1976:827). It is evident from this section that various factors play a role in the possible development of genu varum with physiological intrinsic processes responding to mechanical loads, governed by the Hueter-Volkmann principles (Goldman *et al.*, 2010:48).

2.6.5. Genu valgum

Genu valgum (knock-knees) is the opposite of genu varum where the knees are positioned closer together or even touching when feet are positioned hip distance from each other (Magee, 2006:667). Various researchers mention that genu valgum is one of the reasons why parents consult a paediatric physician, due to concerns that the child's limbs are malaligned. Parents do not realise most toddlers present with peak genu valgum angles around the age of three to five years or seven years, depending on ethnicity (Table 2-1 to Table 2-6) (Sharrard, 1976:826; Sass *et al.*, 2003:461; Saini *et al.*, 2010:579; Farr *et al.*, 2014:1362). Cooke *et al.* (2000:103) investigated LL malalignments and their associated knee disorders and mention that in adults genu valgum is observed less frequently than genu varum angles. Shohat *et al.* (2018:75) corroborated this notion in their retrospective review of 47 588 adolescents. From the total sample, 11.4% (5427), presented with genu varum with an ICD greater than 3.0 cm, whilst 5.6% (2639) presented with genu valgum, where the IMD measured greater than 3.0 cm (Shohat *et al.*, 2018:75). In terms of BMI and the incidence of genu varum or genu valgum, Shohat *et al.* (2018:77) reported an inverse correlation between genu varum and BMI. The lower the BMI, the greater the prevalence of genu varum including the more severe cases (ICD > 5 cm), whilst with greater BMIs, the prevalence of genu varum decreased significantly over both genders. A positive correlation was observed between BMI and genu valgum, where the greater the BMI, the higher the prevalence of genu valgum, which was also observed over both genders, but with greater prevalence among females than males (Shohat *et al.*, 2018:77).

The incidence of genu varum was significantly greater in males (16.2%; p<0.001) than in females (4.4%), whilst genu varum was found significantly (p<0.001) more often in females (9.4%) than in males (2.9%) (Shohat *et al.*, 2018:77). Another interesting finding by Shohat *et al.* (2018:77) was the reported significantly (p<0.001) greater prevalence of genu varum amongst participants residing in rural areas (12.2%) compared to those from urban areas (10.6%). In terms of genu valgum a significantly (p<0.001) greater incidence of genu valgum was reported in those from urban areas (5.8%) compared to those from rural areas (5.3%) (Shohat *et al.*, 2018:77). According to Shohat *et al.* (2018:78), a plausible explanation for the above-mentioned differences in genu valgum and –varum incidences in urban- versus rural areas could be attributed to different lifestyles or differing population compilations in terms of ethnicities and immigration, but this needs further exploration to confirm.

The appearance of genu valgum is associated with diseases such as renal rickets, polyostotic fibrous dysplasia, and developmental dysplasias or progressive inflammatory diseases such as rheumatoid arthritis affecting knee plateaus and subsequently alignment (Cooke *et al.*, 2000:103; Espandar *et al*., 2010:50). Greater Q-angles are associated with genu valgum which tend to prompt lateral patellar subluxations to occur owing to lateral forces forcing the patella from its groove (Cooke *et al.*, 2000:103; Espandar *et al.*, 2010:50; Goldman *et al.*, 2010:47). The lateral compartment of the knee is overloaded whilst the medial collateral ligament is subjected to increased stress. Patellar instability and activity-related pain often arise owing to these factors later in life (Goldman *et al.*, 2010:47). According to Espandar *et al.* (2010:50), various diseases or other factors could cause the development of or progression of genu valgum. The researchers list factors such as deficiencies of the fibula, ITB contracture, trauma such as malunion of a fracture and asymmetric growth which could cause genu valgum. Other factors that could also lead to genu valgum include; infections that lead to asymmetric growth, arthritis of the knee, osteogenesis imperfecta and metabolic bone diseases. Lastly, bone dysplasias could potentially cause genu valgum and Morquio's syndrome, Ellis van Creveld syndrome and Ollier's disease are all positively associated as causes of genu valgum (Espandar *et al.*, 2010:50).

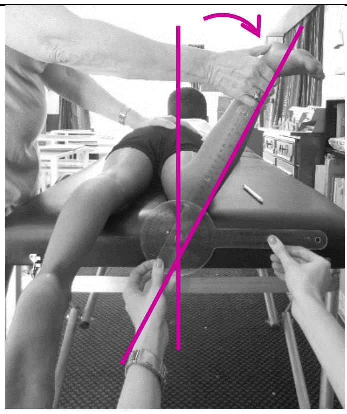
Schnitzler *et al.* (1998:263-264) conducted an investigation into the histomorphometry of iliac crest biopsies taken from children between the ages of 11 to 17 years with slipped capital femoral epiphysis (SCFE), to determine whether metabolic bone disease was contributing to their SCFE. From their sample of 29 black teenagers, 37.9% also presented with genu valgum. Their patients presented with osteopenia, but they did not attribute the osteopenia to calcium deficiency as the patients reflected a good or excellent nutritional status even though they were from socioeconomically disadvantaged areas in and around Johannesburg, South Africa. Vitamin D deficiencies were also excluded as a cause of the osteopenia, due to reported regular sun exposure whilst playing outside. Their sample presented with hypogonadism, sexual immaturity with a prolonged pubertal growth spurt, which is associated with physeal and metaphyseal junction weakness. Hypogonadism is also associated with weakened bone development. Furthermore, the females in their sample were predominantly overweight or obese, which they reasoned were the contributing factor to weakening of the growth plate and the epiphyseal separation due to the increased loads placed on the physeal region (Schnitzler *et al.*, 1998:264; Peterson-Kendall *et al.*, 2005:96-97).

No intervention is required for three- to four-year-old children with bilateral genu valgum deformity and IMD values between 5.0 to 10.0 cm, unless other clinical signs are present, indicating a specific abnormality (Sharrard, 1976:827). Six-monthly follow up measurements could be indicated, if only to set parents at ease. Tending proper diet and exercise for overweight children presenting with these IMD values is also indicated. Only once the IMD becomes greater than 10 cm, should the child be sent for further radiological investigations to determine developmental or perhaps metabolic epiphyseal abnormalities. Unilateral genu valgum could be due to previous trauma to the epiphysis, osteomyelitis or another developmental bone abnormality and requires further radiological investigation (Sharrard, 1976:827).

2.7. PROFILE AND DEVELOPMENT IN THE TRANSVERSE PLANE (TP)

2.7.1. Hip rotation: Femoral anteversion (AV) or –retroversion (RV)

Femoral anteversion (AV), or medial- or internal femoral torsion (Scherl, 2004:53), indicates the forward torsion of the femoral neck (in the FP), permitting internal rotation of the femur and is the angle between the femoral neck axis and the transverse (mediolateral) axis of the knee (Mooney, 2014:1178). It can be measured with the Craig's test (also known as the Ryder test) (Figure 2-9), where the patient lies prone with their knee flexed to 90° (Magee, 2006:621; Souza *et al.*, 2009:587). Maximal AV or RV is measured when the greater trochanter is palpated at its maximal protuberance and lies parallel with the plinth, with the leg in internal or external rotation, respectively (Magee, 2006:624; Souza *et al.*, 2009:587).



A

Figure 2-9: (a) Actual goniometric measurement of femoral anteversion (AV) or -retroversion (RV)[42]

An increased femoral AVA is associated with a greater range of motion (ROM) for femoral internal rotation, and decreased external rotation of the femur and femoral RV is associated with greater external hip rotation than internal hip rotation (Svenningsen *et al.*, 1989:172; Lincoln *et al.*,

[42] Photo demonstrated, modified and published with permission – Photo by M. van Aswegen

2003:317; Sass *et al.*, 2003:463; Mooney, 2014:1178). According to Sass *et al.* (2003:461) normal external hip rotation ROM is between 30° to 65° in five-year-old children, while internal rotation of the hip is between 20° to 60° (Weinberg *et al.*, 2017:125). Any measurement outside this range would be seen as a malalignment (Sass *et al.*, 2003:461). In adults the AVA is far lower than in children, normal AVA of 12° ± 8°, were observed in 19- to 52-year-old females, in comparison to 30° ± 7° which was observed in the same age range, but in patients with increased femoral AVA symptoms (Reikerås, 1992:312). In a study comparing gender and ethnic differences in femoral AV, using *computed tomography* (CT) scans, no statistically significant differences were found in the femoral version between African-Americans, whites and Hispanic adults (Koerner *et al.*, 2013:309). Mean AVA found in 56 white males were 7.92° ±9.67° compared to AV of 8.96° ±9.96° in 159 African-American males. In 16 white females, the mean AVA was 12.91° ±10.23°, compared to 8.19° ±11.13° which was found in 34 African-American females. In males, the ratio of RV cases was greater in whites, where 21.4% of them presented with femoral RV, compared to 15.1% of the African-Americans and 7.1% of the Hispanic males presenting with femoral RV. Female African-Americans presented with a greater ratio of RV cases at 23.5%, compared to 18.8% whites and 14.3% Hispanic females, presenting with femoral RV. From the 15.1% African-American males with RV 5.7% of them presented with greater RV angles (RVA), greater (thus more negative) than -10°. Similarly, from the 23.5% African-American RV cases, 5.9% of them had greater RVA, greater than -10°, while none of the white males or females presented with such angulations (Koerner *et al.*, 2013:310).

Infants are born with femoral AVA of approximately 40°, which decreases to adult values by the age of eight- to nine years old (Lincoln *et al.*, 2003:317; Scherl, 2004:53; Jacquemier *et al.*, 2008:189-190; Mooney, 2014:1178). The “W-sitting position” is often a preferred and comfortable sitting position for children with increased AVA (Lincoln *et al.*, 2003:317; Scherl, 2004:54; Mooney, 2014:1178; Kahf *et al.*, 2019:100). Mooney (2014:1178) states that this sitting position will not hold any detrimental effects to hip development, furthering the AVA. The author furthermore states, parents need not reprimand their child when sitting in this position, as it will not exacerbate the AVA. However, none of the statements are substantiated with any further evidence (Mooney, 2014:1178). Treatment of excessive femoral AV is usually not recommended, as it resolves naturally, between eight- to 11 years of age (Scherl, 2004:54; Kahf *et al.*, 2019:100). Bracing or splinting has been found ineffective and contradicting evidence exists for withholding a child from sitting in the W-position (Scherl, 2004:54; Kahf *et al.*, 2019:100).

Svenningsen *et al.* (1989:172) performed a longitudinal study between 1976 to 1980 on 30 children with in-toeing gait and found an increase in external hip rotation ROM and a decrease in internal hip ROM with an increase in age. Four to ten-year-olds presented with an external hip rotation 19° (±7.2°) and internal hip rotation of 74° (±6.8°), at a follow up evaluation (now seven to 13-year-olds) their external hip rotation increased to 27° (±7.8°) while internal hip rotation decreased to 60° (±7.2°). At the third and final evaluation, the children were now between 15 to 21 years old, and external hip rotation had increased to 37° (±5.9°), and internal rotation had decreased further to 53° (±8.5°) (Svenningsen *et al.*, 1989:172). A later study found correlations between internal- and external femoral rotation and the AVA and RVA, respectively (Kozic *et al.*, 1997:535). They measured 1 140 children between eight and nine years old. For analysis, they divided the results into one of three groups. In group one, internal- and external femoral hip rotation did not differ more than 5°. Of their sample, 90% of the results were categorised in group one. Group two consisted of those who had at least 10° greater internal femoral rotation than external hip rotation, this group consisted of 7% of their sample. In the third group, external femoral rotation was at least 10° greater than internal hip rotation, and only 3% of their sample fitted into this group (Kozic *et al.*, 1997:534). A smaller sample (n=147) was selected for radiographic femoral AVA measurement. The AVA was significantly greater in group two, than any of the other two groups and rendered a strong positive correlation (r=0.80). In comparison, the AVA was significantly smaller in the third group, than the other two groups and rendered a strong negative correlation. Results are tabled in Table 2-10.

Table 2-10: Clinical and radiographic comparison and correlation between femoral rotation and femoral anteversion angles (AVA)

Group (n)	Internal rotation	External rotation	In-toeing gait	AVA	Correlation
	Mean (°)±SD	Mean (°)±SD	n (%)	Mean (°)±SD (n)	
1 - Int = Ext (1030)	43°±4.1°	43°±5.4°	10 (1%)	24°±4.3° (56)	-
2 - Int > Ext (86)	64°±11°	30°±8.5°	27 (31.4%)	36°±7.3° (67)	r=0.80
3 - Int < Ext (24)	23°±12°	58°±13°	3 (12.5%)	14°±8.7° (24)	r=-0.73
Total (N=1140)	**44°±6.8°**	**42°±7.1°**	**40 (3.51%)**	**(147)**	**-**

Legend: AVA = femoral anteversion angle, Ext = external femoral rotation, Int = internal femoral rotation, SD = standard deviation. % = percentage per group.
Table adapted from Kozic et al. (1997:534)

According to Riegger-Krugh *et al.* (1996:167), in-toeing, excessive subtalar pronation, and lateral patellar subluxation are possible correlated motions associated with excessive femoral AV. Individuals with excessive femoral AV might also present with excessive external TT and excessive knee external rotation as compensatory motions. Other compensatory motions include excessive tibial; tibial and femoral, or tibial, femoral and pelvic internal rotation; or all with ipsilateral lumbar spine rotation. For an individual with femoral RV the same correlated- and compensatory motions can be expected, but in the alternate direction, for instance, out-toeing is expected as a correlated motion in a person with femoral RV and in terms of the compensatory motions in the lumbar spine, the direction is now internal and observed in the contralateral lumbar spine (Riegger-Krugh *et al.*, 1996:167).

In their longitudinal study, Svenningsen *et al.* (1989:171) measured femoral AVA over three evaluations. The first evaluation took place between their fourth and tenth birthday (age mean =

seven years, AVA-mean=42°±5.5°) (Svenningsen *et al.*, 1989:171). The second evaluation took place between their seventh and 13th birthday (age mean = ten years, AVA-mean = 36°±6.3°) and the final evaluation took place between their 15th and 21st birthday (age mean = 16 years, AVA-mean = 28°±8.4°). Overall a reduction in the AVA was observed with an increase in age, regardless of the presence of increased femoral AV or normal alignment (Svenningsen *et al.*, 1989:172). In a more recent study on lower extremity characteristics of nine to 18-year-olds, lower AVA (Table 2-11) were reported (Shultz *et al.,* 2008:142) than those found in Norwegian children (Svenningsen *et al.*, 1989:171) and far lower than those in European children (Jacquemier *et al.*, 2008). In American females, AVA were typically greater than those of males, and unlike other studies, a non-linear trend was noted in both males and females, where AV increased from the first maturation group to the second, and decreased from the second to the third (Shultz *et al.*, 2008:144). Comparison between these studies is difficult, based on participant categorisation, with some values reported per age and others forming age categories or maturation categories (Table 2-11). A Belgian study investigated the abnormal torsional development in children (Fabry *et al.*, 1994:24). In a group of children with increased femoral AV (IFA, they reported similarly high AVA to those found by Svenningsen *et al.* (1989:171). The IFA group was further subdivided into participants presenting with internally rotated knees and feet (IRT) and a group presenting with internally rotated knees and either neutral or external pointing feet (ERT) (Fabry *et al.*, 1994:25). AVA was slightly elevated in the ERT group in comparison to the IRT group, which is in agreement with the summary of Riegger-Krugh *et al.* (1996:167). The AVA was substantially lower in children with greater internal TTA in Belgian children, than in the group with IFA (Fabry *et al.*, 1994:24).

In addition to TFA and ICD measures, Cheng *et al.* (1991:155) also assessed the rotational ROM of the hip, but did not measure the actual femoral AVA (through the Craig's test (Magee, 2006:621). Squinting patellae and an in-toed gait is associated with an increased femoral AVA (Magee, 2006:621). Jacquemier *et al.* (2008:189-190) found that femoral AV correlated with age in both males and females and showed to decrease with age. In females, the femoral AVA declined from 39.7° (±19.6°) at age three to 16.8° (±17.8°) at age ten. Similarly, for males, they reported a maximal angle at four years of 30.1° (±18.3°) which then declined to 9.5° (±13.3°) at the age of ten. These values reported were for the right hip only, since they found no differences between the left- and right sides (Jacquemier *et al.*, 2008:189).

Table 2-11: Measurements of femoral anteversion (AV) in children of different ethnicities with normal and abnormal torsion profiles

Demographical region		Measurements of femoral anteversion angle (AVA) and –retroversion angle (RVA) in children AVA means (> 8°) or RVA means (< 8°) in degrees ±Standard deviation (number of participants per age group)							
Age (years)		**3 yr**	**4 yr**	**5 yr**	**6 yr**	**7 yr**	**8 yr**	**9 yr**	**10 yr**
European children (N=1319)[43]	**Males (N=212)**	26.80±19.07	30.12±18.30	21.04±17.88	22.96±20.04	16.27±15.13	12.03±13.89	13.11±17.69	9.59±13.30
	Females (N=215)	39.65±19.61	39.09±23.91	37.31±20.61	31.15±21.44	31.00±23.32	26.69±19.95	18.14±18.05	16.75±17.81

Age groups (years)		**4-10 yr**	**7-13 yr**	**15-21 yr**
Norwegian children (N=30)[44]	**Males & Females**	42±5.5	36±6.3	28±8.4

Maturation groups		**MatGr1±SD**	**MatGr2±SD**	**MatGr3±SD**	**All ages (9-18 yr)**
American (N=173)[45]	**Males (N=88)**	10.2±5.3 (n=26)	13.5±5.2 (n=34)	8.9±5.0 (n=28)	11.1±5.5
	Females (N=85)	10.9±6.5 (n=25)	14.7±6.7 (n=29)	12.7±4.4 (n=31)	12.8±6.0
	All (N=173)	10.5±5.8 (n=51)	14.1±5.9 (n=63)	10.9±5.0 (n=59)	-

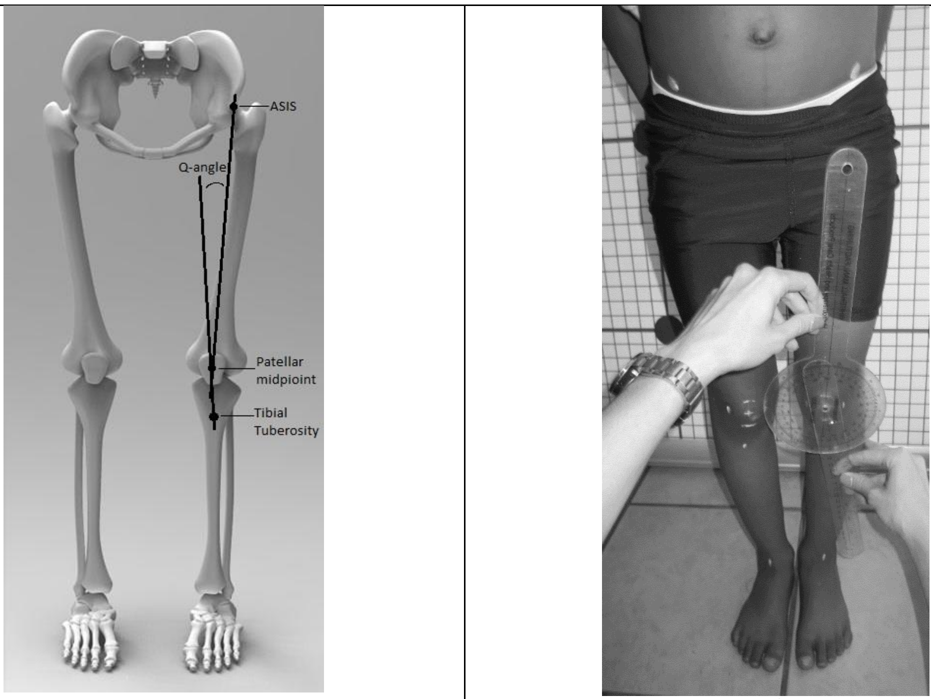
Age			**Mean age±SD**	**4-10 yr**
Belgian (N=124)[46]	**IFA**	**All**	6.9±2.9	39.1±7.9 (M-n=43)(F-n=43)
		IRT		38.2±7.8
		ERT		40.6±8.2
	ITT		6.9±2.7	24.0±5.6 (M-n=18)(F-n=19)

Legend: AVA = anteversion angle (larger than 8°), ERT = external rotated tibia, F = female, F-n = number of females, IFA = increased femoral anteversion, IRT = internal rotated tibia, ITT = internal tibial torsion, M = male, MatGr1 = maturation group 1, MatGr2 = maturation group 2, MatGr3 = maturation group 3, M-n = number of males, n = number of participants per age group, N = total number of participants, RVA = retroversion angle (smaller than 8°), yr = years, SD = standard deviation

[43] Jacquemier *et al.* (2008) only measured the right limb
[44] Svenningsen *et al.* (1989)longitudinal study, between 1976-1980, 30 participants, evaluated 3 times (mean age per evaluation, 3rd evaluation not listed)
[45] Shultz *et al.* (2008) Participants between 9 to 18 years of age were divided into three of the Tanner's 5 stages of maturation. Goniometric measurements performed in standing
[46] (Fabry *et al.*, 1994) Longitudinal study considering only pathological torsion issues, AVA determined with computed (CT) tomography scan

2.7.2. The quadriceps-angle (Q-angle)

The Craig's test is normally utilised for femoral AV or RV (Figure 2-9), however the Q-angle, may also be a useful tool (Magee, 2006:729). The Q-angle (Figure 2-10) is formed by the intersection between the lines from the ASIS to the midpoint of the patella and the midpoint of the tibial tuberosity (Hvid *et al.*, 1982:577; Hahn *et al.*, 1997:43; Livingston *et al.*, 1999:8; Byl *et al.*, 2000:26).



a[47] **b**[48]

Figure 2-10: (a) Determination of the quadriceps-angle (Q-angle), (b) Measurement of the quadriceps-angle (Q-angle) in standing with a goniometer

The Q-angle measures the muscular lateral pull of the quadriceps musculature and its associated tendons and is often used as a patellofemoral dysfunction index (Smith *et al.*, 2008:1068). In the case of large Q-angles, it indicates lateral pull of the patella which increases retro-patellar pressure which in turn can cause pain and articular cartilage degeneration if left untreated (Hvid *et al.*, 1982:579; Bayraktar *et al.*, 2004:759; Smith *et al.*, 2008:1068). An association exists between habitual and traumatic knee dislocation and smaller Q-angles (Bayraktar *et al.*, 2004:759). In addition to this, the Q-angle may be indicative of femoral AV which is associated with increased Q-angles greater than 20°, or femoral RV which is associated with a decreased Q-angle of less than 15° (Hvid *et al.*, 1982:579; Magee, 2006:729). Hvid *et al.* (1982:579) found a statistically significant correlation between measured Q-angles and hip AV ($r=0.428$; $p<0.01$). Statistically significant differences ($p<0.01$) between male versus female Q-angles were found, as well as for male versus female femoral AVA. For both variables, no statistically significant

[47] Q-angle landmarks demonstrated by M. van Aswegen
[48] Photo demonstrated and published with permission – Photo by M. van Aswegen

differences were observed between left- and right limb measurements. Greater Q-angles found in females are believed to be attributed to wider pelvic distances, which subsequently result in larger Q-angles and affects the magnitude of genu valgum observed in females. The correlation between the Q-angle and femoral AV supported their hypothesis that larger femoral AV contributes to a compensated external TT and consequently a greater Q-angle (Hvid *et al.*, 1982:579).

Limited research on Q-angle development in children, especially those younger than five years, is available. One of the largest child Q-angle development studies, was performed in Turkish children by Bayraktar *et al.* (2004:757), who were interested to determine if Q-angle differences exist between active- and sedentary nine- to 19-year-olds. They measured the Q-angle in supine and found significant differences between both the right- and left Q-angles of active (predominantly soccer playing) children and their age-matched sedentary controls. Furthermore, they reported a negative association between Q-angle values and increasing age along with decreased Q-angles in active children compared with sedentary children (Bayraktar *et al.*, 2004:759). Comparison of their Q-angles to those reported in the other child studies, as discussed below, is difficult, since all the other studies reported below, formed age groups and pooled their data within the age groups. Except in the youngest, nine-year-olds, who presented with far greater Q-angles than any of the other reported studies, the other ages are seemingly similar to the findings of Bayraktar *et al.* (2004:758). Bhalara *et al.* (2013:59) were one of the few child studies investigating Q-angle development in children between seven- to 12 years of age. They performed goniometric measurements in 100 male and female child participants. Their results are summarised in Table 2-12. Q-angles of seven- to nine-year-old Indian children (Bhalara *et al.*, 2013:60) do not differ greatly from those observed in five-, seven- to eight-year-old Turkish children (Cavlak *et al.*, 2005:346).

In a study that aimed to determine relationships between soccer playing seven- to nine-year-old school children and their LL development, some significant differences were found between players and non-players (Diaz-Miguel *et al.*, 2018:6-7) (Table 2-13). In terms of Q-angle development, they found statistically significant differences between the left limb Q-angles (p=0.010) of soccer players compared with non-players and similarly the right limb angles (p=0.008) also differed between the groups (Diaz-Miguel *et al.*, 2018:7). The authors argued that although the Q-angles differed significantly between groups, both groups were still within the normal limits of Q-angle development for children of that age, thus arguing the differences were negligible. Based on this, they argued that the difference in Q-angle development between soccer players and non-players did not have a structural influence on LL development (Diaz-Miguel *et al.*, 2018:9). Static Q-angles reported for Swedish children (Örtqvist *et al.*, 2011:2063) between nine to 11 years of age are seemingly lower than those reported for nine to 12-year-old Indian children (Bhalara *et al.*, 2013). These authors did not report any significant differences between limbs, nor between genders. They did find significant differences between the youngest and eldest male groups with p = 0.019. A similar difference was observed in the middle age-group and the eldest group of females with p = 0.028. Most researchers report a decrease in the Q-angle with an increase in age, regardless of gender, whereas the Swedish found a non-linear pattern in females, where the Q-angle increased between the youngest to middle age-group, then decreased between the middle age-group and the eldest age-group (Örtqvist *et al.*, 2011:2064). They argued the differences observed in Q-angle values between their and other studies, are attributed to differences in age groupings, age range and maturation of the children, activity levels between children and lastly measurement method discrepancies (Örtqvist *et al.*, 2011:2064). They found moderate reliability within the use of the Q-angle on a child population and argued more research is required to justify the use of the Q-angle as a clinical measure in children (Örtqvist *et al.*, 2011:2065). Shultz *et al.* (2008:143) found statistically significant differences between the two older maturation groups' males and females, with the female means consistently larger than those of males. The evident differences between the older groups are due to a decrease in the male Q-angle, while the female Q-angle remained relatively the same. This finding was not supported in the available literature, except for the decrease in Q-angles with an increase in activity levels as reported by Bayraktar *et al.* (2004:759). Shultz *et al.* (2008:138) did not investigate bilateral variability, as they measured the dominant leg (stance leg when kicking a ball). Their participants were between nine to 18 years of age and were categorised based on maturation status and not chronological age, which makes the comparison of their results with other studies difficult (Shultz *et al.*, 2008:139) (Table 2-13).

Most information regarding the Q-angle involves studies performed in older adolescents and young adults. In a study investigating the relationship between Q-angles and LL injury risks in 393 high-school (13- to 19-year-olds) cross country-runners, various risk relationships were found (Rauh *et al.*, 2007:726). Bilateral Q-angles measurements were obtained with participants in standing, measured with a goniometer by one researcher, in the pre-season. Coaches of the cross-country teams were trained in completing a daily injury report were athletes had to report any muscular, joint or skeletal injury along with the site of the injury, for instance, the ankle, shin, knee or hip. Practice time missed due to injury was also recorded. The researchers created four Q-angle categories, smaller than 10°, between 10° to 15°, between 15° to smaller than 20° and lastly greater or equal to 20°. The 10° to 15° group was chosen as a reference or normal (Rauh *et al.*, 2007:727). A discrepancy of 4° or larger between the left and right limb was also investigated as a risk factor for injury. Their results showed significantly ($p < 0.001$) larger average Q-angles in females (n=171, Q-angle = 15.4° ± 3.8°) in comparison with the males (n=222, Q-angle = 12.4° ± 3.5°) and average right limb Q-angles (n=393, R-Q-angle = 14.1° ± 4.2°) were consistently larger than left Q-angles (n=393 , L-Q-angle = 13.4° ± 3.9°) (Rauh *et al.*, 2007:727).

Table 2-12: Development of the quadriceps-angle (Q-angle) as reported for Indian and Turkish children of various ages

Demographical region			Measurements of the quadriceps-angle (Q-angle) in children Q-angle means in degrees ±Standard deviation (number of participants per age group)											
Age (years)			**9 yr**	**10 yr**	**11 yr**	**12 yr**	**13 yr**	**14 yr**	**15 yr**	**16 yr**	**17 yr**	**18 yr**	**19 yr**	**All**
Turkish (N=1239)[49]	**AG (N=474)**	**R**	20.29 ±2.64	17.14 ±1.87	16.55 ±2.53	16.47 ±3.49	15.63 ±2.6	14.41 ±3.07	14.39 ±4.65	11.15 ±4.51	10.27 ±4.28	7.64 ±3.69	6.40±4.2 8	**14.54 ± 4.76**
		L	20.35 ±1.77	16.97 ±2.72	16.50 ±0.83	15.9 ±3.07	15.81 ±3.10	14.64 ±3.43	13.83 ±3.79	10.85 ±4.19	10.36 ±3.14	8.14 ±3.39	5.2±2.77	**14.41 ± 4.60**
	SG (N=765)	**R**	20.20 ±2.96	19.57 ±2.27	16.63 ±2.50	19.63 ±2.98	18.03 ±3.08	17.93 ±3.49	16.83 ±3.09	16.07 ±1.62	15.93 ±2.63	15.47 ±1.77	14.8±3.3 2	**17.98 ± 3.23**
		L	20.73 ±2.63	19.93 ±3.37	19.83 ±3.91	19.87 ±2.89	18.67 ±2.89	17.80 ±3.22	16.47 ±3.09	16.13 ±2.13	15.87 ±3.16	15.53 ±2.42	14.67±2. 53	**18.12 ± 3.54**
Age (years)			**7-8 yr**	**9-10 yr**	**11-12 yr**	**Sig: Age**								
Indian (N=100)[50]	**Males (N=50)**		10.1±0.9	15.6±4.5	18.3±3.3	p<0.001								
	Females (N=50)		12.5±2.6	15.7±3.4	16.8±3.0	p<0.001								
Age (years)			**5-7 yr**	**Sig: L vs R**	**Sig: M vs F**									
Turkish (N=104)[51]	**Males (N=46)**	**R**	9.86±1.49	p>0.05	p>0.05									
		L	10.41±1.98											
	Females (N=58)	**R**	10.50±3.54	p>0.05	p>0.05									
		L	12.96±1.73											

Legend: AG = active group, Dom = dominant, L = left, MatGr1 = maturation group 1, MatGr2 = maturation group 2, MatGr3 = maturation group 3, n = number of partcipants per group, N = total number of participants,Non-dom = non-dominant, Non-Soc = non-soccer player group, Q-angle = quadriceps-angle, R = right, yrs = years, SG = sedentary Group, Sig = significance Soc = soccer players, vs = versus

[49] Bayraktar *et al.* (2004) Goniometric measurements in supine
[50] Bhalara *et al.* (2013) Pooled results for both limbs, results pooled for 7- and 8-year-olds, 8- and 9-year-olds, 10- and 11-year-olds. Goniometric measurements in supine.
[51] Cavlak *et al.* (2005) Pooled results for 5- to 7-year-olds, p>0.05 for left vs right limb measures. Goniometric measurements in supine.

Table 2-13: Development of the quadriceps-angle (Q-angle) as reported for European and American children of different age groups

Demographical region			Measurements of the quadriceps-angle (Q-angle) in children (continued Q-angle means in degrees ±Standard deviation (number of participants)			
Age (years)			**7-9 yr**	**Sig: Soc vs non-play - R**		
Spanish (N=115)[52]	**Soc (N=59)**	**R**	13.13±2.06	p=0.010		
		L	13.18±1.93			
	Non-Soc (N=56)	**R**	13.87±3.01	**Sig: Soc vs non-play - L**		
		L	13.86±2.94	p=0.008		
Age (years)			**9-11 yr**	**12-14 yr**	**15-16 yr**	**Sig: Dom vs Non-dom**
Swedish (N=246)[53]	**Males (N=122)**	**Dom**	13.5±1.9 (n=50)	14.3±1.8 (n=38)	14.7±2.5 (n=34)	p>0.05
		Non-dom	13.4±2.0 (n=50)	14.2±2.0 (n=38)	14.5±2.9 (n=34)	
	Females (N=124)	**Dom**	14.3±2.1 (n=30)	15.3±2.8 (n=59)	14.2±2.0 (n=35)	p>0.05
		Non-dom	14.4±2.0 (n=30)	15.3±2.8 (n=59)	14.3±2.1 (n=35)	
Age (years)			**MatGr1**	**MatGr2**	**MatGr3**	**All ages**
American (N=173)[54]	**Males (N=88)**		14.2±5.0 (n=26)	11.1±3.9 (n=34)	10.2±5.2 (n=28)	11.7±4.9
	Females (N=85)		15.1±4.4 (n=25)	17.7±5.8 (n=29)	16.5±5.5 (n=31)	16.5±5.4
	All (N=173)		14.7±4.7 (n=51)	14.1±5.9 (n=63)	13.5±6.2 (n=59)	-

Legend: AG = active group, Dom = dominant, L = left, MatGr1 = maturation group 1, MatGr2 = maturation group 2, MatGr3 = maturation group 3, n = number of partcipants per group, N = total number of participants, Non-dom = non-dominant, Non-Soc = non-soccer player group, Q-angle = quadriceps-angle, R = right, yr = years, SG = sedentary group, Sig, Soc = soccer players, vs = versus

[52] Diaz-Miguel *et al.* (2018:2) Pooled results according to activity, results pooled for 7- to 9-year-olds. Photographic method – participant in standing
[53] (Örtqvist *et al.*, 2011:2063) Pooled results for ages 9- to 11-, 12- to 14- and 15- to 16 years to improve statistical power. Goniometric measurements in supine
[54] Shultz *et al.* (2008) Participants between 9- to 18 years of age were divided into three of the Tanner's 5 stages of maturation. Goniometric measurements performed in standing

In terms of running injury risk, they found a “U-shaped” relationship, with the largest and smallest Q-angles placing the runner at greater risk for injury, while Q-angles of 10° to <15°, presented the lowest risk (Rauh *et al.*, 2007:730). Larger Q-angles (≥20°) and Q-angles between 15° to <20° in males, increased the runner’s risk for knee injuries. The larger Q-angles were also more likely to contribute to missing practice time due to injury. Smaller Q-angles (<10°) showed statistically non-significant greater risk for running injuries. The authors reasoned that the U-shaped relationship with injury risk proves the suggestion by others, that anatomic extremes in malalignment increase the risk for overuse injuries (Rauh *et al.*, 2007:730). Bilateral Q-angle discrepancies (right versus left) larger or equal to 4° were also found to increase the risk for foot (in males) and tibial injuries (in females) running injuries in comparison to those with smaller discrepancies (Rauh *et al.*, 2007:731).

Several authors have mentioned that with even the slightest difference in Q-angle measurement protocol and error in landmarks can lead to significant variation (Livingston *et al.*, 1999:7; France *et al.*, 2001:711-713; Magee, 2006:730-731; Raveendranath *et al.*, 2011:470), which is also the reason why researchers struggle to find consensus regarding normative values. In their systematic review, Smith *et al.* (2008:1077) concluded that there is still great disparity with regards to the reliability (both intra- and inter-reliability) and validity in the use of the clinical Q-angle. Smith *et al.* (2008:1077) were unable to apply a formal meta-analysis to the results of their systematic review, due to the great variability of Q-angle measurement protocols followed by the ten articles they reviewed. Articles in their review reported the traditional Q-angle measurement with the subject in supine, knees in full extension, toes pointing upward. Others researchers performed the measurement in standing, knees extended, but quadriceps relaxed. In some of the studies different methods were compared with another, i.e., with the participant in supine versus the participant in standing, and/or compared the supine method with knees in extension and knees in flexion (differing degrees of flexion) (Smith *et al.*, 2008:1072-1074). Furthermore, some tested the clinical Q-angle measurement with radiographs, in order to test validity (Smith *et al.*, 2008:1072-1074). The interclass coefficient (ICC) of Inter-tester reliability ranged from a very poor 0.20 to a good 0.70, whilst the ICC of intra-tester reliability was found to range between 0.22 to 0.75 as documented by the review of Smith *et al.* (2008:1076). The variability was due to different measurement procedures emphasising the need for standard measurements. Overall stronger reliability was found in protocols where the participant stood, with their knees in extension. Although measuring the Q-angle with the knee in flexion, clinically makes more sense, as the patella tracks further medially, reproduces the gait stance phase better and indicates patellofemoral pain syndrome better, poor reliability was found where the knee was placed in flexion. (Smith *et al.*, 2008:1076).

In general, Q-angles greater than 15° in men and greater than 20° in women, is regarded as a risk factor for the development of chronic knee injuries (Hahn *et al.*, 1997:43; Livingston *et al.*, 1999:7). The Alpha angle, which is used to measure the orientation of the patella to the tibial tubercle and assists in the tracking of the quadriceps pull, is not as often used as the Q-angle, due to issues with reliability in accurate landmark discovery (Magee, 2006:731). Although these clinical measures for femoral AV, the Craig's test, and Q-angle are not optimal, they are routinely used in clinical practice validating the need for normative clinical data (Jacquemier *et al.*, 2008:192).

Hahn *et al.* (1997:46) investigated the Q-angle in athletes, between the ages of 14- to 24 years, in eight different sporting codes. They measured the bilateral Q-angles of 339 active athletes using a long-axis goniometer, with the participant lying in supine with their knees in extension, quadriceps relaxed and feet secured together (Hahn *et al.*, 1997:43), and found significantly higher Q-angle values on the right limb as compared to the left limb and also noted greater Q-angle values in women than in men. They hypothesized that quadriceps muscle size, strength and tonus would determine the patellar position and subsequently affect the Q-angle value. The lower Q-angle values found in men, in comparison to females supported their hypothesis, based on the principle that men generally have stronger and larger musculature than females (Hahn *et al.*, 1997:43). They went further to compare the different sporting codes with Q-angles and found a negative association between the Q-angle and soccer as well as swimming, whilst a positive association was found with years of regular jogging. In swimming and soccer, the LL muscles are trained more dynamically than in jogging. Hahn *et al.* (1997:47) did not expect to see the mentioned greater right-sided Q-angles and smaller left-sided Q-angles differences and none of the previous studies they sited performed bilateral measurements. They reasoned the observed differences to be due to methodical bias such as parallax reading errors or handedness of the investigator.

Similarly, Raveendranath *et al.* (2011:466) also investigated the variability of the bilateral Q-angle in adults in India using the same clinical technique as Hahn *et al.* (1997:43). In addition to the clinical goniometric measurements scaled photographs were also taken after landmarks were marked and the Q-angle was then later determined using Adobe Photoshop software (Raveendranath *et al.*, 2011:467) in order to determine the relative lateral placement of the tibial tuberosity in comparison to the midpoint of the patella. They measured both limbs of 100 adults, between 18 to 43 years of age (200 limbs), 50 females and 50 males. Similarly to Hahn *et al.* (1997:45); Raveendranath *et al.* (2011:470) found non-significantly greater Q-angle means (all 200 limbs) on the right side as compared to the left, but found statistically significant within-subject differences, where a lower than 3° difference between the right and left Q-angle value was noted in 96% of their particpants.

Furthermore, the variability was found to be greater in males (variability noted in 52% of male participants) as compared to females (variability noted in (variability noted in 34% of female participants) (Raveendranath *et al.*, 2011:468). They argued that the greater variability in the Q-angle means of males could be attributed to greater disproportionate bilateral limb usage in men which subsequently contributes to greater variability in quadriceps muscle strength (Raveendranath *et al.*, 2011:470). They also reasoned that any change in any Q-angle value has to be due to a change in one or more of the three landmarks used for its determination, thus either the ASIS; the midpoint of the patella or the tibial tuberosity (France *et al.*, 2001:713; Raveendranath *et al.*, 2011:470). They were interested to see if the relative lateral placement of the tibial tuberosity in relation to the midpoint of the patella, would impact the Q-angle, due to the fact that the ASIS is relatively secure and unlikely to be the cause of bilateral variability (Raveendranath *et al.*, 2011:470). Once again their results indicated a significantly greater variability (for the lateral tibial tuberosity landmark) in especially males with the right limb presenting with a higher mean value than the left. In addition, there was a significant positive correlation between the Q-angle and the relative lateral placement of the tibial tuberosity landmark, which indicates that landmark placement can cause bilateral variability in Q-angle determination. Table 2-14 compares the bilateral variability reported by various studies along with the method of measurements employed.

Table 2-14: Comparison of bilateral variability in mean quadriceps-angles (Q-angle) from different studies

Author and year	Number of normal participants	Bilateral variability in mean Q-angle values	Method of measurement	Details
Hahn *et al.* (1997)	339	R > L	Universal Goniometer	Participant in supine, legs secured together, knees extended and quadriceps relaxed
Byl *et al.* (2000)	34	R > L	Universal Goniometer	Participant standing medial malleoli or -condyles in contact
Livingston *et al.* (2002)	20	R > L *	OPTOTRAK	Participant standing in Romberg stance with quadriceps relaxed
Omololu *et al.* (2009)	477	R = L	Universal Goniometer	Both with participant standing, with medial malleoli or –condyles in contact and with participant in supine, legs secured together, knees extended and quadriceps relaxed
Raveendranath *et al.* (2011)	100	R > L	Universal Goniometer	Participant in supine, legs secured together, knees extended and quadriceps relaxed
Rauh *et al.* (2007)	364	R > L	Universal Goniometer	Participant standing, legs shoulder width apart, body weight evenly distributed, quadriceps relaxed

Legend: R = right, L = left. * Significant differences noted. *Table adapted from Raveendranath et al. (2011:469)*

Omololu *et al.* (2009:2075) argued that Q-angles in African ethnicities cannot be compared to those of white ethnicities due to skeletal differences. They aimed to establish Q-angle norms for the normal asymptomatic Nigerian adult population and measured the Q-angles of 354 males and 123 females from a randomly selected stratified cross-section of the society. Measurements were performed with the participant in both supine and standing, and string was taped to the landmarks to allow increased accuracy (Omololu *et al.*, 2009:2074). Their findings were not confirmed radiographically and six trained physicians collected their data. Intra-tester reliability was determined with 20 participants and coefficients for supine measurements were 0.89 and 0.90 respectively and standing measurement coefficients were 0.92 and 0.91 respectively. Male Q-angles, both standing and supine measures correlate with values previously reported for white males (Hahn *et al.*, 1997:43; Byl *et al.*, 2000:30). The female values are however consistently higher than those reported for white females (Hahn *et al.*, 1997:43; Byl *et al.*, 2000:30) and are in fact far higher than the cut-off values prescribed for women (20°). The higher Q-angles found in this Nigerian female population is not well understood, but Omololu *et al.* (2009:2075) reasoned it could be, although not investigated in their study, due to a wider pelvis or due to shorter femur lengths of the Nigerian female as compared to the equivalent white female. No discrepancy between left and right-sided Q-angle mean values were found in neither supine nor standing measures, unlike the findings of Hahn *et al.* (1997), Byl *et al.* (2000) and Raveendranath *et al.* (2011), who found larger right-sided Q-angles as compared to the left side. Furthermore, they found a tendency in Q-angle values found in the standing position to be larger than those measured in the supine, this was attributed to weight bearing mechanics in standing that altered the Q-angle (Omololu *et al.*, 2009:2075).

2.7.3. Tibial rotation: Medial- or lateral tibial torsion (TT)

In adults, some external TT, between 13° to 18°, is considered normal. In children, this value is lower (Magee, 2006:801), but age-dependent (Cheng *et al.*, 1991:158; Jacquemier *et al.*, 2008:191). Toeing-out is when TT is greater than 18° in adults, whilst toeing-in is represented by a lower than 13° angle (Magee, 2006:801). Pigeon-toes, or extreme toeing-in, in children may be caused by foot pronation, tibia vara (Blount's disease), developmental genu varum or developmental genu valgum, when a protective medial shift of the centre of gravity occurs (Magee, 2006:773, 801). Further, internal TT, internal femoral torsion or excessive femoral AV have also been associated with Pigeon-toes (Fabry *et al.*, 1994:25; Scherl, 2004:53; Magee, 2006:773, 801; Mooney, 2014:1177).

Fabry *et al.* (1994:25) argue that in-toeing is predominantly owed to increased femoral AV rather than increased internal TT. TT tended to decrease (become more internal) in the internal torsion (ITT – Table 2-15) group, while TT tended to increase (become more external) in the group of children with increased femoral anteversion (IFA) (Fabry *et al.,* 1994:25). Greater external TT angles were noted in children with externally rotated tibia (ERT – Table 2-15) when the patella was facing forward, which simultaneously increased the Q-angle and correcting the in-toeing gait (Fabry *et al.*, 1994:25). It is difficult to compare the results of Fabry *et al.* (1994:24) since their work is based on Belgian children presenting with pathological or abnormal torsion angles, it does however, provide some reference guideline. Jacquemier *et al.* (2008:188) measured TT, in a seated position, of children between the ages of three to 10 years of age (Table 2-15). Their results were very similar to that of Cheng *et al.* (1991:155) in that they did not observe any differences between males and females. Jacquemier *et al.* (2008:191) reported a mean TT of 34.07° (±6.39°) at three years and a TT of 36.05° (±4.91°) at 10 years, whilst Cheng *et al.* (1991:158-160) reported a steady increase of TT from 15° at two years to 35° at 12 years of age. The differences in the reported TT values between these two studies could be attributed to the different clinical method employed, Cheng *et al.* (1991:155) assessed the thigh-foot angle (Figure 2-11) with the participant in prone, whilst Jacquemier *et al.* (2008:188) assessed TT through the transmalleolar axis with the participant in a seated position (Jacquemier *et al.*, 2008:192). In a study investigating normal TT development in Norwegian children, CT scans were utilised in 78 participants between three- and 11 years for the child group (n=54) and 18- to 51 years in the adult group (n=26) (Kristiansen *et al.*, 2001:521). Their data were pooled according to chronological ages, with three to five-year-olds, six to eight-year-olds and nine to 11-year-olds forming the three child groups. TT increased with 1.0° per age after the age of four years. By the age of ten years, TT had increased to 34° from the 28° which achieved at four years of age (Kristiansen *et al.*, 2001:520). As evident in Table 2-15, Staheli *et al.* (1985:43) reported far lower thigh-foot angles in American children, than both Cheng *et al.* (1991:160) and Jacquemier *et al.* (2008:191), regardless of using the same clinical method as Cheng *et al.* (1991:160).

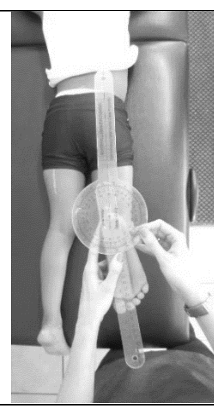


Figure 2-11: Measurement of tibial torsion (TT) with a goniometer[55]

In the one-year-old American white children an internal TT of -5.0° (±35°) was reported, from four years of age external TT of 8° (±16°) was noted for the first time (Staheli *et al.*, 1985:43), which is still far lower than the 24° (±13°) and 35° (±6.0°) reported by Cheng *et al.* (1991:160) and Jacquemier

[55] Photo demonstrated and published with permission – Photo by M. van Aswegen

et al. (2008:191) respectively. Shultz *et al.* (2008:140) employed both a different participant categorisation method and measurement method than described above. TT was measured in supine as the bisection of lines between the medial- and lateral malleoli and the medial and lateral femoral epicondyles and true vertical. The participant lies in supine with the knee flexed to 90°, the researcher palpates the medial and lateral malleoli and place the one arm of the goniometer at a right angle to this line, the other goniometer arm is extended to true vertical. Internal TT was reported in negative degrees (Shultz *et al.*, 2008:140). TT of the youngest maturation group (nine- to 14-year-olds: Table 2-15) in Belgian children, are seemingly similar to those found in nine-year-old Chinese children (Cheng *et al.*, 1991:160). Regardless of the method employed to measure or categorise participants, it is evident that TT steadily increases with age (Staheli *et al.*, 1985:43; Cheng *et al.*, 1991:160; Jacquemier *et al.*, 2008:191; Shultz *et al.*, 2008:140).

Table 2-15: Measurements of normal and abnormal tibial torsion (TT) limits in children of different ethnicities and ages

<table>
<tr><th colspan="3">Demographical region</th><th colspan="20">Measurements of Tibial Torsion (TT)
TT means in degrees ±Standard deviation (number of participants), positive = external torsion, negative = internal torsion</th></tr>
<tr><th colspan="3">Age (years)</th><th colspan="2">1 yr</th><th colspan="2">2 yr</th><th colspan="2">3 yr</th><th colspan="2">4 yr</th><th colspan="2">5 yr</th><th colspan="2">6 yr</th><th colspan="2">7 yr</th><th colspan="2">8 yr</th><th colspan="2">9 yr</th><th colspan="2">10 yr</th></tr>
<tr><td>European children (N=1319)[56]</td><td colspan="2">Males & females (N=427)</td><td colspan="2">-</td><td colspan="2">-</td><td colspan="2">34.1 ±6.4</td><td colspan="2">34.8 ±6.2</td><td colspan="2">35.1 ±5.8</td><td colspan="2">33.1 ±6.2</td><td colspan="2">33.8 ±6.9</td><td colspan="2">34.5 ±6.3</td><td colspan="2">36.3 ±4.9</td><td colspan="2">36.5 ±4.9</td></tr>
<tr><td>American white Children (N=500)[57]</td><td colspan="2">Males & Females (N=205)</td><td colspan="2">-5±35 (n=16)</td><td colspan="2">4±16 (n=22)</td><td colspan="2">5±18 (n=29)</td><td colspan="2">8±16 (n=27)</td><td colspan="2">11±14 (n=18)</td><td colspan="2">12±16 (n=22)</td><td colspan="2">13±13 (n=16)</td><td colspan="2">14±12 (n=20)</td><td colspan="2">11±19 (n=19)</td><td colspan="2">12±13 (n=16)</td></tr>
<tr><td>Chinese children (n=2630)[58]</td><td colspan="2">Males & Females (n=2500)</td><td colspan="2">-</td><td colspan="2">22 ±11</td><td colspan="2">23 ±13</td><td colspan="2">24 ±13</td><td colspan="2">25 ±12</td><td colspan="2">27 ±25</td><td colspan="2">34 ±27</td><td colspan="2">34 ±22</td><td colspan="2">35 ±23</td><td colspan="2">31 ±26</td></tr>
<tr><th colspan="3">Age groups (years)</th><th colspan="5">-</th><th colspan="5">3-5 yr</th><th colspan="5">6-8 yr</th><th colspan="5">9-11 yr</th></tr>
<tr><td>Norwegian Children (N=52)[59]</td><td colspan="2">Males & Females (n=52)</td><td colspan="5">-</td><td colspan="5">27.7±5.9 (n=14)</td><td colspan="5">32.3±6.6 (n=17)</td><td colspan="5">33.6±6.5 (n=21)</td></tr>
<tr><th colspan="3">Age groups (years)</th><th colspan="5">Mean age±SD</th><th colspan="15">4-10 yr</th></tr>
<tr><td rowspan="4">Belgian (N=124)[60]</td><td rowspan="3">IFA</td><td>All</td><td colspan="5" rowspan="3">6.9±2.9</td><td colspan="15">12.6±11.8 (M-n=43 ; F-n=43)</td></tr>
<tr><td>IRT</td><td colspan="15">5.3±7.9 (74 limbs)</td></tr>
<tr><td>ERT</td><td colspan="15">21.6±9.9 (50 limbs)</td></tr>
<tr><td colspan="2">ITT</td><td colspan="5">6.9±2.7</td><td colspan="15">-5.3±9.6 (M-n=18; F-n=19)</td></tr>
<tr><th colspan="3">Age (years)</th><th colspan="5">MatGr1</th><th colspan="5">MatGr2</th><th colspan="5">MatGr3</th><th colspan="5">All ages (9-18 yr)</th></tr>
<tr><td rowspan="3">American Children (N=173)[61]</td><td colspan="2">Males (N=88)</td><td colspan="5">15.8±9.6 (n=26)</td><td colspan="5">21.3±6.7 (n=34)</td><td colspan="5">24.9±5.8 (n=34)</td><td colspan="5">20.8±8.2</td></tr>
<tr><td colspan="2">Females (N=85)</td><td colspan="5">15.7±6.7 (n=25)</td><td colspan="5">18.3±6.9 (n=29)</td><td colspan="5">21.5±7.8 (n=31)</td><td colspan="5">18.6±7.5</td></tr>
<tr><td colspan="2">All (N=173)</td><td colspan="5">15.7±8.2 (n=51)</td><td colspan="5">19.9±6.9 (n=63)</td><td colspan="5">23.1±7.1 (n=65)</td><td colspan="5">-</td></tr>
</table>

Legend: ERT = external rotated tibia, F = female, IFA = increased femoral anteversion, IRT = internal rotated tibia, ITT = internal tibial torsion, M = male, yrs = years, MatGr1 = maturation group 1, MatGr2 = maturation group 2, MatGr 3 = maturation group 3, n = number of participants per age group, N = total number of participants, SD = standard deviation, yr = year(s)

[56] Jacquemier *et al.* (2008) only measured the right limb.
[57] Staheli *et al.* (1985) Thigh foot angle measured with participant in prone. Values read from grahps. Adult values omitted here.
[58] Cheng *et al.* (1991) Thigh foot angle measured with participant in prone, results read from graphs.
[59] Kristiansen *et al.* (2001) Tibial torsion measured in standing, with Computed Tomography (CT) scan, adult values omitted here.
[60] (Fabry *et al.*, 1994) Longitudinal study considering only pathological torsion issues, TTA determined with computed tomography (CT) scan.
[61] Shultz *et al.* (2008) 9 to 18-year-olds divided into 3 of the Tanner's 5 stages of maturation. Goniometric measurements performed in supine.

Profiling information will first be required for the development of the hip, knee, and ankle in Setswana-speaking children, since this is not available. The other reason why profiling information is required, is owed to various researchers from different continents, finding differences in the development of the TFA in children when comparing their results. Differences were observed in TFA development especially when comparing children of different ethnicities and races. Similarly, differences in rotational angles, including the AVA and TTA have been reported by various researchers (Staheli *et al.*, 1985:43; Cheng *et al.*, 1991:155; Jacquemier *et al.*, 2008:189-190). The development of the TFA and rotational angles in black Setswana children have not been determined, hence this is a gap in literature and will be addressed in the first objective where the profile and development of the TFA and rotational angles affecting the femur and tibia in black Setswana-speaking children between the ages of two to nine years will be determined. A cross-sectional clinical investigative study is required for this type of research, requiring 100 participants per age group, to allow profiling. The TFA can be used to diagnose excessive genu varum or –valgum in children. Health care professionals such as paediatricians, physiotherapists, occupational therapists, and biokineticists will use the profiles produced by this study, in order to classify and diagnose the presence of genu varum or –valgum in the FP.

Since the knee is part of the lower kinetic chain and subject to correlated motions, it can not only be assessed from a FP perspective (Riegger-Krugh *et al.*, 1996:166; Magee, 2006:661), TT and hip AV occurring in the TP should also be investigated simultaneously. TT, hip AV, and the Q-angles are the rotational angles that were also addressed in the first objective. Chapter three addresses the first objective, in the form of an article. The above-mentioned tests, TFA, Q-angle, femoral AV, TT are all static clinical measurements, with clear differences in children of different ethnicities, genders and activity levels. In order to best compare biomechanical differences, the kinematic differences between these groups should be compared. The following section will describe child gait kinematics.

2.8. LOWER LIMB (LL) KINETIC CHAIN EFFECTS LINKED TO GENU VARUM OR -VALGUM

The LL consists of the ankle, knee, and hip and forms a kinetic chain. Ankle motions, affect the knee and hip, therefore, the knee being the centre of the LL kinetic chain, necessitates the assessment of it in the FP, while considering the hip and tibia in the TP too (Magee, 2006:661). Riegger-Krugh *et al.* (1996:166) mention in their review on skeletal malalignments of the lower quarter that correlated motions[62] such as tibia vara (lateral tilting of the tibia in the FP), medial TT (internal rotation of the tibia in the TP) and external rotation of the hip in the TP is found to accompany genu varum. The correlated motions associated with genu valgum include pes planus, excessive subtalar pronation, external TT, lateral patellar subluxation, excessive hip adduction and ipsilateral hip excessive internal rotation along with the contralateral rotation of the lumbar spine (Riegger-Krugh *et al.*, 1996:166).

Similarly, genu varum is associated with compensatory motions[63] such as forefoot valgus (plantar flexion of the forefoot in relation to a neutral rearfoot), excessive subtalar pronation and pelvic internal rotation (Riegger-Krugh *et al.*, 1996:166). The compensatory motions in individuals with genu valgum include forefoot varus and in order to allow the lateral calcaneus to make ground contact, excessive subtalar supination occurs. In order to reduce lateral pelvic sway during the gait, the individual compensates by walking with an in-toeing gait. The individual with genu valgum might also present with ipsilateral pelvic external rotation as a compensatory motion.

For the foot, leg, and hip, the normal range of rotation is accepted as values that fit within two standard deviations from the mean (Sass *et al.*, 2003:461). Cheng *et al.* (1991:155) also assessed rotation of the tibia (medial- or lateral TT (Magee, 2006:801)) in the establishment of knee development from genu varum to genu valgum to neutral as children age. They attempted to measure the foot progression angle (a measure of in-toeing or out-toeing during walking) too, but after their pilot study revealed great variability and unreliability, it was excluded (Cheng *et al.*, 1991:155). Jacquemier *et al.* (2008:187-188) were later the first to aim to establish a rotation profile of the LL in children and measured TT, femoral AV in 1319 healthy children. They also performed a visual gait analysis where the foot progression angle was observed, but not recorded (Jacquemier *et al.*, 2008:188).

Jacquemier *et al.* (2008:187) investigated the rotational profile of the LL in 1 319 healthy children between the ages of three to ten years of age, in schools in France. They aimed to establish norms for TT and femoral AV in healthy children according to age and gender. TT was measured in a sitting position, whilst femoral AV was measured in prone with the angle between the tibia and true vertical representing the femoral AVA once the greater trochanter was found to be at the maximal prominence (Jacquemier *et al.*, 2008:188). The reported results indicated no differences between male and female participants in terms of TT. Results for the genders were pooled for TT however,

[62] Motions or postures which are normally expected somewhere in the kinetic chain, when a joint has a skeletal malalignment (Riegger-Krugh *et al.*, 1996:165)
[63] Motions or postures which may occur in response to skeletal malalignments to improve neuromusculoskeletal function (Riegger-Krugh *et al.*, 1996:165)

differences between males and females were found in terms of femoral AV and analysed separately (Jacquemier *et al.*, 2008:190).

The population studied by Jacquemier *et al.* (2008:192) were divided into one of the following four rotational profiles; the first and largest category, regardless of age, were for those with normal femoral AV and normal TT, where 84% (8-year-old males) to 98% (6-year-old males) of the population fit into this profile. The other categories were for normal femoral AV and low (internal) TT, which was observed in three- to eight-year-olds in both genders, at 1.9% (six-year-old males) and an 8.7% (eight-year-old males) occurrence rate. A high femoral AV and normal TT, was observed in almost all age clusters, yet more often in males, with an occurrence rate from 1% (six-year-old females) and 8.5% (nine-year-old females). A high femoral AV and low (internal) TT, was the least common profile observed, but most often in four- and five-year-old males, at an occurrence rate of 0.8% (four-year-old males) to 1.5% (five-year-old males). The combination of a normal femoral AV with a high (external) TT or a high femoral AV with a high (external) TT was not observed in their population at all (Jacquemier *et al.*, 2008:190). In a later study on adult cadaver LL profiles, TT and femoral AV were found to be predictors of another. Internal TT was associated with greater femoral AV, with the reverse pattern also observed (Weinberg *et al.*, 2017:124). The authors argued the finding was likely attributed to gait compensation, to allow a neutral foot progression angle (Weinberg *et al.*, 2017:126). When they compared rotational profiles of African-Americans to whites, they found the African-Americans to be more likely to present with increased internal TT and femoral AV in comparison to whites. The authors did not find any association between osteoarthritis and increased internal TT or femoral AV. Based on their large random sample and the lack of an association with osteoarthritis, they concluded it provided enough evidence to not treat malalignments in children unless they present with significant symptoms or gait disturbances (Weinberg *et al.*, 2017:127).

2.9. KINEMATIC EFFECTS

2.9.1. Motor development task: Factors influencing independent walking

Perhaps the greatest motor development task, or developmental milestone, all children should master within the first two years of life is independent walking. Postural changes take place to allow at first, an upright standing posture, which is then further developed to allow walking (Sutherland, 1997:163; Malina, 2004:53; Johnston *et al.*, 2014:204). An infant must first accomplish neck and head control, followed by control of the upper trunk and upper extremities and then control of their entire trunk to allow the ability to sit unsupported. Initial locomotion is in some a prone stomach crawling manoeuvre, followed by prone creeping on hands and knees, and/or feet (Malina, 2004:53).

Progressed locomotion efforts ensue, which include the child standing up against furniture into a standing, supported position. The child may attempt to walk, using the furniture or an individual as support before they finally walk independently (Malina, 2004:53). Initial walking gait is easily identified as children walk with a wide base of support, arms stretched out and the lack of knee flexion and therefore jerky gait is very characteristic of this initial independent walking phase (Malina, 2004:53). Walking ability develops at an exponential rate, once the child starts walking. Increases are seen in stride length, walking speed, and cadence. As this walking ability or proficiency improves, adult-like walking patterns emerge (Malina, 2004:53).

Malina (2004:50) classifies motor development as a continuous process of movement pattern and skill acquisition. He lists five factors which have the potential of affecting child motor development, including; the child's neuromuscular maturation status, their physical growth and behavioural characteristics, the tempo of their physical growth, the child's biological maturation and behavioural development, their previous movement experiences and lastly, their new movement experiences. These factors interact with the child's physical and socio-cultural environment and together they affect the child's motor development and ability (Malina, 2004:50). The development of fundamental movements such as running, jumping, hopping, catching and striking, to name a few, are all affected by the environment in which the child is reared. Children learn through experimentation and the context of the environment(s) in which they experiment in, such as at home, playgrounds in the community, the crèche or preschool, all contribute to skill development and ability (Malina, 2004:54). Asencio *et al.* (2019:32) utilised a questionnaire to determine whether psychomotor development factors, or developmental milestones, such as crawling, crawling age and walking age would contribute to the risk of developing paediatric planovalgus foot (PPVF) in addition to the well-recognised obesity risk factor. They found an increased risk of PPVF development in the left foot of males who started independent walking at a later age, thus showing that variation in milestone attainment, can affect LL development (Asencio *et al.*, 2019:33).

2.9.2. Development of normal walking patterns

Kinematic adult-like heel-to-toe gait develops within the first three years of age, but adult-like velocity and cadence changes are only established in the first seven years of age (Ganley *et al.*, 2005:141; Johnston *et al.*, 2014:204). Chester *et al.* (2006:726) aimed to identify any age-related differences in the kinematic and kinetic gait patterns in children and to identify when adult-like kinetic gait patterns emerge in the child population. Their data can be utilised for the diagnoses and treatment of gait abnormalities in children. They utilised a motion capture system along with three force plates and compared sagittal joint angles and joint kinetics by dividing the children into age groups of three- to four-year-olds, five- to six-year-olds, seven- to eight-year-olds and nine to 13-year-olds. Their results indicated some temporal-spatial differences between the age categories, which were expected as children differ in body size, proportion, and walking schemes. Similar to other research, they found that adult-like joint angle patterns emerge from three years of age, as they did not see any significant differences during gait in the sagittal hip, knee or ankle angles (Chester *et al.*, 2006:729). Significant differences were found between the youngest group (three- to four-year-olds) and the eldest group (nine to 13-year-olds) for mean peak hip- and knee moments, with the mean peak hip flexion moment at mid-cycle significantly smaller for the youngest group. Similarly, peak knee extension moment in early stance was significantly smaller in the youngest group as compared to the eldest group, and progressively increased with age. No differences in sagittal hip- or knee joint peak powers between the different age groups were found. However, mean peak plantarflexion moments during late stance increased with increasing age. The eldest group generated peak plantar flexor moments of 1.4 N-m/kg of body weight which is similar to adult values, whilst the youngest group generated a significantly smaller peak plantarflexion moment of 0.93 N-m/kg. The seven- to eight-year-old group also generated a significantly smaller peak plantarflexion moment of 1.19 N-m/kg which suggest that adult-like peak plantar flexor moments during late stance emerges only after nine years of age due to a lack in neuromuscular maturity in younger children (Chester *et al.*, 2006:731).

2.9.3. Measuring of gait kinematics

During human gait, complex and vast amounts of data can be gathered in terms of joint and segment kinematics (Benedetti *et al.*, 1998:204). When dealing with large information sets, the investigator needs to follow a systematic approach which can become quite demanding. Furthermore, the investigator needs to compare their results to normal kinematic gait findings of similar populations and here the reliability of their measures and protocol is often challenged (Benedetti *et al.*, 1998:204). When analysing gait using a stereophotogrammetric method, thus with the aid of wall-mounted cameras (usually in a circular pattern, to ensure coverage of all angles focused on the participant or participant), reflective skin markers are placed over various skeletal landmarks (Benedetti *et al.*, 1998:204), to represent either an anatomical landmark such as the ASIS or a technical- or anatomical frame such as the femur (Cappozzo *et al.*, 1995:172-173). For the technical frame, various markers are placed for example on the medial- and lateral femoral condyles and on the medial- and lateral epicondyles on the ankle, the program will then link these markers to estimate the position of the LL (Cappozzo *et al.*, 1995:172-173). Since these markers are placed on the skin to represent underlying anatomical landmarks, one should remember the probability of error due to skin movement during walking or error when placing markers (Benedetti *et al.*, 1998:204). Other errors that could arise, include instrument measure error, where marker coordinates are not properly measured within the laboratory or calibration error, where either the skin placed markers, or plate-mounted markers, do not reconstruct the anatomical landmark position correctly (Benedetti *et al.*, 1998:206). The calibrated anatomical systems technique (CAST) protocol, is an experimental protocol described by Cappozzo *et al.* (1995:176), which assumes joint centres such as the acetabular joint centre. This protocol is best used and most reliable for non-pathological gait investigation in normal participants, since mounting of cluster marker-sets on a plate, produces an estimated 3 mm less error than direct skin markers (Benedetti *et al.*, 1998:207).

Benedetti *et al.* (1998:206) investigated a total of 124 kinematic and kinetic gait parameters, in their data management study, where they tested the reliability of the CAST gait analysis protocol. They included temporal-spatial (time-distance), kinematic and kinetic variables in their analysis. The kinematic gait analysis parameters which describe the LL biomechanics of the participant during gait, as developed by Benedetti *et al.* (1998:206) are summarised in Table 2-16. When performing gait analysis for clinical applications, precision, accuracy, and reproducibility are required (Benedetti *et al.*, 1998:212). The CAST gait analysis protocol is a suitable protocol to use in able-bodied participants and compares well with other popular gait analysis reports. Unfortunately, as with any protocol using skin markers, skin motion artefacts will always lead to reduced reliability, especially for parameters in the FP and TP (Benedetti *et al.*, 1998:213; Sinclair *et al.*, 2015:120). Sinclair *et al.* (2012:16) aimed to assess the reliability of the CAST technique of Cappozzo *et al.* (1995:173), using a test-retest method and a three dimentional (3D) kinematic approach. In terms of hip-, knee- and ankle kinematics, no statistically significant differences were found in any of the three cardinal planes (Sinclair *et al.*, 2012:18). In addition, strong correlations were observed at the hip joint between pre- and post-kinematic waveform comparisons in the sagittal plane (R^2 = 0.99), FP (R^2 = 0.98) and TP (R^2 =0.96). At the knee joint similar results were obtained with R^2 = 0.99 in the sagittal plane, R^2 = 0.96 in the FP and TP. Ankle joint correlations were also strong at R^2 = 0.96 in the sagittal plane, R^2 = 0.90 in the FP and R^2 = 0.91 in the TP.

The fifth and final objective of the current study will compare the kinematic gait pattern differences between blank BC Setswana-speaking children with black non-BC Setswana-speaking children between seven years to nine years of age. For this objective, a smaller randomised sample, also of a cross-sectional design, will be selected from the larger sample. This objective makes sense to investigate, as any static orthopaedic change in limb alignment will likely have dynamic consequences and should be observable in kinematic gait analysis. This study is based on science and will add to new knowledge of the orthopaedic effects of BC on the lower kinetic chain in terms of static developmental effects and the kinematic effects.

Table 2-16: Temporal-spatial- and Kinematic gait analysis parameters

Time-distance data			Pelvis rotations (°)		
P1	Stance duration	%stride	HR1	Min. rot. Sagittal plane	
P2	Swing duration	%stride	HR2	Max. rot. Frontal plane	
P3	Stride length	cm	HR3	Max. rot. Frontal plane	
P4	Stride length	%height	HR4	Max. rot. Transverse plane	
P5	Cycle duration	ms			
P6	Cadence	stride/min			
P7	Velocity	cm/s	(%stride)		
P8	Velocity	%height			
			THR1	**Time at HR1**	
			THR2	Time at HR2	
			THR3	**Time at HR3**	
			THR4	**Time at HR4**	
HIP ANGLES PARAMETERS (°)		**KNEE ANGLES PARAMETERS (°)**		**ANKLE ANGLES PARAMETERS (°)**	
H1	Flexion at heel-strike	K1	Flexion at heel-strike	A1	Flexion at heel-strike
H2	Max. flex. at loading resp.	K2	Max. flex. at loading resp.	A2	Max. plant. Flex. loading resp.
H3	Max. ext. in stance-phase	K3	Max. ext. in stance-phase	A3	Max. dorsiflex. in stance-phase
H4	Flexion at toe-off	K4	Flexion at toe-off	A4	Flexion at toe-off
H5	Max. flex. in swing-phase	K5	Max. flex. in swing-phase	A5	Max. dorsiflex. in swing-phase
H6	Total sagittal plane excursion	K6	Total sagittal plane excursion	A6	Total sagittal plane excursion
H7	Total frontal plane excursion	K7	Total frontal plane excursion	A7	Total frontal plane excursion
H8	Max. add. in stance-phase	K8	Max. add. in stance-phase	A8	Max. eversion in stance-phase
H9	Max. add. in swing-phase	K9	Max. add. in swing-phase	A9	Max. inversion in swing-phase
H10	Total trans. plane excursion	K10	Total trans. plane excursion		
H11	Max. int. rot. in stance-phase	K11	Max. int. rot. in stance-phase		
H12	Max. ext. rot. in swing-phase	K12	Max. ext. rot. in swing-phase		
(%stride)		**(%stride)**		**(%stride)**	
TH2	Time at H2	TK2	Time at K2	TA2	Time at A2
TH3	**Time at H3**	**TK3**	**Time at K3**	**TA3**	**Time at A3**
TH5	Time at H5	TK5	Time at K5	TA5	Time at A5
TH8	Time at H8	TK8	Time at K8	TA8	Time at A8
TH9	Time at H9	TK9	Time at K9	TA9	Time at A9
TH11	Time at H11	TK11	Time at K11		
TH12	Time at H12	TK12	Time at K12		

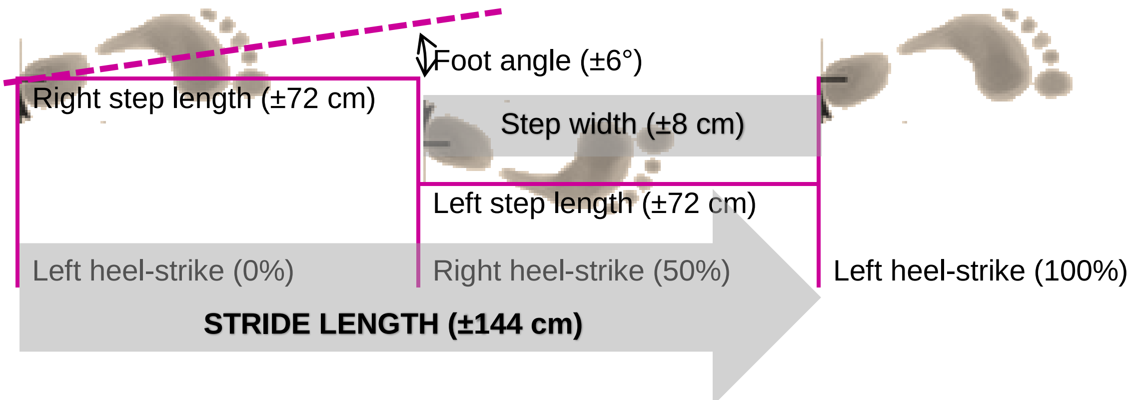
Legend: A = ankle, abd =abduction, add = adduction, cm = centimetre, cm/s = centimetre per second, dorsiflex = dorsiflexion, ext = extension, flex = flexion, H = hip, HR = Hip Rotation, int = internal, K = knee, max = maximal, min = minimal, ms = millisecond, plant = plantar, resp = response, rot = rotation, stride/min = stride per minute, T = Time, TA = Time at Ankle, TH = Time at Hip, TK = Time at Knee, THR = Time at Hip Rotation, trans = transverse

Table adapted from Benedetti et al. (1998:206)

2.9.4. Kinematics: Temporal-spatial differences

While walking, the same series of cyclical movements are constantly repeated, of which a gait cycle or the synonym, a stride, is the most fundamental movement (Neumann, 2013:527). With foot contact, normally the heel strikes first thus the gait cycle is initiated with a heel-strike (H-S). This is often denoted by 0% of the gait cycle and completion or 100% of the gait cycle is regarded as soon as the heel of the same foot strikes again. A full gait cycle (from 0% to 100%, first H-S to next H-S of the same foot), can further be divided into the stance- and swing phase. Thus, two steps are taken during one gait cycle, one left- and one right step (Neumann, 2013:527). From H-S to toe-off (T-O) of the same foot, is referred to as the stance phase, whilst in the contralateral limb, from the T-O to H-S (airborne) is termed the swing phase. Normally the stance phase lasts 60% of the full gait cycle and the swing phase lasts the remaining 40% thereof (Neumann, 2013:529). Spatial descriptors (Table 2-16) of the gait cycle include the stride length (P3 & P4), step length, step width, and the foot angle, whilst the temporal descriptors of gait include the cadence (P6), stride time and step time. Walking speed (P7 & P8), is seen as a combination of both spatial- and temporal measures.

Spatial Gait Descriptors



Legend: cm = centimetre, % = percentage of the gait phase
Figure adapted from Neumann (2013:527))

Figure 2-12: Spatial gait descriptors and adult values

In terms of the spatial descriptors, stride length (Figure 2-12), the distance achieved in one gait cycle between consecutive heel contacts of the same foot, is the most basic (Neumann, 2013:527). Step length is the distances achieved during the left step (calculated from the right foot's heel contact to the heel contact of the left foot), and right step (Figure 2-12). Chester *et al.* (2006:728) observed similar step lengths of 0.5 m in children between the ages of three- to 13 years, which did not change with age. The 10 cm difference in step length observed between studies by Farr *et al.* (2014) (step length = 0.61 m) and Chester *et al.* (2006) (step length = 0.50 m) could be attributed by the significantly older children (five- to 16-year-olds) that participated in the former study and slightly younger (three- to 13-year-olds) in the latter study. The lateral distance between the heel centres of the left and right foot contacts, is called the step width and is approximately 7.0 cm to 9.0 cm in adult gait. The foot angle or foot progression angle, which measures the amount of external torsion (toe-out) or internal torsion (toe-in), is the angle between the walking line and the long axis of the foot (from the centre of the heel to the second metatarsal head) (Neumann, 2013:527-528). This angle is approximately 7° (external) in adults (Neumann, 2013:527-528).

Cadence (P6) or step rate, is the most basic temporal gait descriptor and is calculated as the number of steps taken per minute. Chester *et al.* (2006:728) observed significantly higher cadences in their youngest group of three to four-year-olds presenting with 146.6 steps per minute in comparison to the eldest group of children older than nine years with 120.2 steps per minute. Stride time is the time taken to complete a full gait cycle, whilst step time is the time taken to complete a left or a right step and can be derived from the cadence if the gait is symmetrical (Neumann, 2013:528). Chester *et al.*

(2006:728) compared temporal-spatial parameters of different age group children between three- to 13 years of age, and found significant differences in stride time between younger age groups (three to four-year-olds: 0.83s) and older age groups (nine years and older: 1.1s), with younger ages presenting with shorter stride times.

Walking speed (P7 & P8), which is the combination of spatial and temporal measures, is calculated as the distance covered in a given amount of time and is usually presented as units of meters per second (m/s). Various ways exist to calculate speed, for example by calculating the time taken to cover a certain distance, or the distance travelled in a given amount of time, or through the multiplication of the step rate and step length (Sutherland, 1997:165). Walking speed was found to increase significantly ($p = 0.002$) with age in the study by Chester *et al.* (2006:728). Children older than nine years of age, attained a walking speed of 1.1 m/s whilst the youngest group of children between three- and four years only managed 0.9 m/s (Chester *et al.*, 2006:728). Factors such as age or physical traits such as height and weight may impact walking speeds (Chester *et al.*, 2006:729), and although walking speed varies considerably between individuals, it is one of the most functional measures of walking ability. To increase walking speed, an individual might choose one of two strategies or utilize a combination of the two: either increasing the stride or step lengths or increasing cadence. Since all the other spatial, temporal and kinematic gait measures depend on the walking speed, it is important to include the walking speeds at which data is collected, for proper interpretation (Neumann, 2013:528-529).

Two periods of double-limb support (bilateral foot contact with the ground) and two periods of single-limb support (only one foot on the ground) are observed within a gait cycle. With increasing gait speeds, the double-limb support times become shorter until they disappear completely in running, where they are replaced with both feet simultaneously spending time in the air. On the contrary, at slower walking speeds, the double-limb support periods become increasingly longer and provide greater stability, which is commonly seen in the elderly to prevent falls (Neumann, 2013:530-531). Further subdivision of the stance phase into five separate events includes heel contact, foot flat, mid-stance (M-S), heel-off (or heel rise) and T-O. Heel contact starts at 0% of the gait cycle as soon as it makes contact with the ground. Foot-flat occurs at around 8% of the gait cycle and is defined as the moment the whole plantar surface of the foot makes contact with the ground. M-S is observed at 30% and 50% of the gait cycle and has three definitions: Firstly, when the bodyweight is directly supported over the LL in contact with the ground and secondly, the contralateral foot in swing phase passes the stance phase LL and thirdly, when the greater trochanter of the femur is directly above the midpoint of the supporting foot in the sagittal plane. Heel-off is observed at about 40% of the gait cycle and is defined as the instant the heel lifts off the ground. T-O is seen at 60% of the gait cycle and is the moment the toes leave the ground. Shortly before T-O is a period termed push-off, which takes place between 40% to 60% of the gait cycle where the ankle moves into plantar flexion (Neumann, 2013:531).

The swing phase depicts somewhat greater variation but can be subdivided into three phases, namely early-, mid- and late swing. Early swing is observed between 60% to 75% of the gait cycle as the period shortly after T-O and the mid-swing phase (Neumann, 2013:532). Mid-swing is observed around 75% to 85% of the gait cycle and parallels the M-S phase (with the swinging limb moving past the stance limb) observed in the contralateral leg, and lasts until the late swing phase. The late swing phase is observed between 85% to 100% of the gait cycle and lasts until foot contact occurs (Neumann, 2013:532).

2.9.5. Joint kinematics and joint angle patterns

When analysing kinematic human body motion, such as walking and running, the body, or body segments or parts of segments are described without concern for the forces involved or the torques that produce these motions (kinetics) (Sutherland, 1997:166; Neumann, 2013:3). Translation and rotation are two of the most common motions that occur and are described by kinematics. Linear translatory motion occurs when a rigid body segment or body part moves parallel to and in the same direction as another body part, which is either rectilinear (in a straight line) or curvilinear (along a curved line) (Neumann, 2013:4). An example of curvilinear motion is the path followed by a fixed point on the head whilst walking. Rotation is when a body segment follows a spherical path around an axis or pivot point, for example, shaking the head “no”, from left to right (Neumann, 2013:4-5). Translation motion is described by units of meters, whilst rotation is described by units of degrees. Position, velocity, and acceleration are the primary kinematic variables of concern when analysing human motion (Neumann, 2013:5). Motions can occur in various directions thus kinematics utilizes the three cardinal planes, namely the; SP, FP and TP, to describe the motion. The SP splits the body into left and right sections and allows movements such as knee flexion, hip flexion, plantar- and dorsiflexion. These movements occur around the perpendicular axis of rotation which is the medial-lateral (ML) axis in this case (Neumann, 2013:5). The FP splits the body into anterior and posterior sections and permits shoulder- and hip abduction or adduction and lateral neck flexion. The anterior-posterior (AP) axis permits these FP based movements. Lastly, the TP splits the body into superior and inferior sections and permits rotation such as left- and right neck rotation, elbow supination or -pronation and internal- or external hip rotation. The longitudinal axis allows these rotary movements in the TP (Neumann, 2013:5).

Each joint within the human body allows a specific number of independent movements and is classified as the degrees of freedom (DOF), with the maximal number of three, based on the joint structure and the three cardinal planes (Neumann, 2013:6). Both the hip and shoulder are synovial ball-and-socket joints and have three DOF, permitting movement toward all three of the cardinal planes, whilst the knee joint allows only one DOF and the ankle two DOF (Neumann, 2013:6-7). Joints in the human body are not perfectly congruent or spherical, therefore they permit varying amounts of translation in addition to rotation due to ligament laxity and muscle action. These slight translatory motions that occur are called accessory motions and can also be described in the three linear directions. Specific tests are utilized to determine ligament integrity of joints, by comparing the translation motion possible in a relaxed joint (Neumann, 2013:7). Since joints are made up of two bones, generally a distal bone and a proximal bone, movement can be analysed from two perspectives. Firstly, where the distal segment is relatively fixed and permits the proximal segment to rotate about it (proximal-on-distal perspective) versus secondly, where the proximal segment is relatively fixed and permits the distal segment to rotate about it (distal-on-proximal perspective). During human gait, both these perspectives are utilized in the analysis. In the stance phase, the LL is planted and the upper body moves on it. In the swing phase, the LL moves forward and the upper body is relatively fixed.

Although displacement of the body occurs in a linear direction due to the summation of LL angular rotation of which most occur in the sagittal plane, some motion although smaller in magnitude, also occurs in both the FP and TP and cannot be ignored. During analysis it is important to note when relative motions (joint kinematics: the relative motion of one bone compared to another) and relative bone motions (bone kinematics: relative motion without comparison to other bones or joints) are described (Neumann, 2013:535).

2.9.5.1. Sagittal plane (SP) kinematics

Descriptions of sagittal plane pelvic motions are small and are describing the movement of the bone structure itself, whilst movements at the other joints are of larger magnitude and are described as joint kinematics (Neumann, 2013:536). Should gait abnormalities occur, they are easiest to observe in the sagittal plane at the ankle and knee (Sutherland, 1997:166).

Pelvis

Pelvic motion in the sagittal plane uses a neutral pelvic position (at 0°) as the point of reference to describe anterior- or posterior pelvic tilt about the ML axis (Neumann, 2013:537). Neutral pelvis is obtained in a relaxed stance and since the pelvis is a rigid structure both iliac crests are considered to move together. At normal walking speeds the amount of pelvic tilt (anterior or posterior) is small (about 2 to 4°). When plotting the pattern of pelvic motion during the full gait cycle, a sine wave with two full cycles is observed (Neumann, 2013:537).

An almost neutral pelvis is seen at H-S, then during the loading response (0% to 10%), some posterior pelvic tilt occurs which changes to an anterior tilt shortly after M-S (30%). Posterior pelvic tilt is again observed shortly after T-O, but it changes back to anterior tilt during initial and mid-swing (60% to 87%) and again back into a posterior direction at the terminal swing phase (87% to 100%) (Neumann, 2013:536). As the speed of walking increases, an increase in pelvic motion is also observed. This increased pelvic tilt serves to increase the functional leg length in order to increase step length required to increase walking speeds (Neumann, 2013:537).

Hip

To allow normal walking, an individual needs at least 30° of hip flexion and at least 10° of hip extension (Neumann, 2013:537). At heel contact at a normal walking speed, hip flexion of approximately 30° is seen, whilst a maximum amount of hip extension of about 10° is seen just before T-O. Hip flexion starts during the pre-swing (50 to 60%) where the hip is in neutral (0°). Hip flexion is required in the swing phase in order to bring the lower extremity forward to prepare for the next foot contact and maximal hip flexion of just over 30° is observed shortly prior to H-S. At heel contact, the hip needs to already move toward extension in order to prepare for weight acceptance (Neumann, 2013:537). Similarly, to pelvic tilting in the sagittal plane, the amount of hip flexion and –extension increases with an increase in walking speed (Neumann, 2013:537).

In the work by Chester *et al.* (2006:729), there is a slight and steady decrease in maximal hip flexion angles observed in children as they advanced in age. Maximal hip flexion was 43° at around 85% of the gait cycle in three to four-year-old children, whilst it was 36° also around 85% of the gait cycle in nine to 13-year-olds (Chester *et al.*, 2006:729). Hip extension in the stance phase was reported as 10° for children with genu varum and 14° for children in the control group in the work by Stief *et al.* (2011:493) (Figure 2-17).

Knee

Knee kinematics is more complex than those occurring at the hip (Neumann, 2013:538). To allow normal walking, an individual needs about 60° of knee flexion and nearly full extension. Approximately 5° of knee flexion is observed at heel contact, but this increases to 10° to 15° during the initial 15% of the gait cycle. Eccentric action of the quadriceps allows this slight knee flexion in order to absorb shock and to allow weight acceptance with weight transfer to the limb. Full knee extension follows the initial slight knee flexion until heel off (40%), from here knee flexion of about 35° is observed until T-O (60%) and by mid-swing (73%) maximum knee flexion of about 60° is observed. Knee flexion in the initial swing phase shortens the LL length to allow toe clearance from the ground. The knee extends again from mid to terminal swing to almost full extension in preparation of H-S (Neumann, 2013:538).

Chester *et al.* (2006:729) observe greater knee flexion angles in the younger children (three- to four years old), than the older children (nine- to 13 years old), but also greater flexion angles than mentioned above, but this may be attributable to age (Table 2-17). Maximal knee flexion angles of 70° were observed in three to four-year-olds, which declined to 58° in nine- to 13-year-olds. These were both observed around 70% to 75% of the gait cycle and corresponding to Neumann (2013:538). Full knee extension findings of Chester *et al.* (2006:729) also reflect similarity to that of Neumann (2013:538) as maximal knee extension in seven to eight-year-olds were 6° at approximately 43% of the gait cycle, in nine to 13-year-olds a much smaller knee extension angle of 2° was observed around 43% of the gait cycle. Stief *et al.* (2011:493) investigated the maximal knee flexion angles in the stance phase and did not observe any significant differences (p=0.15) between children with genu varum (17°) and their age-matched controls (15°). Knee extension angles in the terminal phase did vary significantly (p=0.02), with children with genu varum presenting with a knee extension angle of 8° versus an angle of 4° in the control group (Table 2-17).

Ankle (Talocrural joint)

In one-year-olds plantar- and dorsiflexion ankle movements are limited (Sutherland, 1997:166). H-S is absent in one-year-olds but develops slightly, six months later. Slight plantar flexion (0° to 5°) is observed at heel contact (Sutherland, 1997:166). The ankle dorsiflexors control plantar flexion eccentrically, to allow flat placement of the foot on the ground after heel contact. Ankle dorsiflexion of up to 10° is seen as the tibia moves forward over the planted foot (8% to 45%). Plantar flexion is initiated just after heel off and maximal plantar flexion of 15° to 20° is seen just after T-O (40%). Drop-foot positions were reported by Sutherland (1997:166) during the swing phase of 1.5-year-old children, while dorsiflexion to a neutral position of 0° was observed by Neumann (2013:538) during the swing phase in order to allow ground clearance of the toes.

The observations of Neumann (2013:538) was validated by two different studies, Ho *et al.* (2000:274) found maximal dorsiflexion of 18° at approximately 47% of the gait cycle (these values were obtained from graphs) in children with neutral gait patterns, and 1.1° dorsiflexion at 40% of the gait cycle in in-toeing children and 14° in out-toeing children (Table 2-17). Maximal dorsiflexion angles presented by Chester *et al.* (2006:729) were 9.77° in three- to four-year-olds, 8.85° in five- to six-year-olds, 9.88° in seven- to eight-year-olds and 6.58° in nine- to 13-year-olds, most of which occurred at 65% to 67% of the gait cycle. Normal walking speeds need between 10° of dorsiflexion and 20° of plantar flexion, and greater dorsiflexion ranges are required for the stance phase than in the swing phase. Limited ankle ROM will lead to abnormal gait patterns, such as greater "toe-out" gait to compensate for limited dorsiflexion, but places increased stress on the medial aspects of the foot and knee (Neumann, 2013:539).

Table 2-17: Child kinematic gait findings in the sagittal plane (SP) at the hip, knee, and ankle

	Maximal hip angle	**Maximal knee angle**	**Maximal Ankle angle**
Ho *et al.* (2000) [5 to 6-year-olds] Maximal degrees at percentage gait cycle (SD)	**Out-toeing (n=18)**		
	-		2° (plt flx) at 65% -14° (dorsiflx) at 47%
	Neutral (n=59)		
	-		5° (plt flx) at 0% -18° (dorsiflexion) at 47%
	In-toeing (n=9)		
	-		18° (plt flx) at 65% -1.1° (dorsiflx) at 40%
Chester *et al.* (2006) [3 to 13-year-olds] Maximal degrees at percentage gait cycle (SD)	**3 to 4-year-olds (n=13)**		
	43.24° (flx) at 85% (8.5°) -7.96° (ext) at 54% (11.54°)	70.19° (flx) at 75% (8.2°) 7.55° (ext) at 43% (6.51°)	20.57° (plt flx) at 42% (5.55°) -9.77° (dorsiflx) at 67% (8.95°)
	5 to 6-year-olds (n=10)		
	37.49° (flx) at 85% (10.63°) -8.00° (ext) at 54% (7.83°)	67.74° (flx) at 72% (10.95°) 10.64° (ext) at 43% (6.93°)	19.77° (plt flx) at 42% (5.13°) -8.85° (dorsiflx) at 65% (10.37°)
	7 to 8-year-olds (n=12)		
	39.51° (flx) at 85% (6.89°) -8.15° (ext) at 54% (8.96°)	61.35° (flx) at 72% (8.47°) 6.18° (ext) at 43% (7.86°)	17.42° (plt flx) at 45% (7.18°) -9.88° (dorsiflx) at 65% (8.58°)
	9 to 13-year-olds (n=12)		
	36.41° (flx) at 85% (8.71°) -8.15° (ext) at 54% (7.97°)	58.05° (flx) at 70% (6.42°) 1.53° (ext) at 43% (5.36°)	20.49° (plt flx) at 49% (4.91°) -6.58° (dorsiflx) at 65% (6.54°)
Stief *et al.* (2011) [12 to 19-year-olds] Flexion values are reported in stance phase Hip Extension values in stance phase Knee Extension values in terminal stance phase	**Maximal hip flx/ext in degrees (SD)**	**Maximal knee flx/ext in degrees (SD)**	-
	Genu Varum (n=14)		
	-9.97° (ext) (10.17)	17.23° (flx) (5.12°) 8.19° (ext) (6.20°)*	-
	Control (n=15)		
	-13.47° (ext) (8.35)	14.55° (flx) (4.65°) 3.58° (ext) (3.69°)*	-
	p=0.32	p=0.15 p=0.02*	-

Legend: ext = extension, flx = flexion, flx/ext = flexion/extension, plt flex = plantar flexion, dorsiflx = dorsiflexion, SD = standard deviation
Negative = hip-/knee extension and dorsiflexion, positive = hip-/knee flexion and plantar flexion (H0 – read from graphs)

First tarsometatarsal joint

This joint provides some flexibility to the medial longitudinal arch of the foot and dorsiflexes slightly during the loading phase of walking due to bodyweight forces. The shock-absorption ability of the medial longitudinal arch is reduced if this joint is stiff (Neumann, 2013:505). In general, this joint permits slight amounts of both plantar- and dorsiflexion during gait (Neumann, 2013:539).

First metatarsophalangeal joint

This joint is also known as the hallux or great toe and proper motion here is crucial to normal gait (Neumann, 2013:539). The hallux is slightly hyperextended at heel contact and moves into relatively neutral shortly after heel contact to heel off. The joint hyperextends to about 45° to 55° (angle between the long axis of the first metatarsal and the proximal first phalange) somewhere between heel off and just before T-O. This joint returns to a neutral angle somewhere between the late part of the stance phase and the initial swing. An exaggerated toe-out gait is observed in those with limited hyperextension capabilities, which in turn leads to increased stress to the medial foot, hallux and knee structures (Neumann, 2013:539).

2.9.5.2. Frontal plane (FP) kinematics

Smaller amplitude rotations are observed within the FP in comparison with those occurring in the sagittal plane. Although smaller in amplitude, the FP based rotations occurring especially at the hip and subtalar joints are regarded as important (Neumann, 2013:539). Ho *et al.* (2000:274) investigated FP ankle kinematics in children with an out-toeing- versus neutral- versus in-toeing gait, their findings are tabularized in Table 2-18 In terms of ankle inversion and –eversion, they noted relatively similar patterns in in-toeing and neutral gait children, except that inversion angles, were more pronounced in the in-toeing group. At H-S they observed significantly ($p < 0.001$) different inversion angles between all three groups; the out-toeing gait children presented with 2.6° inversion, and neutral gait children presented with 3.4° inversion, whilst in-toeing gait children presented with 8.1° of inversion (Ho *et al.*, 2000:274) (Table 2-18).

Pelvis

Pelvic motions occurring in the FP are best observed from an anterior- or posterior perspective, watching the lateral rise and fall of the iliac crests. A total of 10 to 15° of rotation from pelvic-on-femoral (hip) adduction and abduction is seen. In the first 15 to 20% of the gait cycle in weight acceptance on the lower extremity, a pelvic drop is observed on the contralateral hip due to pelvic-on-femoral adduction of the stance hip. After this, between 20 to 60% of the gait cycle, progressive hip abduction of the stance limb is observed as the contralateral limb in the swing phase' iliac crest is elevated (Neumann, 2013:540).

Hip

All FP hip motion observed is due to pelvic-on-femoral movement and corresponds to the pattern of elevation and depression of the iliac crests as described above. In the swing phase, both FP pelvic motions and the relatively free-moving femur returns the hip joint to its neutral FP motion (Neumann, 2013:540).

In Stief *et al.* (2011:493) significant differences (p=0.03) were observed in the stance phase of gait for hip adduction angles of 4° in children with genu varum and 8° in the control group. Significant differences (p=0.05) were also observed in terms of hip abduction in the stance phase, with children with genu varum presenting with an abduction angle of 8° and the controls with an abduction angle of 6° (Stief *et al.*, 2011:493) (Table 2-18).

Knee

The knee is relatively stable in the FP owing to the articular geometry and strong collateral ligaments. There is some angular movement that occurs, but it is so minute that it is difficult to quantify. With bone pins planted into femoral and tibial cortices, 1.2° of knee abduction (valgus) with heel contact was found. The small amount of valgus remains there during the stance phase and then increases to approximately 5° during the initial swing. Maximal knee abduction coincides with maximal sagittal plane knee flexion and then returns to its slightly abducted angle just before the next heel contact. Abnormal lower extremity alignments such as genu valgum, could have an impact on the FP motion observed in the knee during gait (Neumann, 2013:540).

Significant differences (p<0.001) were observed in knee adduction angles during the stance phase in children with genu varum (11°) and their age-matched controls (4°), whilst the ROM of adduction versus abduction in this phase did not produce significant differences at 9° and 6° respectively (Stief *et al.*, 2011:493) (Table 2-18).

Ankle (Talocrural joint)

Dorsiflexion and plantar flexion are the primary motions of the ankle joint yet some eversion and abduction of the ankle are observed along with dorsiflexion, whilst inversion and adduction occur along with plantar flexion. These secondary motions are minute and will not be discussed further (Neumann, 2013:540).

Foot or subtalar joint

Pronation and supination movements are triplanar and are allowed through the interaction of the subtalar and transverse tarsal joints. The combination of eversion with abduction and dorsiflexion pronation is produced, whilst supination occurs due to inversion, adduction and plantar flexion. Neumann (2013:541) considered subtalar joint eversion and inversion to represent the triplanar motion of pronation and supination respectively and measured the angle between the posterior calcaneus and posterior lower leg.

At heel contact, subtalar inversion of about 2 to 3° is seen, which rapidly changes into eversion of the calcaneus immediately after heel contact until M-S (30% to 35%) where maximal eversion of 2° is seen. From here, the joint moves back toward an inverted position, but at heel off (40% to 45% of the gait cycle), the calcaneus is in a relatively neutral position. The initiated movement back toward inversion continues between heel-off and T-O, where it reaches about 6° of inversion. The inverted position is maintained in preparation for the next heel contact. Neumann (2013:541) mentions that this is the general pattern reported by most researchers, but varies slightly depending on measurement preferences.

Table 2-18: Child kinematic gait findings in the frontal plane (FP) at the hip, knee, and ankle

Author	Maximal hip abduction/adduction in degrees (SD)	Maximal knee adduction in degrees (SD)	Ankle inversion/eversion angles Degrees at % of gait cycle				
Ho *et al.* (2000) [5- to 6-year-olds]	**Out-toeing (n=18)**						
	-	-	0% 2.6°	20% 1.8°	50% 0.8°	80% 1°	100% 3°
	Neutral (n=59)						
	-	-	0% 3.4°	20% 4.1°	50% 4.9°	80% 4.5°	100% 3.5°
	In-toeing (n=9)						
	-	-	0% 8.1°	20% 10.2°	50% 11°	80% 10.6°	100% 9.5°
Stief *et al.* (2011) [12- to 19-year-olds] Values reported in stance phase	**Genu Varum (n=14)**						
	4.14° (ADD) (4.68°)† -7.65° (ABD) (3.55°)*	10.91° (ADD) (5.13°)‡ 8.97° (ROM add/abd) (5.61°)	-				
	Control (n=15)						
	7.45° (ADD) (2.71°)† -5.48° (ABD) (2.09°)*	3.55° (ADD) (2.45°)‡ 6.44° (ROM add/abd) (2.43°)	-				
	p=0.03† p=0.05*	p<0.001‡ p=0.12	-				

Legend: ABD = abduction, ADD = adduction, add/abd = full range attained, n = number of participants, ROM = range of motion, SD = standard deviation
Negative = abduction & eversion, Positive = adduction & inversion. Read from graphs (Ho)

2.9.5.3. Transverse plane (TP) kinematics

The rotations of the pelvis, femur, and tibia described in the sections below, describe the movements of the bones themselves in the TP. Hip- and knee rotations described below refer to the rotations occurring in the joints (Neumann, 2013:542).

Pelvis (bone kinematics)

Pelvic rotation in the TP is facilitated about the longitudinal axis of rotation and coincides with the hip joint of the stance leg. This rotation is best observed from a superior view (this section is described for the right gait cycle). At heel contact of the right leg, the right ASIS is more anterior than the contralateral left ASIS. Counter-clockwise rotation of the pelvis is observed in the initial 15% to 20% of the gait cycle, whilst a clockwise rotation is seen throughout the rest of the right leg' stance phase. The clockwise rotation is due to the left ASIS which comes forward along with the forward-moving left leg in the swing phase. The right ASIS is more posterior to the left at T-O from the right leg. Pelvic rotation of 3.0° to 4.0° to either direction, is observed throughout the gait cycle. Greater pelvic rotation is observed with faster walking speeds, in order to allow greater step lengths (Neumann, 2013:542).

Hip

Femoral and pelvic rotations occur simultaneously. Slight external hip rotation based on the relative posterior placement of the left ASIS is observed at right heel contact. During most of the stance phase on the right leg, a net internal movement of the right hip is seen, whilst the left ASIS is moving forward. At left heel contact (50%) maximal internal rotation of the right leg is observed, which then moves into external rotation after this until mid-swing as the right leg lifts and moves forward. Slight right hip internal rotation takes place from mid-swing into right heel contact (Neumann, 2013:543).

The TP gait kinematics observed in children are summarized in Table 2-19 below. Farr *et al.* (2014:1363) observed significantly ($p < 0.001$) greater mean external hip rotation in children with genu valgum (-11.2°) as compared to children with normal LL alignment (control group). Children in the control group presented with a mean internal hip rotation of 3.7° (Farr *et al.*, 2014:1363). In contrast, Stief *et al.* (2011:493) did not find any significant differences between patients presenting with genu varum and their age-matched controls. Both the patient and control group presented with internal hip rotation angles in the stance phase, of 16° and 14°, respectively (Table 2-19).

Femur (bone kinematics)

Internal femoral rotation occurs after heel contact for the first 15% to 20% of the gait cycle, which reverses into external rotation from 20% of the gait cycle until just after T-O. The swing phase consists mostly of internal rotation of the femur. Rotation of 6.0° to 7.0° of the femur is seen in either direction during gait (Neumann, 2013:542).

Knee

Two to three degrees of relative external knee rotation (external rotation of the tibia relative to the femur) is observed at heel contact. Progressive internal rotation is seen throughout the stance phase due to greater internal rotation of the tibia in comparison to the femur. Relative internal rotation of approximately 5° is seen in T-O (tibia relative to the femur). External knee joint rotation is seen during the swing phase in preparation for the following heel contact. Excessive pronation of the foot could cause knee pain during walking due to disruption of this synchrony of the movement between the tibia and femur, but the validation of this is obstructed due to the difficulty of accurate measurement of TP knee kinematics (Neumann, 2013:543).

Significant differences ($p < 0.001$) in TP knee rotations were observed in a study by Farr *et al.* (2014:1365), when they compared the gait of children with genu valgum to children with normal knee alignment (Table 2-19). Children with genu valgum presented with lower external knee rotation angles (-11.2°) as compared to controls (-19.9°). The researchers were unable to determine whether the significantly altered kinematics at the hip and knee were compensatory motions or independent factors in children with genu valgum, but they reasoned that the decreased external knee rotation could be a compensatory mechanism based on the foot progression angle. Foot progression angles were not significantly different, but they presented greater external rotation than the control group (Farr *et al.*, 2014:1367). In contrast, no significant differences were observed between children with genu varum and their age-matched controls in the study by Stief *et al.* (2011:493) and both populations presented with internal knee rotation in the stance phase of 5.0° and 4.0° respectively.

Table 2-19: Child kinematic gait findings in the transverse plane (TP) at the hip, knee, and ankle

Author	Maximal Hip rotation In degrees (SD)	Knee rotation In degrees (SD)	Foot progression angle In degrees (SD)
Farr *et al.* (2014) [8 to 16-year-olds] Values reported in stance phase	**Genu Valgum (n=33)**		
	-6.3° (ER) (7.7°)	-11.2° (ER) (8.4°)	-10.1° (ER) (6.2°)
	Control (n=11)		
	3.7° (IR) (5.6°)	-19.9° (ER) (8.4°)	-7.8° (ER) (4.6°)
	<0.001*	<0.001*	p=0.065
Stief *et al.* (2011) [12 to 19-year-olds] Values reported in stance phase	**Genu Varum (n=14)**		
	15.69° (IR) (9.74°)	4.86° (IR) (16.26°)	-4.26° (ER) (6.68°)
	Control (n=15)		
	14.14° (IR) (7.67°)	3.66° (IR) (6.73°)	-5.93° (ER) (5.40°)
	p=0.64	p=0.79	p=0.46

Legend: ER = external rotation (negative values), IR = internal rotation (positive values), n = number of participants, SD = standard deviation

Tibia (bone kinematics)

Tibial rotations amount to approximately 8.0° to 9.0° in either direction and are very similar to femoral movements that were described above (Neumann, 2013:543).

Ankle and foot

Inversion and eversion are the primary movements allowed by the subtalar joints and were described by movements occurring in the FP. Other TP movements of the ankle and foot are considered minute and hence not further described (Neumann, 2013:543). Farr *et al.* (2014:1363) also investigated the kinematic effects on the foot progression angle in children with genu valgum in comparison with children with normal LL alignment and did not find any significant differences between the two groups. The mean foot progression angle of children with genu valgum was 10.1° of external rotation whilst children with normal LL alignment presented with 7.8° of external rotation (Table 2-19). Stief *et al.* (2011:493) found similar results and children with genu varum presented with a mean external ankle rotation of 4° and 6° in the control group, which also did not differ significantly.

The section above describes child kinematic gait findings in the three planes and refers on occasion to angular or rotational malalignments in comparison to normal kinematic gait patterns. Gait analysis renders large and complex data sets, which requires careful analysis (Benedetti *et al.*, 1998:204). It is evident from the studies performed that researchers do not tend to analyse the complete 124 gait parameters as suggested by (Benedetti *et al.*, 1998:206), neither are all the kinematic and temporal-spatial parameters as presented in Table 2-16 analysed at once. Researchers rather tend to focus on a certain cardinal plane, such as in the case of Chester *et al.* (2006:726-732) mainly investigated kinetic differences, but in terms of kinematics, they focused on maximal hip, knee and ankle angles found in the SP. Alternatively, researchers focus on a certain joint and the angles observed during certain gait cycles, for example, the study by Ho *et al.* (2000:271-277), who focused on angles observed at the ankle joint, in the various cardinal planes at various phases or percentages of the gait cycle. The following section focuses on gait characteristics in children with genu valgum or genu varum.

2.9.6. Angular malalignments and gait

Goldman *et al.* (2010:48) note the belief that gait will be affected in those with angular malalignments of the LL, yet very little literature is available regarding this topic. In terms of general gait patterns, tibia vara is associated with an in-toeing gait and a lateral knee thrust whilst genu valgum is associated with out-toeing.

2.9.6.1. Gait characteristics of children with genu valgum

Farr *et al.* (2014:1367) investigated the gait characteristics of children and adolescents with idiopathic genu valgum (patient population) in the FP and TP, in comparison to children with healthy normal knees (control population). They compared the kinematic data to radiographic data used for clinical diagnostic purposes in order to establish if a correlation exists between these variables. Surgeons often utilise radiographic indications to determine if surgery to correct LL malalignment is warranted. Farr *et al.* (2014:1362) reasoned that 3D gait analysis will enable clinicians to determine subsequent compensatory effects caused by LL malalignments, which are not revealed with static imaging, through assessment of the dynamic load characteristics during gait. Their results indicated, as found by others, that knee loading in the stance phase was substantially higher in the patient population, than the control population. The patient population also showed a decrease in internal knee valgus moment which results in a pathological lateral load at the knee instead of the physiological medial load found in control populations. They were unable to obtain literature on investigations of paediatric gait in the TP for valgus malalignments, to compare their findings with. They found their patient population to exhibit increased external rotation at the hip whilst lowering the external rotation at the knee and a foot progression angle which was directed more outward. Due to a lack of comparative data, they were unable to establish if these findings were due to independent gait characteristics or due to compensation for the malalignment, but they suspect it was compensatory. When they applied linear regression analysis it indicated that foot progression angle and knee rotation were the strongest predictors of frontal knee angle moment changes (Farr *et al.*, 2014:1367). They did not note any significant differences between patient and control trunk position during gait and all their findings in the TP showed a range of rotation ranges for the patient population rather than a uniform pattern. Due to this, they recommended future studies to confirm their findings. In terms of the correlation between static radiographs and 3D gait analysis, they did not find a strong correlation for any of the parameters (Farr *et al.*, 2014:1369).

Böhm *et al.* (2015:396) later indicated a similar low correlation between static- and dynamic measures when they measured the effects of guided growth (a surgical procedure to correct either genu varum or –valgum) on the normalization of FP knee joint moments during gait and concluded that dynamic load change can be predicted from changes in static alignment. Böhm *et al.* (2015:396) concluded that 3D gait analysis can expose the reasons why discrepancies are found between static- and dynamic measures at the knee joint, for instance, torsional deformities at the knee which causes a toe-out gait (Böhm *et al.*, 2015:396). Farr *et al.* (2014:1369) found the strongest correlation was between the mechanical lateral distal femoral angle (mLDFA) on the radiograph and increased lateral loading in the knee, which raised the question if surgery would be more merited if the genu valgum originated at the distal femur as opposed to at the proximal femur. No other strong correlations were found and the authors speculated it was due to compensatory measures. The use of gait analysis software to determine the hip joint centre accurately was questioned, due to the researchers not finding a strong comparison between the knee varus or valgus angle obtained through gait and radiographic measures. The reason for the interpretation was due to the fact that in overweight children the determination of the hip joint centre is more difficult to find and prone to bias. Finally, they reasoned that comparing different modalities such as static radiographs with dynamic gait, results in too differing findings (Farr *et al.*, 2014:1369). A discussion based on a case study comparing the kinetic and kinematic gait differences between a 13-year-old female with unilateral genu valgum with a normally aligned counterpart was omitted (Ganesan *et al.*, 2016:3169).

2.9.6.2. Gait characteristics of kids with genu varum

Stief *et al.* (2011; 2014) investigated the kinematic and kinetic effects of genu varum in adolescents in two separate studies. In their more recent study, Stief *et al.* (2014:689) investigated the effects of genu varum malalignment on the foot progression angle, on internal rotation occurring at the knee and internal rotation occurring at the hip joint, in terms of the TP. Patients with genu varum were between 12 and 19 years of age and presented with a mechanical axis angle (MAA) larger than 1.3°. The MAA is determined radiographically and consists of the angle between the line from the femoral head centre to the femoral intercondylar notch centre and the line from the centre of the talus to the centre of the tibial spine. They used these same skin marked landmarks, which were added in addition to the Helen Hayes marker set, in their gait analysis (Stief *et al.*, 2014:689). Three kinematic variables were identified as the foot progression angle, and internal rotation occurring at the knee in respectively the terminal stance phase and the stance phase, which were correlated to the static MMA obtained in the radiographs. The patient population consisted of 18 individuals and 15 age-matched controls (Stief *et al.*, 2014:689). No significant findings were observed in the control groups in terms of the mentioned kinematic variables. The foot progression angle was determined as the angle of the long axis of the foot in the stance phase measured against the walking direction axis and presented a medium linear correlation to the MMA ($r = 0.584$; $p = 0.022$). The foot progression angle was progressively more internally rotated (9°) in patients with genu varum than in the age-matched controls (1.3°) with normal knee alignment. This increased internal rotated foot progression angle may be attributed to a higher internal tibial rotation (7.9°) that was observed in genu varum patients as opposed to the controls (3.7°) (Stief *et al.*, 2014:690-691). A high linear correlation was observed for maximal knee internal rotation in the terminal stance phase and MMA ($r = 0.696$; $p = 0.004$), but in terms of maximal hip internal rotation in the stance phase there was no significant correlation ($r = -0.459$, $p = 0.085$) (Stief *et al.*, 2014:690-691). Stief *et al.* (2014:691) argued that these TP rotation differences might be compensatory mechanisms adopted by patients with genu varum during gait, since there were not any significant differences in passive TP hip and TT between the controls and patients.

In their earlier study, Stief *et al.* (2011:492-493) also investigated the kinematic and kinetic compensatory strategies adopted by adolescents (12 to 19 years of age) with genu varum, in terms of hip, knee and ankle motion in the SP, FP and TP. The same protocol and groups were utilised as described in the section above, but in this study, they investigated the peak angles of the hip, knee, and ankle in the three cardinal planes. In the patient group, a significantly lower maximum knee extension (8.19°) was found in the terminal stance phase than in the control group (3.58°). In the FP, significant differences were observed for all the peak angles measured in terms of hip- and knee abduction and adduction, but no significant findings were observed for the foot, knee or hip peak angles in the TP (Stief *et al.*, 2011:493). In terms of spatio-temporal parameters, no differences of significance were observed between patients and controls (Stief *et al.*, 2011:493). In terms of kinetic findings, they observed a decrease in the maximum knee extension moment in the terminal stance phase and argued that this reduction could be attributed to the significantly lower maximum knee extension found in the patient group in the same gait phase. None of their patients presented with osteoarthritis, but similar to patients with osteoarthritis, the patient group had a 32% greater knee adduction moment in both the mid and terminal stance phase caused by a higher maximum knee adduction angle in the stance phase attributed to their knee malalignment. This important finding implies the greater risk associated with the progression of osteoarthritis in individuals with genu varum malalignment (Stief *et al.*, 2011:494). The authors argued that the observed significant compensatory actions found in both the TP (Stief *et al.*, 2014:692) and sagittal plane (Stief *et al.*, 2011:494) are reason enough to not view genu varus malalignment solely from a FP perspective.

This section divulged important information regarding the development of kinematic gait patterns in children. Often linking normal gait patterns to those of patient populations, or child gait patterns to those of adults. It seems that adult-like kinematic gait patterns are established by the age of seven years. No studies were found investigating differences between children who were BC and those who were not BC. The methods employed by Farr *et al.* (2014:1369); and Stief *et al.* (2014:494) can be utilised to determine whether kinematic differences between BC children and non-BC children exist.

2.10. SUMMARY

BC is synonymous with African mothering methods and the act of BC has various detriments and benefits. Investigations aimed toward the effects of BC on school readiness, peripheral vision and cognition (Pretorius *et al.*, 2002a:586; Pretorius *et al.*, 2002b:175) showed detrimental effects on the child. BC also show benefits which include keeping the child safe whilst the mother is working (Graham *et al.*, 2015:59), improved bonding between mother and child (Russell, 2015:1131), less fussy children as they are soothed whilst being BC (Hunziker *et al.*, 1986:645-646) and possibly the most important benefit being that the BC position most probably contributes to the prevention of the development of DDH in the BC child (Griffiths, 1970:90-91; van Meerdervoort, 1974:2463; Roper, 1976:157; Graham *et al.*, 2015:59). The positive orthopaedic effect of BC on hip development could possibly translate to other effects, either positive or negative, in the inferior kinematic chain. Changes in terms of the TFA in the FP or, alterations at the hip, knee and lower leg in the TP; altering hip AV, potentially affecting the Q-angle or the TT profile of the BC child, could exist. These possible effects of BC on the knees have never been investigated. Future study should determine in black South African children that are BC, the impact of the act of BC on the development of the LL of the child at the hip, knee and ankle. Kinematic gait differences at the TFJ, between BC children and non-BC children would contribute to understanding the differences that might be present in static and kinematic movement. In order to answer the posed potential research questions, a cross-sectional, observational study was developed, recruiting Setswana-speaking children, aged two- to nine years. The study protocols and results will be presented in the Chapters that follow, as research papers.

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CHAPTER 3 : ARTICLE 1

THE PROFILE AND DEVELOPMENT OF THE LOWER LIMB IN BLACK SETSWANA-SPEAKING CHILDREN BETWEEN THE AGES OF TWO- TO NINE YEARS

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ABSTRACT:

Introduction

Back-carrying of children, often deep into toddlerhood, is a culturally accepted behavior of Setswana mothers. Back-carrying positively impacts hip development, in the possible prevention of developmental hip dysplasia, but the impact on knee development is unknown. Ethnic differences in the development of lower limb measures in children were reported. Profile data on normal lower limb development and specifically tibiofemoral angle (TFA) development in black Setswana-speaking South African children are lacking. This study aimed to provide profiles on the development of the TFA and rotational angles affecting the femur and tibia in black Setswana-speaking children between the ages of two- to nine years.

Methods:

Measurements of the TFA, intercondylar distances or intermalleolar distances (IMD), quadriceps-angle, hip anteversion (AVA)- and tibial torsion angle (TTA), were clinically obtained with a goniometer or tape measure from 691 healthy two- to nine-year-old Setswana-speaking children. All measures were obtained in standing except the anteversion- and TTA angles were measured in prone positsion, with the knee flexed to 90°.

Results:

Nearest to genu varum angles at -3.4° (±3.4°) were observed in two-year-olds. At three years of age, a peak of -5.7° (±2.3°) genu valgum was documented, which plateaued at -4.5° (±2.1°) at age nine years of age. IMD results supported TFA observations. Small quadriceps-angles were observed in the two-year-old group (-3.81°±3.77°), which increased to a mean peak of -9.2° (±4.4°) in the nine-year-old group. From the age of four years old, children presented with neutral TTAs, whilst two- and three-year-olds presented with internal TTAs. Hip anteversion was the greatest in the three-year-old age group at 77.6°±13.8° and decreased to a mean angle of 70.8°±6.9° in the nine-year-old age group.

Conclusions:

The TFA of Setswana-speaking children developed similarly to those tested in European, Asian and Nigerian children, but the AVA and internal TTA were greater in the Setswana population than angles reported in European children. These developmental profiles assist in identifying out of normal ranges in knee development of black Setswana-speaking children, to enable corrective interventions early in life.

This is a level II prognostic study.

Keywords: Lower limb development, Tibiofemoral angle, Hip anteversion.

INTRODUCTION

Knee development profile information is vital to healthcare providers e.g., pediatricians, physical therapists while assessing child knee alignment [1-3]. The development of the tibiofemoral angle (TFA), previously described in American- [4], Chinese- [1], Indian- [3], and Nigerian cohorts [5, 6], is used to investigate knee alignment [1, 3-14]. In normal children, there is a progression of the knee angle, which varies mildly between children from different ethnicities [1, 4, 9, 10, 12, 15-17]. Infants present with knee varus angles (bow-legs) shortly after birth, which changes to a valgus angle (knock-knees) in early childhood [1, 3, 4, 8, 9, 12]. In addition to TFA, intercondylar distance (ICD) for genu varum (distance between the medial femoral condyles) or the intermalleolar distance (IMD) for genu valgum (distance between medial tibial malleoli) [1, 3-10, 17], is often used to assess knee alignment.

Tibia vara, internal tibial torsion (TT) and femoral retroversion (RV), often accompanies genu varum [18]. This necessitates the inclusion of whole kinetic chain measurements, from the hip to the ankle, including both frontal- and transverse plane observations, such as femoral anteversion (AV) and TT. The quadriceps-angle (Q-angle) indicates the muscular lateral pull of the quadriceps musculature and may be indicative of femoral AV [19]. Differences in Q-angle measurement protocol can lead to significant variation in measurements [19, 20]. In spite of the limitations, the field Q-angle measure is still valuable.

In South Africa, a low-middle income country, where over - and undernutrition exist within the same population [21], back-carrying (BC) of children is a culturally accepted norm. Against the background of potentially poor nutrition at the onset of life, profiling lower limb (LL) development and the influence of BC on LL development, would be of interest because current data is lacking. Setswana-speakers (approximately 12 million) reside in the larger central region of South Africa and Botswana, but the language is also spoken in parts of Namibia, Zimbabwe, and Lesotho [22]. This study forms part of a larger study where LL development of back-carried (BC) Setswana-speaking children will be compared to the LL development of non-back-carried (non-BC) children. This comparison of LL development in Setswana-speaking children requires normative data of LL development. It will not be sufficient to compare LL development of Setswana-speaking children to the development reported in children of other ethnicities, due to researchers finding differences in LL development in children of different ethnicities [1, 3-14]. The aim of this study is, to profile the normal development of the LL, in terms of the TFA, IMD or ICD, Q-angle, femoral AV, and TT, in black Setswana-speaking, South African children between two- to nine years of age.

METHODS

The study was approved by the North-West University (NWU) Ethics Committee (NWU – 00094-17-A1). Permission was granted to perform this study at primary schools and crèches by the Department of Education and the Department of Social Development. All participants and their legal guardians voluntarily signed (or verbally assented) assent and informed consent, respectively.

Participants:

The 1 382 LL measurements were taken from 691 (Table 1), black Setswana-speaking children between the ages of two- to nine years. Infants and children younger than two years of age, who cannot walk independently were excluded due to the majority of tests being performed with the participant in standing. Previous research found neutral limb alignment occurs at seven years of age, thus the age limit of nine years was decided upon for the current study. It was aimed to recruit 100 children per age category, to allow percentile ranking, however, recruitment of the younger age categories, between age two- to four years, proved challenging. Recruitment was conducted at crèches and primary schools in Potchefstroom and Ikageng, North-West Province, South Africa, listed and registered by the Department of Education and the Department of Social Development. Of the potential 18 crèches and 24 primary schools in Potchefstroom and Ikageng, six schools and eight crèches agreed to participate. Typically, primary schools have approximately 180 learners per grade. This renders a total population of 3 240 potential participants, across three grades (excluding grade R, since many primary schools did not have a grade R). Principals of ten schools declined participation, based on the lack of Setswana-speaking children attending their schools. The crèches visited typically are much smaller with a total of approximately 50 to 80 children attending a crèche. Children were grouped to the nearest integer, according to their chronological age. All participants were black Setswana-speaking, healthy, with no known history of musculoskeletal disorders and could walk independantly. A total of 724 children were tested, of which 33 were excluded for reporting musculoskeletal disorders in a self-report questionnaire.

Table 1. Demographic characteristics of the participants per age group, in black Setswana-speaking children

	Total					**Males**					**Females**				
Age group	n	Mean Age (yr) ±SD	Mean Height (cm) ±SD	Mean Body mass (kg) ±SD	Mean BMI (kg.m^{-2}) ±SD	n	Mean Age (yrs) ±SD	Mean Height (cm) ±SD	Mean Body mass (kg) ±SD	Mean BMI ±SD	n	Mean Age (yrs) ±SD	Mean Height (cm) ±SD	Mean Body mass (kg) ±SD	Mean BMI (kg.m^{-2}) ±SD
2	38	2.10	85.19	12.41	17.13	23	2.06	84.62	12.23	17.11	15	2.17	8.14	12.70	17.15
		±0.28	±7.51	±1.99	±1.92		±0.27	±6.13	±1.51	±1.65		±0.30	±9.54	±2.63	±2.36
3	52	3.00	91.36	14.08	16.77	28	2.96	91.20	14.41	16.93	24	3.05	91.57	13.65	16.21
		±0.26	±6.19	±2.34	±1.95		±0.26	±4.94	±1.78	±2.54		±0.26	±7.61	±2.89	±2.17
4	54	4.06	101.81	16.19	15.53	25	4.13*	103.15	17.09†	15.94†	29	4.00*	100.65	15.40†	15.19†
		±0.23	±5.60	±2.61	±1.34		±0.21	±6.44	±3.12	±1.43		±0.24	±4.57	±1.79	±1.18
5	112	5.08	107.46	18.14	15.61	58	5.10	108.67‡	18.75††	15.79††	54	5.05	106.17‡	17.50††	15.42††
		±0.27	±5.46	±3.32	±1.75		±0.27	±5.74	±3.12	±1.56		±0.27	±4.87	±3.43	±1.92
6	113	6.06	113.16	20.05	15.57	63	6.06	113.23	19.80	15.39	50	6.06	113.06	20.38	15.79
		±0.28	±5.21	±4.08	±2.34		±0.28	±4.79	±2.86	±1.55		±0.28	±5.76	±5.25	±3.08
7	98	7.01	118.52	21.93	15.49	47	6.97	118.98	21.85	15.34	51	7.04	118.11	22.01	15.63
		±0.27	±6.13	±4.56	±2.01		±0.28	±6.44	±4.39	±2.01		±0.26	±5.87	±4.75	±2.03
8	127	8.07	125.12	26.32	16.66	50	8.06	125.25	25.61	16.25	77	8.07	125.03	26.79	16.93
		±0.27	±6.11	±7.37	±3.59		±0.27	±5.78	±5.23	±2.68		±0.27	±6.34	±8.47	±4.06
9	97	8.92	129.77	27.33	16.11	41	8.91	129.93	27.45	16.17	56	8.93	129.65	27.24	16.07
		±0.24	±6.59	±5.93	±2.61		±0.23	±6.76	±5.32	±2.30		±0.25	±6.52	±6.39	±2.84
Total	**691**	**6.20**	**113.56**	**21.05**	**16.11**	**335**	**5.99****	**112.57**	**20.55†††**	**15.96**	**356**	**6.40****	**114.55**	**21.53†††**	**16.03**
		±2.03	**±14.07**	**±6.73**	**±2.49**		±2.03	±14.24	±5.81	±2.06		±2.00	±13.85	±7.48	±2.87

Significant differences between males and females:
*Age differences; *p=0.040, d=0.578, **p=0.000, d=2.151; Height differences: ‡p= 0.015, d=0.471; Weight differences: †p=0.16, d=0.687, ††p=0.47, d=0.382, †††p=0.05, d=0.15; BMI differences: †p=0.038, d=0.080, ††p=0.015, d=0.216*
Legend: yr = years, cm = centimetre, kg = kilogram, kg.m^{-2} = kilogram per square meter, SD = standard deviation

Procedure:

A self-report questionnaire was utilized to determine inclusion- and exclusion criteria. Prior to measurements, all anatomic landmarks were identified through palpation and marked. The measurements were performed by the main researcher (MvA), while trained assistants ensured the participant maintained neutral hip rotation and full knee extension. TFA testing considered the angle between the line from the anterior superior iliac spine (ASIS) to the center of the patella and the line from the center of the patella to the center of the ankle joint [1, 3]. Varus angles were reported in positive degrees and valgus angles as negative degrees, as measured with a goniometer. The ICD was measured when the child presented with a varus alignment, as the distance between the femoral condyles, whilst the child was standing with his/her hips and knees in neutral alignment and extended, and the ankles touching. IMD was similarly measured for a child presenting with a valgus alignment as the distance between the medial malleoli and with the knees touching [1, 3, 6].

The Q-angle was identified as the angle between a line from the ASIS to the center of the patella and a line from the center of the patella to the tibial tuberosity. The Q-angle was obtained with the child standing, knees in extension, quadriceps musculature relaxed and the feet and hips in neutral alignment [19]. Measurements of anatomical and functional limb lengths [23, 24], body mass, height, and body mass index (BMI) were included for descriptive statistical purposes.

AV or RV was determined clinically through Craig's test [19], where the child lay in a prone position with the knee flexed to 90°. The position where the greater trochanter projected most laterally and parallel to the plinth surface, upon internal and external hip rotation was held. The angle between the true vertical and the lower leg was measured. To allow accurate measurement, the angle between the horizontal border of the plinth and the central axis of the LL was measured and subtracted from 90°. The tibial torsion angle (TTA) or thigh-foot angle, was measured with the child in prone with the knee flexed to 90°.

Statistical analysis:

Descriptive statistics, including means, standard deviations (SD), medians and first and third quartiles were reported. The differences between left and right TFAs, Q-angles, TTA and AV of the participants were assessed using t-tests with Bonferroni adjustments. Cohen's d was used to estimate effect size (ES).

Table 2. **Bilateral tibiofemoral angle (TFA) differences between males and females, per age in black Setswana-speaking children**

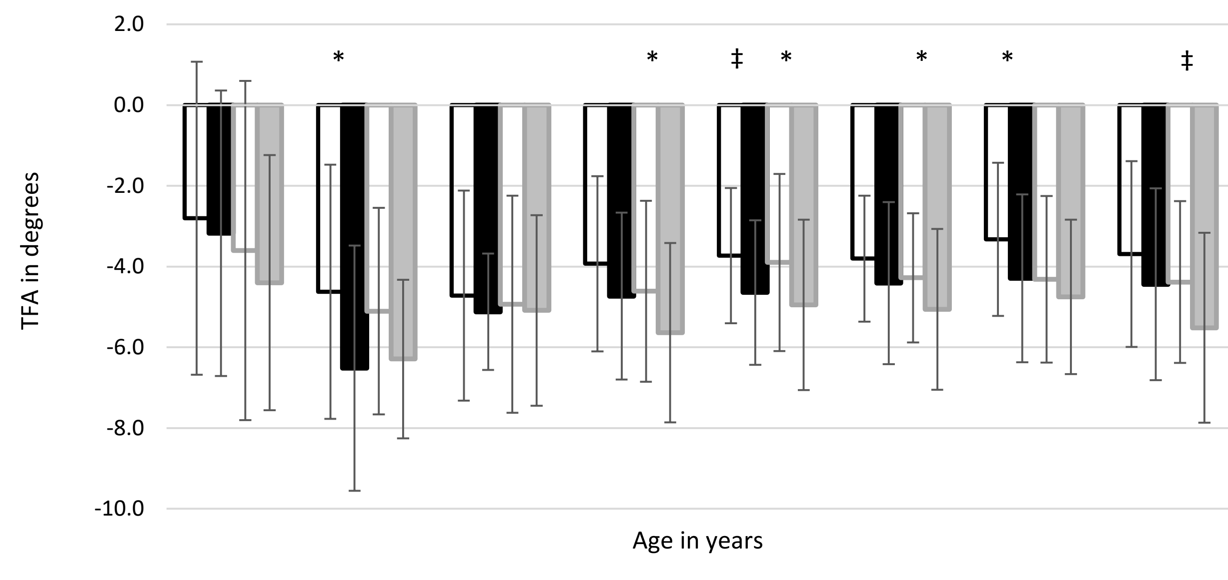
		Total				Females					Males					Significance		
Age	n	Mean (°) ±SD	Q1	Q2 (Median)	Q3	n	Mean (°) ±SD	Q1	Q2 (Median)	Q3	n	Mean (°) ±SD	Q1	Q2 (Median)	Q3	p-value	Cohen's D	Bonferonni
2	38	-3.39 ±3.43	-5.44	-4.00	-1.81	15	-4.00 ±3.46	-6.75	-4.25	-3.13	23	-2.99 ±3.43	-5.13	-3.75	-1.38	0.38	-0.29	1.00
3	52	-5.63 ±2.26	-7.00	-5.50	-4.25	24	-5.70 ±1.83	-7.06	-5.38	-4.44	26	-4.86 ±1.72	-7.00	-5.63	-3.81	0.84	-0.06	1.00
4	54	-4.97 ±1.90	-6.25	-5.13	-3.75	29	-5.01 ±2.08	-6.50	-5.00	-3.75	26	-4.86 ±1.72	-6.25	-5.25	-4.25	0.87	-0.05	1.00
5	112	-4.71 ±2.02	-5.75	-4.50	-3.50	54	-5.13* ±2.01	-6.00	-5.13	-4.00	56	-4.36* ±2.00	-5.50	-4.25	-2.75	0.04*	-0.40	0.22
6	113	-4.29 ±1.61	-5.25	-4.00	-3.25	50	-4.43 ±1.78	-5.94	-4.00	-3.25	63	-4.20 ±1.46	-5.00	-3.75	-3.25	0.44	-0.15	2.62
7	98	-4.40 ±1.60	-5.50	-4.44	-3.25	51	-4.67 ±1.56	-5.75	-4.75	-3.63	50	-4.01 ±1.61	-5.19	-4.00	-3.00	0.08	-0.36	0.49
8	127	-4.25 ±1.77	-5.38	-4.25	-3.00	77	-4.53* ±1.71	-5.75	-4.50	-3.25	47	-3.80* ±1.73	-5.00	-3.38	-2.56	0.02*	-0.41	0.14
9	97	-4.58 ±2.09	-6.25	-4.50	-3.25	56	-4.95 ±1.99	-6.75	-4.63	-3.50	42	-4.14 ±2.17	-5.25	-4.00	-2.25	0.04*	-0.43	0.23
Total	**691**	-4.51 ±2.03	-5.75	-4.50	-3.25	356	**-4.79†† ±1.95**	-6.00	-4.75	-3.50	335	**-4.22†† ±2.07**	-5.50	-4.25	-3.00	**0.00††**	-0.28	**0.00 ††**

Significant differences in TFA development between males and females:
*All children: ‡‡ t=-3.73, p=0.00, d=-0.28; 5 years, *p=0.04, d=-0.40; 8 years, *p=0.02, d=-0.41; 9 years, *p=0.04, d=-0.43.*
*†at level p<0.05 after Bonferroni correction; ‡ at level p<0.01 after Bonferroni correction; ‡‡ at level p<0.001 after Bonferroni correction; * Not significant after Bonferroni correction*
Legend: TFA = Tibiofemoral angle in degrees (°), Q1 = 1st quartile, Q2 = 2nd quartile, Q3 = 3rd quartile, Q4 = 4th quartile, SD = standard deviation

RESULTS

Tibiofemoral angle (TFA) and intermalleolar distance (IMD)

The mean TFA in two-year-olds was -3.39°±3.43° and the closest to varus angulation of all the age groups (Table 2). Peak valgus was observed in three-year-olds with a mean TFA of -5.63°±2.26° with -11° as the minimum and -0.5° as the maximum. The TFA progressed from valgus towards more neutral measures. After Bonferroni correction, significant differences between left- and right limb TFA measures were observed in six-year-old males (t(124)=2.96, p<0.001, d=0.53 at p<0.01) and in nine-year-old females (t(110)=2.74, p=0.01, d=0.52 at p<0.01), after Bonferroni correction (Figure 1).



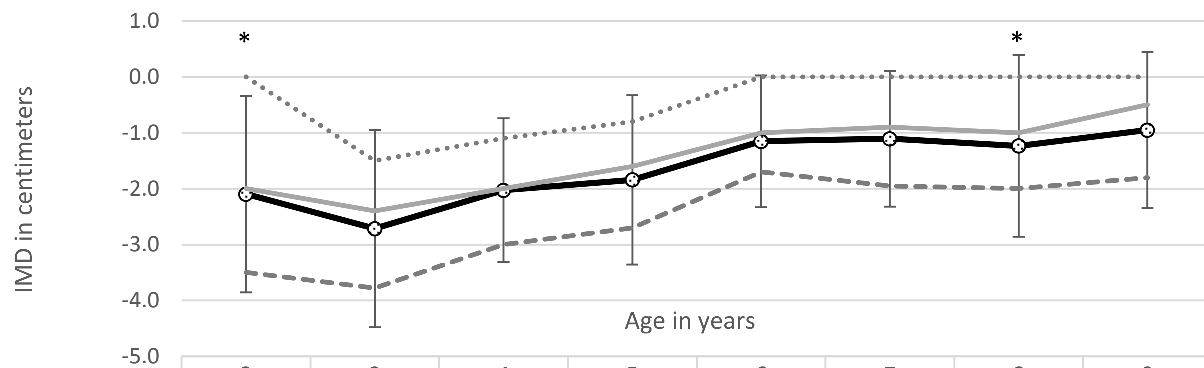
	2	3	4	5	6	7	8	9
Male TFA L	-2.8	-4.6	-4.7	-3.9	-3.7	-3.8	-3.3	-3.7
Male TFA R	-3.2	-6.5	-5.1	-4.7	-4.6	-4.4	-4.3	-4.4
Female TFA L	-3.6	-5.1	-4.9	-4.6	-3.9	-4.3	-4.3	-4.4
Female TFA R	-4.4	-6.3	-5.1	-5.6	-5.0	-5.1	-4.8	-5.5

Significant differences between left and right:
*Males: 2 years, *p=0.026, d=0.61; 6 years, ‡p=0.004, d=0.53; 8 years, *p=0.02, d=0.49.*
*Females: 5 years, *p=0.02, d=0.46; 6 years, *p=0.02, d=0.49; 7 years, *p=0.03, d=0.43; 9 years, ‡p =0.01, d=0.52.*
†at level p<0.05 after Bonferroni correction; ‡ at level p<0.01 after Bonferroni correction; ‡‡ at level p<0.001 after Bonferroni correction;
** Not significant after Bonferroni correction*

Legend: L = left limb, R = right limb, TFA = tibiofemoral angle

Figure 1. Differences in tibiofemoral angle (TFA) between black Setswana-speaking males and females, left- versus right leg

The right limb measures were larger than those of the left limb. Figure 2 shows a peak in valgus angulation of the IMD in three-year-olds (-2.7cm, ±1.8cm). Female IMDs were typically greater than those of males, except in three-year-olds and five-year-olds (Figure 2).



	2	3	4	5	6	7	8	9
IMD mean	-2.1	-2.7	-2.0	-1.8	-1.2	-1.1	-1.2	-1.0
Quartile 1	-3.5	-3.8	-3.0	-2.7	-1.7	-2.0	-2.0	-1.8
Quartile 3	0.0	-1.5	-1.1	-0.8	0.0	0.0	0.0	0.0
Median	-2.0	-2.4	-2.0	-1.6	-1.0	-0.9	-1.0	-0.5

*Significant differences in IMD development between males and females: 2-year-olds; *p=0.02, d=-0.83; 8-year-olds: *p=0.03, d=0.42, * not significant after Bonferonni correction.*

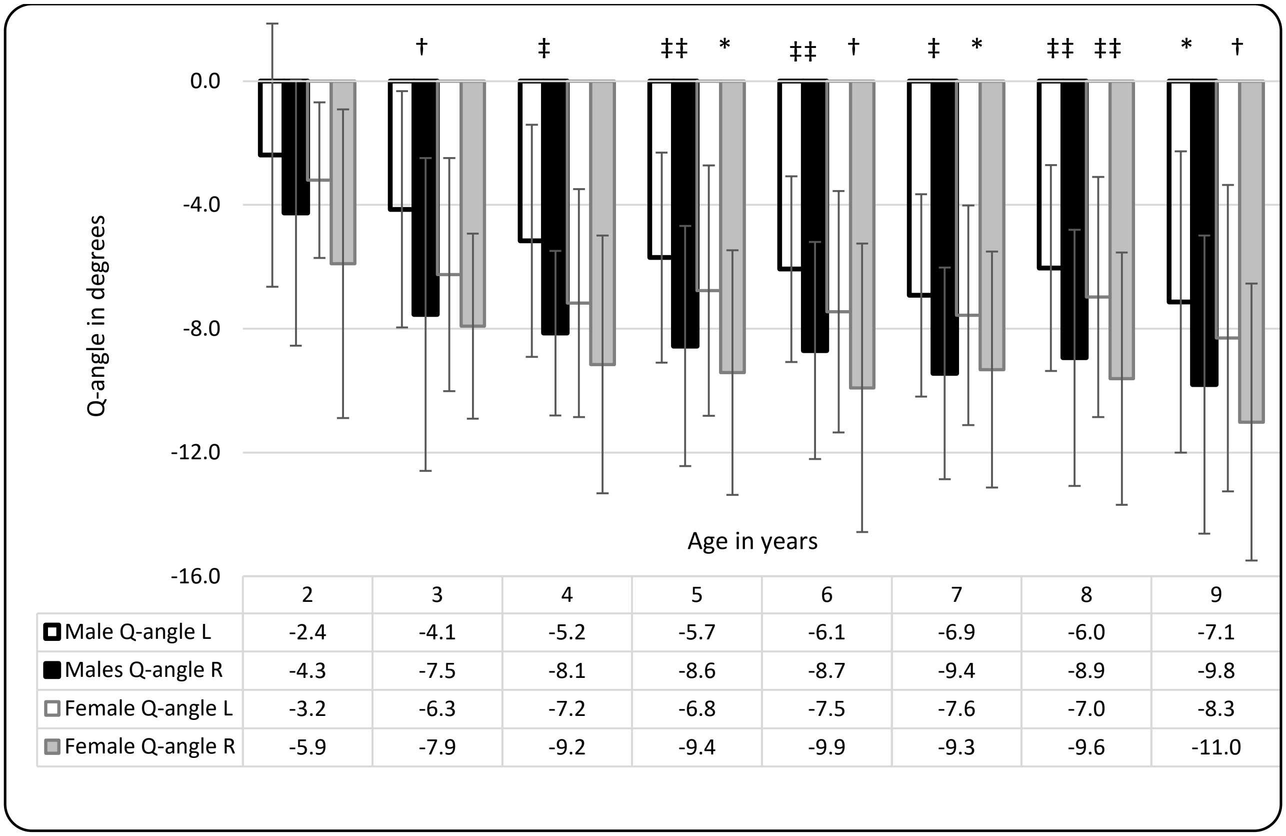
Legend: IMD = intermalleolar distance

Figure 2. Intermalleolar distance (IMD) development in black Setswana-speaking children from age 2- to 9 years

Quadriceps-angle (Q-angle) measurements

Q-angles from male and female participants were similar, yet consistently larger angles were observed in females (Table 3). In males, statistically significant differences between left- and right measures were observed in three-year-olds (t(54)=2.8, p=0.006, d=0.77 at p<0.05); four-year-olds (t(48)=3.2, p=0.002, d=0.93 at p<0.01); five-year-olds (t(114)=4.2, p<0.001, d=0.79 at p<0.001); six-year-olds (t(124)=4.5, p<0.001, d=0.81 at p<0.001); seven-year-olds (t(92)=3.7, p<0.001, d=0.08 at p<0.01) and eight-year-olds (t(98)=3.8, p<0.001, d=0.78 at p<0.001).

In females, significant differences are observed between left- and right measures in five-year-olds (t(106)=3.4, p=0.001, d=0.66 at p<0.01); six-year-olds (t(98)=2.9, p=0.005, d=0.57 at p<0.05); eight-year-olds (t(152)=4.1, p<0.001, d=0.66 at p<0.001) and nine-year-olds (t(110)=3.0, p=0.003, d=0.58 at p<0.05) (Figure 3).



	2	3	4	5	6	7	8	9
Male Q-angle L	-2.4	-4.1	-5.2	-5.7	-6.1	-6.9	-6.0	-7.1
Males Q-angle R	-4.3	-7.5	-8.1	-8.6	-8.7	-9.4	-8.9	-9.8
Female Q-angle L	-3.2	-6.3	-7.2	-6.8	-7.5	-7.6	-7.0	-8.3
Female Q-angle R	-5.9	-7.9	-9.2	-9.4	-9.9	-9.3	-9.6	-11.0

Significant differences between left and right:
Males: 3 years; †p=0.01, d=0.77; 4 years; ‡p=0.00, d=0.93; 5 years; ‡‡p=0.00, d=0.79; 6 years; ‡‡p=0.00, d=0.81; 7 years; ‡p=0.00, d=0.76;
*8 years; ‡‡p=0.00, d=0.78, 9 years; *p=0.02, d=0.55.*
*Females: 5 years; *p=0.00, d=0.66; 6 years; †p=0.01, d=0.57; 7 years; *p=0.02, d=0.48; 8 years; ‡‡p=0.00, d=0.66; 9 years; †p=0.00, d=0.58.*
*† at level p<0.05 after Bonferroni correction; ‡ at level p<0.01 after Bonferroni correction; ‡‡ at level p<0.001 after Bonferroni correction; * Not significant after Bonferroni correction*

Legend: L = left limb, Q-angle = quadriceps-angle, R = right limb

Figure 3. Differences in quadriceps-angle (Q-angle) development between black Setswana-speaking males and females, left- versus right leg, from age 2- to 9 years

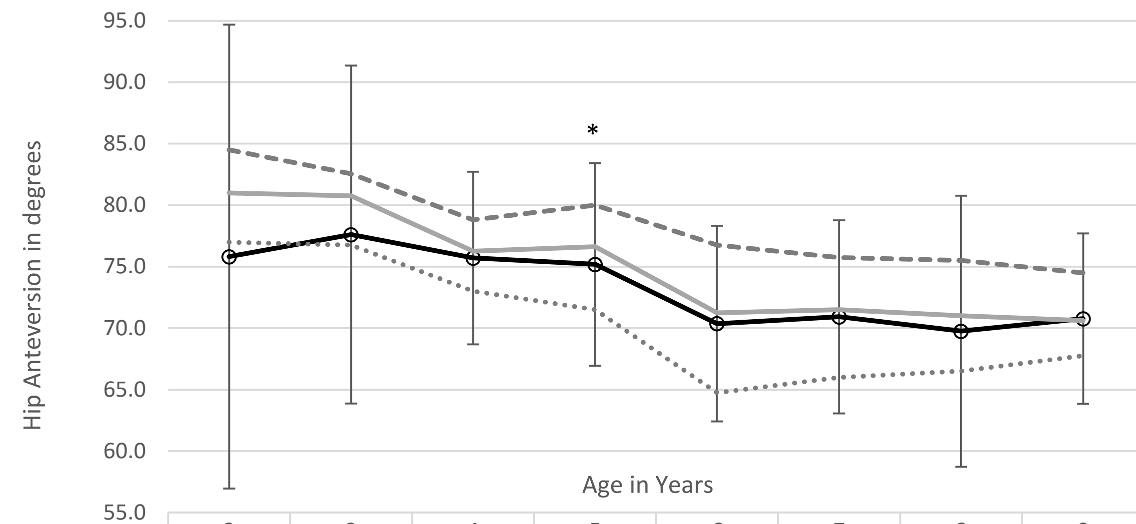
Hip anteversion (AV)

Bilateral means for AV of both males and females are reported (Figure 4) since no differences are noted between left- and right limb measurements after Bonferonni correction. The greatest AV is noted in three-year-olds (77.6°±13.75°), which steadily declined with an increase in age.

Table 3. Bilateral quadriceps-angle (Q-angle) differences between males and females, per age in black Setswana-speaking children

		Total				Females					Males					Significance		
Age	**n**	**Mean ±SD**	**Q1**	**Q2** (Median)	**Q3**	**n**	**Mean ±SD**	**Q1**	**Q2** (Median)	**Q3**	**n**	**Mean ±SD**	**Q1**	**Q2** (Median)	**Q3**	**p-value**	**Cohen's D**	**Bonferroni**
2	38	-3.81 ±3.77	-6.69	-4.88	-1.81	15	-4.55 ±3.32	-7.38	-5.50	-2.25	23	-3.33 ±4.03	-6.38	-4.00	-1.38	0.33	-0.33	1.00
3	52	-6.41 ±3.09	-7.50	-6.25	-4.75	24	-7.08 ±2.71	-8.13	-6.50	-5.19	28	-5.84 ±3.31	-7.06	-5.75	-4.19	0.15	-0.40	0.90
4	54	-7.46 ±2.92	-9.38	-7.25	-4.81	29	-8.16 ±3.11	-10.00	-8.50	-6.50	25	-6.65 ±2.49	-8.25	-6.25	-4.75	0.06	-0.54	0.34
5	112	-7.59 ±3.40	-9.31	-7.25	-5.00	54	-8.09 ±3.65	-10.19	-8.13	-5.31	58	-7.13 ±3.10	-9.00	-6.75	-4.56	0.13	-0.29	0.81
6	113	-7.96 ±3.29	-10.50	-7.50	-5.50	50	-8.68* ±3.56	-11.38	-8.25	-6.06	63	-7.39* ±2.96	-9.75	-6.88	-5.13	0.04*	-0.40	0.22
7	98	-8.32 ±2.91	-10.25	-8.25	-6.31	51	-8.44 ±2.94	-10.38	-8.50	-6.50	47	-8.18 ±2.91	-10.25	-8.00	-6.13	0.66	-0.09	3.96
8	127	-7.98 ±3.30	-10.25	-7.25	-5.75	77	-8.29 ±3.31	-10.50	-8.25	-6.00	50	-7.49 ±3.25	-9.50	-6.88	-5.56	0.18	-0.24	1.00
9	97	-9.16 ±4.36	-12.25	-9.50	-5.75	56	-9.66 ±4.27	-12.31	-9.88	-6.00	41	-8.47 ±4.45	-11.00	-7.75	-5.25	0.19	-0.27	1.11
Total	**691**	**-7.74 ±3.59**	**-10.00**	**-7.50**	**-5.25**	**356**	**-8.30‡‡ ±3.58**	**-10.50**	**-8.25**	**-6.00**	**335**	**-7.14‡‡ ±3.51**	**-9.25**	**-6.75**	**-4.88**	**0.00‡‡**	**-0.33**	**0.00‡‡**

*Significant differences in Q-angle development between males and females: 6-year-olds; *p=0.04, d=0.40; all children: ‡‡p=0.00, d=-0.33.*
*†at level p<0.05 after Bonferroni correction; ‡ at level p<0.01 after Bonferroni correction; ‡‡ at level p<0.001 after Bonferroni correction; * Not significant after Bonferroni correction*
Legend: Q1 = 1st Quartile, Q2 = 2nd Quartile, Q3 = 3rd Quartile, Q4 = 4th Quartile



	2	3	4	5	6	7	8	9
Mean	75.8	77.6	75.7	75.2	70.4	70.9	69.8	70.8
Quartile 1	77.0	76.8	73.0	71.5	64.8	66.0	66.5	67.8
Quartile 3	84.5	82.6	78.8	80.0	76.8	75.8	75.5	74.5
Median	81.0	80.8	76.3	76.6	71.3	71.5	71.0	70.6

*Significant differences between male and females: 5 years; *p=0.05, d=-0.38 * Not significant after Bonferroni correction*

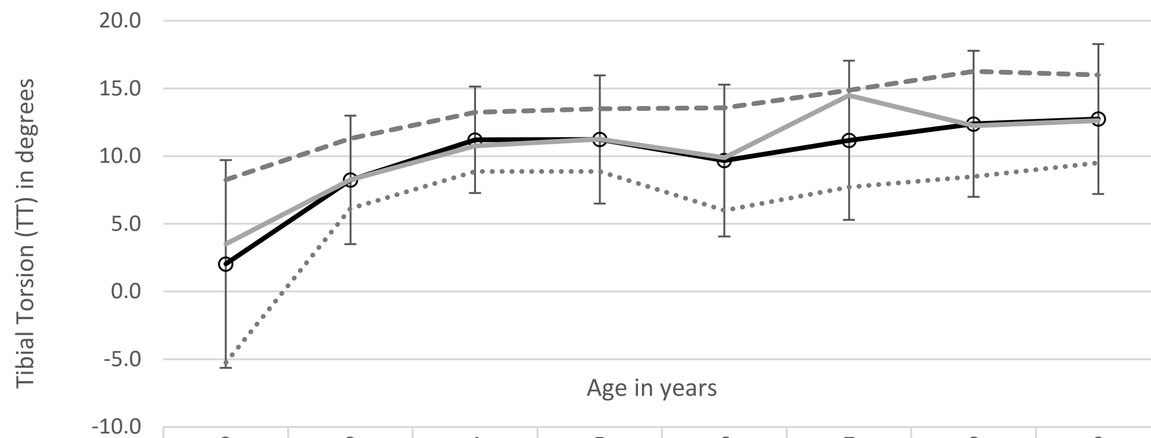
Figure 4. Bilateral hip anteversion angle (AVA) development in black Setswana-speaking children from age 2- to 9 years

Tibial torsion (TT)

Two- and three-year-old children presented with internal TT (in-toeing), from the age of four years all the children presented with neutral TT (Figure 5). No statistically significant differences in TT angles between males and females are found.

DISCUSSION

This study aims to provide profiling data on LL development for, black Setswana-speaking children, between two- to nine years of age. Profile data of LL development in this population is required in order to address another study, where LL development of BC children will be compared with the LL development in non-BC children. Thus, the novelty of this study does not reside in the methods employed, but rather within the study population. Previous research reported differences in the development of the TFA, from different ethnicities [1, 4, 9, 10, 12, 15, 17] but in South African black Setswana-speaking male- and female children this data was lacking.



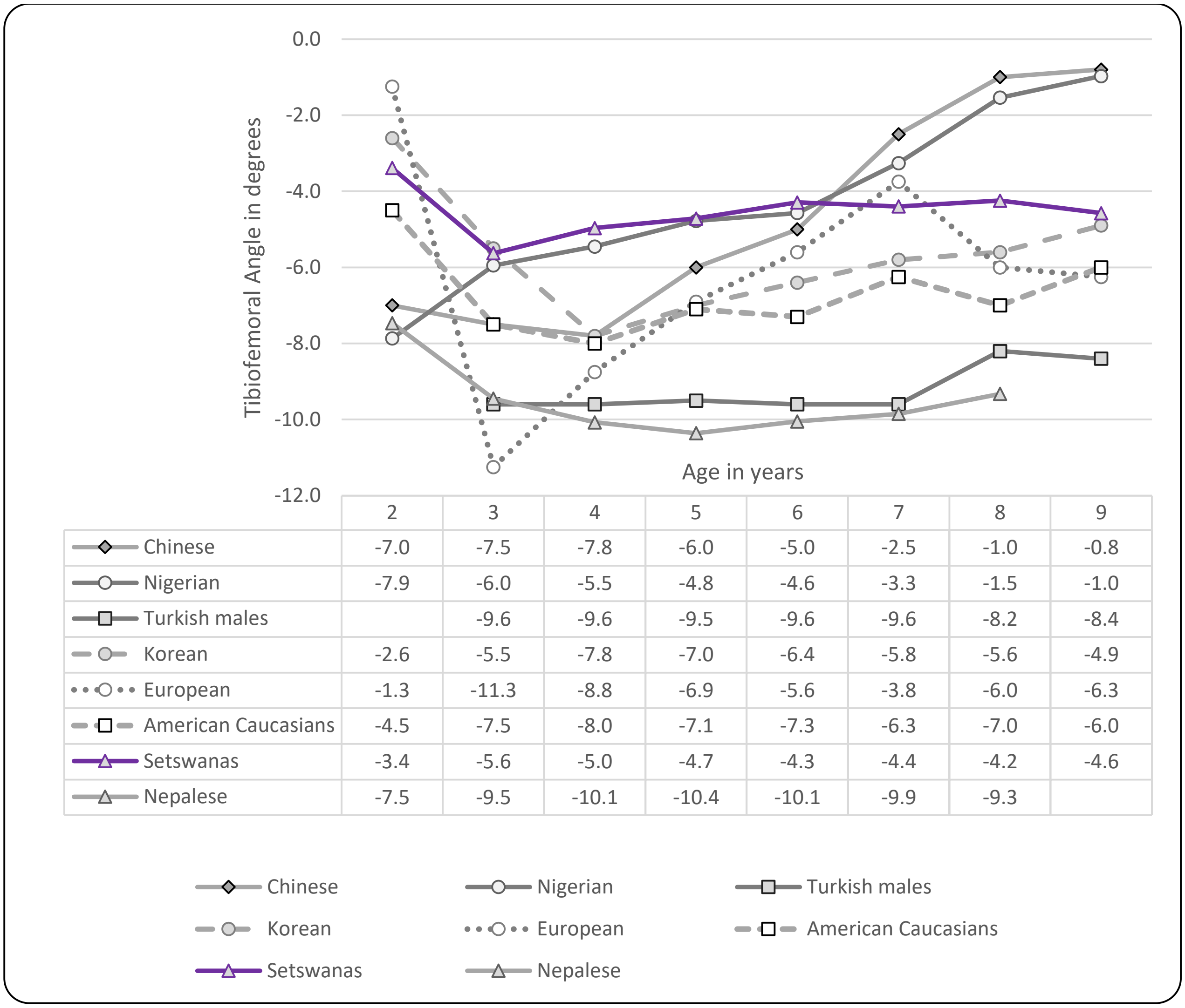
	2	3	4	5	6	7	8	9
Mean TT	2.0	8.2	11.2	11.2	9.7	11.2	12.4	12.7
Quart 1	-5.3	6.1	8.9	8.9	6.0	7.7	8.5	9.5
Quart 3	8.3	11.3	13.3	13.5	13.6	14.9	16.3	16.0
Median	3.5	8.3	10.8	11.3	9.9	14.5	12.3	12.6

Negative values = internal tibial torsion, positive values = external tibial torsion

Legend: Quart 1 = first Quartile, Quart 3 = third Quartile, TT = Tibial torsion

Figure 5. Bilateral tibial torsion angle (TTA) development in black Setswana-speaking children from age 2- to 9 years

We observe a similar general progression (Figure 6) in the knee angle as found by others [1, 3, 4, 8-10, 12, 15-17]. However, the differences in peak valgus angulations differ in both the ages observed and the value of the peaks. In black Setswana-speaking children, the differences in the TFA between the different age groups are much milder, than those observed in other studies. Most of the findings from studies illustrated in (Figure 6) were obtained using clinical goniometry, with the exception of the Korean study [12] and European study [15] who utilized radiographs and the American white [4] study, who used photogrammetry. Thus, it is clear that racial differences exist in terms of TFA development. In Greek children between three- to eight years of age, researchers concluded that a physiologic valgus (below 8°) is present and valgus angles greater than 8° should be considered as abnormal in this population [17]. In Nepalese children, a maximum valgus of 10.5° was seen in three-year-old males and 10.6° for females. Authors concluded that 11° valgus angles in children between one- year and eight years old, should be regarded as abnormal valgus [16]. Overall the greatest valgus (-5.6°), was found in three-year-old black Setswana-speaking children, hence any valgus TFA greater than 6°, can be regarded as abnormal in the black Setswana-speaking population. Two separate studies in Indian children [3, 13], reported significant differences between males and females. Saini *et al*. [3] agreed with Salenius and Vanka [15] that differences in TFA development, observed between male and female children, is physiological [3]. In Setswana-speaking children, significant differences in TFAs between males and females are only observed at ages six and nine years. Similar to Q-angle findings, the right limb measures were consistently, yet non-significantly, larger than the left.



	2	3	4	5	6	7	8	9
Chinese	-7.0	-7.5	-7.8	-6.0	-5.0	-2.5	-1.0	-0.8
Nigerian	-7.9	-6.0	-5.5	-4.8	-4.6	-3.3	-1.5	-1.0
Turkish males		-9.6	-9.6	-9.5	-9.6	-9.6	-8.2	-8.4
Korean	-2.6	-5.5	-7.8	-7.0	-6.4	-5.8	-5.6	-4.9
European	-1.3	-11.3	-8.8	-6.9	-5.6	-3.8	-6.0	-6.3
American Caucasians	-4.5	-7.5	-8.0	-7.1	-7.3	-6.3	-7.0	-6.0
Setswanas	-3.4	-5.6	-5.0	-4.7	-4.3	-4.4	-4.2	-4.6
Nepalese	-7.5	-9.5	-10.1	-10.4	-10.1	-9.9	-9.3	

Negative values = valgus angles, positive values = varus angles

Figure 6. Tibiofemoral angle (TFA) development reported in children from different ethnicities [1, 4, 9, 10, 12, 15, 16] from age 2- to 9 years

In terms of the Q-angle, we observe an increase with age and significant differences between left- and right limb Q-angles (right larger than the left) in both males and females (Figure 3). The measurement of the Q-angle and TFA are rather similar, thus it could be argued that similar factors contribute toward the bilateral variability of both the Q-angle and TFA observed in our study. The Q-angle bilateral variability observation is supported by two other studies, although these were in older populations [25, 26]. The right limb Q-angle in athletes [25] was unexpectedly, significantly greater than the left Q-angle. The observed differences were attributed to methodical bias, including parallax reading errors, or handedness of the investigator [25]. Similarly, in another study, the bilateral variability in Q-angle observations was attributed to a significant positive correlation found between the Q-angle and the relative lateral placement of the tibial tuberosity landmark. [26].

A study investigating Q-angle development in Indian children between seven- to 12 years of age, reported significant positive correlations between Q-angles and age, where the Q-angle increased with age [27]. Although the authors acknowledged that measurement of the Q-angle is more functional if measured with the participant in standing, they measured it with the participant in supine, to allow comparison with an earlier study. In the seven to eight-year-old Indian children, they reported mean Q-angles of 10.1±0.9° for males and 12.5±2.6° in females, while in the nine- to ten-year-old males the Q-angle was 15.6±4.5° in males and 15.7±3.4° in females [27]. In a larger study, performed in active (n=474) and inactive (n=765) Turkish children, between nine and 19 years of age, authors aimed to determine the change of the Q-angle with age and level of activity [28]. The Q-angles of their youngest, nine-year-old participants (both the active and inactive groups, Q-angle mean all = 20.4°), were greater than those of older (19-year-old) participants (Q-angle mean all = 10.3) [28], and also far greater than the Q-angles observed in nine-year-old black Setswana-speaking children. Furthermore, Q-angles of the active group (Q-angle right mean = 14.5±2.8°, Q-angle left mean = 14.4±4.6°) were significantly lower than those of inactive or sedentary (Q-angle right mean = 18.0±3.2°, Q-angle left mean = 18.1±3.5°) children [28]. Increased quadriceps strength is linked to smaller Q-angles, explaining the differences of Q-angle measures between the active and inactive groups in the Turkish study [28]. The Q-angles reported for the Indian-[27] and Turkish children[28] are both greater than the observed Q-angles for black Setswana-speaking children. The discrepancies are possibly due to differences between the methods employed, since both the Indian- and Turkish studies were performed with the participant in supine, while the Setswana study was performed with the participants in standing. However, supine measures of the Q-angle are normally smaller than standing Q-angle measures, which could mean an ethnic difference exists, between Indian-, Turkish- and Setswana-speaking children.

Another explanation for the negative association between age and the Q-angle found in the Turkish study [28], may be population age discrepancies between the studies. It is possible that the Q-angle increases during the early years of life as noted in black Setswana-speaking and Indian children, then start decreasing after puberty. Bilateral variability was not investigated in the Indian child study, nor were significant differences found between male and female participants [27]. In the Turkish study, significant bilateral variability was noted in the active group, but not in the inactive group [28]. The participants in the active group, were predominantly soccer players and the bilateral variability may be attributed to stronger musculature of the dominant leg versus the non-dominant leg [28].

Lastly, the normal Q-angle range in adults has been established at 15° to 20°. Similar to the findings in Turkish children, in black Setswana children, the mean Q-angle was well below 15°, yet none of the children reported any musculo-skeletal injuries. Thus, indicating the use of adult reference values in a child population is not appropriate [28].

Bafor *et al.*[10] reported similar IMDs to this study in Nigerian children. Mathew and Madhuri [11] argued that IMD is inaccurate, in comparison to TFA measurements, based on a slight alteration in standing position of the participant. Thus TFA measurements are recommended and IMD measures should be used in addition to the TFA, and not as a standalone measure [11]. A more recent study on TFA and IMD development in one- to eight-year-old Nepalese children, utilized the same method for IMD determination, and found increases in IMD, thus an increase in the valgus angulation with an increase in age [16]. Their TFA showed maximal valgus in four to five-year-old males and in five- to six-year-old females, while the IMD was at maximal in both genders in seven- to eight-year-olds. They did find a strong correlation between the TFA and IMD as well as a fair correlation between TFA and body mass. They attributed the largest IMD observations in overweight children to soft tissue obstructions. Although not mentioned, it is possible that the older children were predominantly overweight, thus contributing to the greater IMDs observed in this age group in comparison to the TFA [16].

Femoral AV indicates the forward torsion of the femoral neck (in the frontal plane), permitting internal rotation of the femur and is the angle between the femoral neck axis and the transverse (mediolateral) axis of the knee [29]. Increased femoral AV is associated with a greater range of motion (ROM) for femoral internal rotation, and decreased external rotation of the femur [29-31]. In an older longitudinal study, performed on 30 children with in-toeing gait, AVA was assessed over three evaluations [31]. The first evaluation took place between the participants' fourth and tenth birthday (age mean = seven years, AVA-mean=42°±5.5°). The second evaluation took place between their seventh and 13th birthday (age mean = ten years, AVA-mean = 36°±6.3°) and the final evaluation took place between their 15th and 21st birthday (age mean = 16 years, AVA-mean = 28°±8.4°) [31]. Overall, a reduction in the AVA, with an increase in age was observed, regardless of the presence of increased AVA or normal alignment [31]. Furthermore, increases in external hip rotation ROM were found accompanied by a decrease in internal hip ROM with an increase in age [31]. Four to ten-year-olds presented with an external hip rotation 19±7.2° and internal hip rotation of 74±6.8°. At a follow-up evaluation (now seven- to 13-year-olds), external hip rotation increased to 27±7.8° while internal hip rotation decreased to 60° ±7.2°. At the third and final evaluation, (15- to 21-year-olds), presented with an increased external hip rotation of 37±5.9° and decreased internal rotation of 53±8.5° [31]. In another study, a total of 1 140 children between eight and nine years old were measured. Correlations between internal- and external femoral rotation and the AVA and retroversion angle (RVA), were found, respectively [32]. Based on the data, three groups were formed and analyzed. In group one, internal- (43 ± 4.1°) and external femoral hip rotation (43 ± 5.4°) were almost similar and did not differ more than 5° from another. Of the sample, 90% of the results were categorized in group one. In group two internal femoral rotation (64 ± 11°) was at least 10° greater than external hip rotation (30 ± 8.5°), this group represented 7% of the sample. External femoral rotation (58 ± 13°) was at least 10° greater than internal hip rotation (23 ± 12°) in the third group and represented 3% of the sample [32]. A smaller sample (n=147) was selected for radiographic femoral AVA measurement. The AVA was significantly greater in group two (36 ± 7.3°), than any of the other two groups and rendered a strong positive correlation (r=0.80). In comparison, the AVA was significantly smaller (14 ± 8.7°) in the third group, than the other two groups and rendered a strong negative correlation (r=-0.73) [32].

A Belgian study investigated abnormal torsional development in children [33]. In a group of children with increased femoral AV, similar high AVA to those observed in Norwegian children were reported [31]. The increased femoral AV group was further subdivided into an internal rotation group with internally rotated knees and feet and an external rotation group, with internally rotated knees and either neutral or external pointing feet [33]. The AVA was slightly elevated in the external rotation group in comparison to the internal rotation group, which finding supports the summary of Riegger-Krugh and Keysor (1996). The AVA of Belgian children was substantially lower in those with greater internal TTA than in the group with increased femoral AV [33]. In a more recent study [34], on lower extremity characteristics of nine to 18-year -old American children, lower AVAs were reported than those found in Norwegian children [31] and far lower than those reported in European children [35]. Children were categorized into one of three groups, according to their maturation level in this American study [34]. Maturation status and categorization of the participants were determined according to the Tanner five stages of maturity index, through a self-reported questionnaire. The AVA of females were typically greater than those of males and unlike the other studies [31, 33, 35], a non-linear trend was noted in both American males and –females [34]. AV increased from the first maturation group to the second, then decreased from the second to the third group [34]. Comparison of AVA development in children between these studies [31, 33-35] are difficult, based on participant categorisation, with some values reported per age and others forming age categories or maturation categories.

In general, the AVA in children is far greater than those in adults. In adult females between 19 to 52 years of age, normal AVA of 12°±8°, were observed, in comparison to 30°±7° observed in the same age range, but in patients with increased femoral AVA symptoms [36]. Infants are born with AVAs of approximately 40°, which decreases to adult values by the age of eight to nine years old [29, 30, 35]. AVA stabilized and did not decrease further after eight years of age in European children [33] Child participants were divided into groups, according to torsional problems including increased AVA and internal TT.

Increases were noted in TT (toward external TT) were noted in those with increased AVA along with increased femoral medial rotation [32, 33]. Decreases in TT (toward internal TT) were noted in those with increased internal TT, with age [33]. Significantly lower AVA, which decreased with an increase in age, were reported in European children [29, 30, 32, 33, 35, 37] in comparison to black Setswana-speaking children. This might be attributed to the low validity of Craig's test, to clinically measure the AVA, as suggested by Souza and Powers[38], or an actual occurrence in the black Setswana-speaking population. The Craig's test was previously found to be reliable, yet not as valid as *magnetic resonance imaging* (MRI) measures[38]. Greater external TTA was reported in separate studies on European-[35] and Chinese children[1], in comparison to our findings (Figure 5). Our TTA correspond to those observed in children with increased AVA [33], indicating a relationship between high AVA and internal TT. Without other Southern African norms, it is difficult to assess whether the greater AVA and smaller TTA measures found in black Setswana-speaking children, is an ethnical occurrence, or owed to the clinical methods employed.

The findings had to be interpreted against the limitations experienced with this study. Firstly, the sampling was conducted in a relatively small demographic area. Sampling from a larger demographic area would render a more accurate representation of developmental trends. However, the North-West is widespread and further North consists of rural tribal villages, which are often difficult to access. Secondly, clinical measurements are always under scrutiny for reliability and validity. However, radiographic or MRI investigations are costly, especially given the large cohort in this study. Exposing the child to radiation, perhaps unnecessarily, is an ethical dilemma.

In conclusion, the general development pathway of the TFA in black Setswana-speaking children was similar to those reported in European, Asian and West African children. The peak angles differed slightly and occurred at different ages than other ethnic groups, which is attributed to ethnic differences in development. Clinical measurement of torsion angles, especially the AVA, is often avoided, due to difficulties experienced in the reliable evaluation thereof [39, 40]. We found greater AVA and smaller TTA in the black Setswana-speaking population than reported for European children. We suggest a follow-up study on this population, including MRI testing of all the parameters, but especially AVA, to confirm our data. The data from this study can be used as norms for black Setswana-speaking children by clinical practitioners.

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Author Contributions

MvA has contributed to the conception and design of the work, data collection, performed statistical analyses and drafted the manuscript.

SC, the promoter of MvA ,SC contributed to the work by supporting the conception, statistical analysis interpretation, designing and revising the work critically.

SM, the co-promoter, contributed to the work by supporting the conception and revising the work critically.

All authors read and approved the final article.

Conflict of Interest Statement

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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CHAPTER 4 : ARTICLE 2

BACK-CARRYING IN BLACK SETSWANA-SPEAKING CHILDREN RELATED TO LOWER LIMB DEVELOPMENT

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This research article will be submitted for publication to: *Gait and Posture.* (Appendix F)

This results of this article were presented by M van Aswegen, as an oral at the 30th FIEP World Congress, held in Barcelona Spain, between the 27th and 29th of June 2019. (Appendix K)

ABSTRACT

Background

Back-carrying of children is a culturally accepted method of transport, soothing and safekeeping of infants in many African cultures, including the Batswana. Developmental hip dysplasia (DDH) in black African children is lower than in cultures who do not back-carry their children. Only the low incidences of DDH have been reported in black children, but developmental consequences related to back-carrying practices have not been directly investigated. The purpose of this study was to determine the relationship between lower limb (LL) development, in the frontal- and transverse plane, and back-carrying practices in black Setswana-speaking children.

Research question

What is the possible relationship between back-carrying-practices and LL development, at the hip, knee, and ankle, in two- to nine-year-old black Setswana-speaking children?

Methods

In a total of 691 black Setswana-speaking children, aged two to nine years, the tibiofemoral angle (TFA), intermalleolar distance (IMD), femoral anteversion angle (AVA) and tibial torsion angle (TTA), were measured to determine LL development. We recorded back-carrying-practices with a questionnaire and data was analysed with *Classification and Regression Tree* (CART) analysis.

Results

Various highly significant ($p<0.001$) relationships, between back-carrying-practices and LL development, is discovered. Significantly greater genu valgum ($F(5,690)=7.2$, $p<0.001$), greater internal TTA ($F(9,684)=17.8$, $p<0.001$), and smaller AVA ($F(13,685)=5.1$, $p<0.001$) were consistently observed in children back-carried more frequently than children back-carried less frequently.

Significance

There are definite relationships between back-carrying practices and LL development in both the frontal- and transverse plane. Further research is necessary to determine the exact back-carryingpractice factors (age until which the child is back-carried) to impact LL development the greatest. Clinical health-providers in rural settings, dealing with children presenting with LL malalignments, especially genu valgum and internal TTA, will find this paper of significance.

Keywords: Lower limb development, back-carrying, tibiofemoral angle

INTRODUCTION

South African children of black ethnicity are generally back-carried (BC) by their mothers, with the aid of blankets or towels [1-3], and this tradition is also accepted and practised by black Setswana-speaking mothers [1,4,5]. Head-, upper- and lower limb (LL) movements of the child are restricted while BC and vision become constrained. Mothers from a lower socio-economic status will back-carry (BC) their child for extended periods, as long as eight (intermittend) hours per day, while working or travelling on foot, to keep the child safe. [1,3].

Child development can be disadvantaged and benefitted by back-carrying (BC) [3]. Previous research reports that BC children are hampered in terms of school readiness and struggled with fine motor skills, specifically integrating movement with observational ques [3]. BC children develop strong emotional and social bonds with their mothers, however, some experience difficulties with unfamiliar situations, which was linked to their limited exploration ability while being BC [3]. Possible prevention of developmental dysplasia of the hip (DDH) in BC children, or contribution thereof to the rarity of DDH, is the most significant benefit [2,6-8]. The incidence of DDH in black children residing in Indiana, USA, was slightly higher than expected, with 4% of black children diagnosed with DDH, which may be attributed to the fact that these children are more likely transported in strollers, than BC [9].

DDH is treated with a brace (Pavlik harness) or hip spica cast, that maintains hip flexion and abduction [7], resembling the BC position. Hence, researchers postulate that BC practices of African mothers contribute to the low incidence of DDH in African populations [6-8]. In a retrospective review that included a total of 40 683 children under the age of 16 years, no infants presented with or were treated for symptomatic DDH [2]. Researchers concluded that BC of infants contributed to the low incidence of DDH found in Malawi [2]. These very significant results from Graham et al. [2], who raise the question of whether BC would also have additional effects on LL development at the knee and ankle.

Normal angular alignment of the LL may be perturbed by both intrinsic and extrinsic factors, such as dietary and vitamin intake, physical trauma, infections and high intakes of exogenous metals such as lead and fluoride could all contribute to genu varum [10]. Environmental factors such as the chair, desk, and bed the child uses could also affect postural alignment [11], arguably BC could also affect LL alignment. One study reported a constant knee-valgus and external torsion pressure on the LL and feet is produced, when a child is BC [4].

Treatment of excessive LL malalignments such as genu varum poses high burdens on health systems [12]. However, social or cultural causes of knee malalignments have not been studied. The consequences of children BC in their childhood, in relation to their knee development have not been reported. Previous studies on the low incidence of DDH in BC children did not directly investigate the developmental consequences of BC practices [2,6]. This study divulges important information about the relationship between LL angle measures and black Setswana-speaking children BC. The purpose of this study is therefore to determine relationships between LL angle measures and BC practices in black Setswana-speaking children. Firstly, the relationship between frontal plane (FP) measures (tibiofemoral angle (TFA), intermalleolar- (IMD) or intercondylar distance (ICD), and quadriceps-angle (Q-angle)), in BC and non-back-carried (non-BC) children is determined. Secondly, the relationship between transverse plane (TP) torsion measures (femoral anteversion angle (AVA) and tibial torsion angle (TTA), in BC and non-BC children is determined.

MATERIALS AND METHODS

This cross-sectional design study was approved by the Human Health Research Ethics Committee (HREC) of the North-West University (NWU) (NWU-00094-17-A1) and upheld the declaration of Helsinki of 1964.

Participants

All primary schools and crèches situated in Potchefstroom and Ikageng, listed by the departments of education and –social development, were invited to voluntarily participate. Thirteen schools and crèches agreed to participate. Ten schools declined based on the lack of black Setswana-speaking children attending their schools. A total of 724 black Setswana-speaking children (two- to nine years) were measured and the results from 33 children with known musculoskeletal disorders (which may have caused malalignments of their LL), were excluded. Data from non-natively Setswana-speaking children were excluded from the analyses. Measurements from 691 children were included in the analysis. Exclusion criteria were to limit interference in the data and to allow tracking the development of the TFA in apparently healthy, black Setswana-speaking children [13-15]. Participants were grouped according to chronological age, rounded off to the nearest integer. Random sampling was not possible due to a limited number of schools in Potchefstroom agreeing to participate, and the smaller number of black Setswana-speaking children attending these schools as compared to those in Ikageng.

Procedure

The respective legal guardian signed an informed consent and the child provided assent (if able), prior to the measurements. Information from a self-reported questionnaire was used to determine participant inclusion or exclusion.

The questionnaire collected data on the child's development age, place of birth and commencement of independent walking age. Parents/legal guardians indicated whether or not leg deformities (bow-legs or knock-knees) were observed in the child and if these deformities changed (from bow-leg to knock knee), worsened or improved. Furthermore, parents indicated whether or not the child is/was BC, and how the child was BC, with the legs spread around the mother's back or BC with the legs hanging down. If parents did BC, they indicated the frequency of BC on a Likert scale from very little, sometimes, often and always. For the BC-frequencies, we asked parents where the infant or toddler was placed for safekeeping when they were with them while they were working or travelling, if their only option for safekeeping was BC, they frequently selected "always". Parents also indicated pram use and swaddling.

The same researcher performed all measurements once anatomic landmarks were identified through palpation and marked. Trained assistants maintained neutral hip rotation and full knee extension of the participants at measurement. Previously published measurement methods for the FP and TP measures were used [14,16,17], with varus angles reported as positive degrees (or centimetres for ICD) and valgus angles as negative degrees (or centimetres for IMD). TP measurements included the AVA and TTA, both measured in prone, with the knee flexed to 90°.

Statistical analysis

The sample size estimates indicated 63 participants per group (BC versus non-BC), but due to data required for an ancillary study profiling the development of knees in this population, we recruited 375 participants per group. All data were analysed with SPSS, Version 24, Inc., Chicago, IL, USA.

The means of the IMD and the bilateral TFAs, Q-angles, TTA and AVA were determined from two to three measurements obtained per limb per variable, for each participant. The mean values of the various measurements were linked to each participant's questionnaire data, indicating their BC preferences and frequencies. Participants with missing BC data were excluded from the analysis.

We used a *Classification And Regression Tree* (CART) analysis, which allows the examination of multiple complex variables, whereby the algorithm focuses on the most relevant parameters. The

CART groups categorise independent variables and do not assume linear relationships or any underlying distribution. Instead, it aims to classify the sample into subgroups with the means of the subgroups as diverse as possible. CART analysis was applied to each clinical measurement separately. The interaction between BC and age, and the TFA, -Q-angle, -AVA and -TTA were first analysed, followed by an analysis of TFA, Q-angle, AVA and TTA in terms of age, sex and body mass index (BMI).

CART analysis is exploratory and does not provide quantitative (e.g. p=value, test values, etc.) measures. Therefore, ANOVA was applied to determine significance between end nodes and partial eta-squared as a measure of effect size (ES). Duncan's and Sheffe's posthoc tests were used to screen for type I errors. The CART was used to separate the data of participants into groups of BC versus non-BC or in terms of BC frequency for example, groups of participants who were BC always, or less than always, per age.

RESULTS

General Participant Descriptives:

The FP and TP mean measures and standard deviations (SD) along with participant numbers are summarised in Table 1

Table 1: Descriptive statistics for frontal- (FP) and transverse plane (TP) measures: Total, females, and males; per age in black two- to nine-year-old Setswana-speaking children

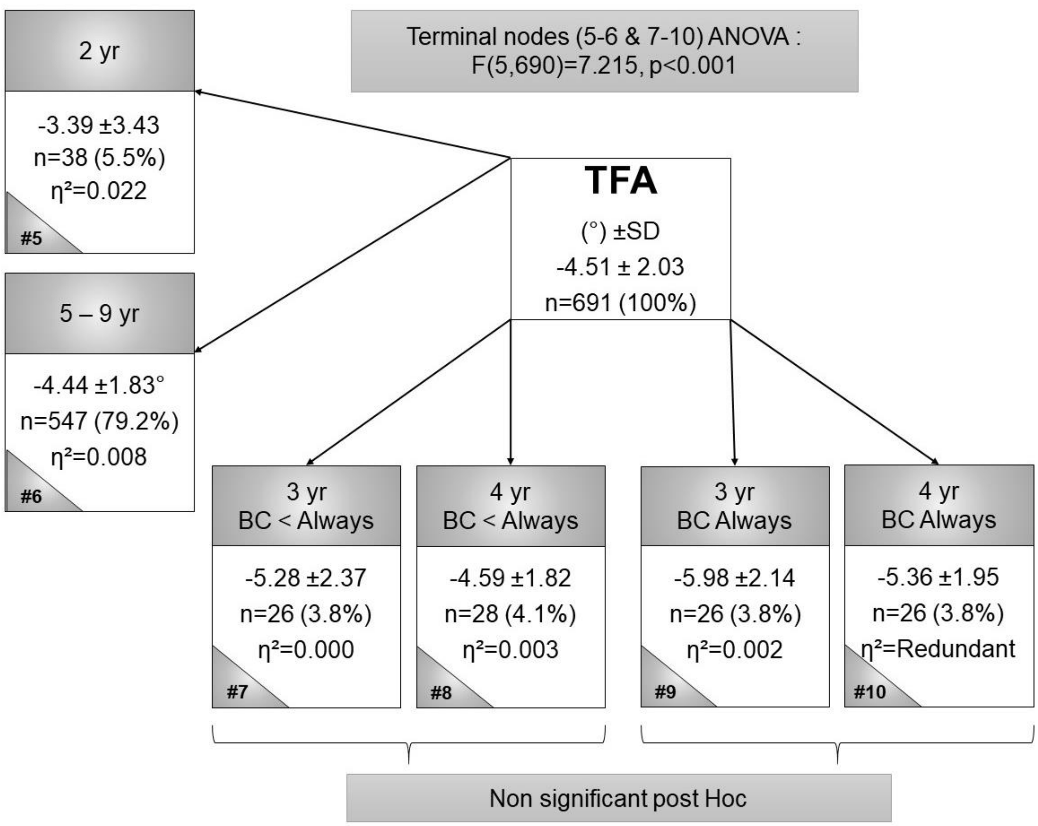
	TFA			Q-angle			IMD			AVA			TTA		
Age	**Total Mean (°) ±SD (n)**	**Females Mean (°) ±SD (n)**	**Males Mean (°) ±SD (n)**	**Total Mean (°) ±SD (n)**	**Females Mean (°) ±SD (n)**	**Males Mean (°) ±SD (n)**	**Total Mean (cm) ±SD (n)**	**Females Mean (cm) ±SD (n)**	**Males Mean (cm) ±SD (n)**	**Total Mean (°) ±SD (n)**	**Females Mean (°) ±SD (n)**	**Males Mean (°) ±SD (n)**	**Total Mean (°) ±SD (n)**	**Females Mean (°) ±SD (n)**	**Males Mean (°) ±SD (n)**
2	-3.39 ±3.43 (n=38)	-4.00 ±3.46 (n=15)	-2.99 ±3.43 (n=23)	-3.81 ±3.77 (n=38)	-4.55 ±3.32 (n=15)	-3.33 ±4.03 (n=23)	-2.09 ±1.76 (n=37)	-2.94 ±1.56 (n=14)	-1.58 ±1.70 (n=23)	75.82 ±18.87 (n=37)	75.30 ±15.23 (n=14)	76.13 ±21.10 (n=23)	2.03 ±7.69 (n=37)	4.50 ±7.09 (n=14)	0.53 ±7.79 (n=23)
3	-5.63 ±2.26 (n=52)	-5.70 ±1.83 (n=24)	-4.86 ±1.72 (n=26)	-6.41 ±3.09 (n=52)	-7.08 ±2.71 (n=24)	-5.84 ±3.31 (n=28)	-2.71 ±1.76 (n=52)	-2.29 ±1.68 (n=24)	-3.08 ±1.78 (n=28)	77.61 ±13.75 (n=52)	79.53 ±4.36 (n=24)	75.96 ±18.29 (n=28)	8.24 ±4.74 (n=52)	8.38 ±3.62 (n=24)	8.13 ±5.59 (n=28)
4	-4.97 ±1.90 (n=54)	-5.01 ±2.08 (n=29)	-4.86 ±1.72 (n=26)	-7.46 ±2.92 (n=54)	-8.16 ±3.11 (n=29)	-6.65 ±2.49 (n=25)	-2.03 ±1.28 (n=53)	-2.04 ±1.30 (n=28)	-2.01 ±1.29 (n=25)	75.70 ±7.02 (n=52)	74.96 ±3.50 (n=27)	76.50 ±9.49 (n=25)	11.21 ±3.94 (n=51)	11.14 ±3.46 (n=27)	11.28 ±4.49 (n=24)
5	-4.71 ±2.02 (n=112)	-5.13* ±2.01 (n=54)	-4.36* ±2.00 (n=56)	-7.59 ±3.40 (n=112)	-8.09 ±3.65 (n=54)	-7.13 ±3.10 (n=58)	-1.84 ±1.51 (n=112)	-1.79 ±1.34 (n=54)	-1.89 ±1.67 (n=58)	75.19 ±8.24 (n=111)	76.41 ±6.07 (n=54)	74.06 ±9.76 (n=57)	11.24 ±4.73 (n=111)	11.40 ±5.08 (n=54)	11.08 ±4.42 (n=57)
6	-4.29 ±1.61 (n=113)	-4.43 ±1.78 (n=50)	-4.20 ±1.46 (n=63)	-7.96 ±3.29 (n=113)	-8.68* ±3.56 (n=50)	-7.39* ±2.96 (n=63)	-1.15 ±1.18 (n=113)	-1.22 ±1.30 (n=50)	-1.10 ±1.09 (n=63)	70.37 ±7.96 (n=113)	68.73 ±7.09 (n=50)	71.67 ±8.42 (n=63)	9.68 ±5.62 (n=112)	9.66 ±5.83 (n=50)	9.69 ±5.48 (n=62)
7	-4.40 ±1.60 (n=98)	-4.67 ±1.56 (n=51)	-4.01 ±1.61 (n=50)	-8.32 ±2.91 (n=98)	-8.44 ±2.94 (n=51)	-8.18 ±2.91 (n=47)	-1.11 ±1.21 (n=98)	-1.25 ±1.23 (n=51)	-0.95 ±1.18 (n=47)	70.92 ±7.85 (n=97)	69.91 ±8.25 (n=51)	72.05 ±7.30 (n=46)	11.17 ±5.88 (n=98)	11.11 ±6.27 (n=51)	11.24 ±5.49 (n=47)
8	-4.25 ±1.77 (n=127)	-4.53* ±1.71 (n=77)	-3.80* ±1.73 (n=47)	-7.98 ±3.30 (n=127)	-8.29 ±3.31 (n=77)	-7.49 ±3.25 (n=50)	-1.23 ±1.63 (n=127)	-1.49 ±1.71 (n=77)	-0.84 ±1.40 (n=50)	69.75 ±11.02 (n=126)	69.30 ±9.34 (n=77)	70.44 ±13.28 (n=49)	12.39 ±5.39 (n=127)	12.26 ±5.22 (n=77)	12.58 ±5.69 (n=50)
9	-4.58 ±2.09 (n=97)	-4.95 ±1.99 (n=56)	-4.14 ±2.17 (n=42)	-9.16 ±4.36 (n=97)	-9.66 ±4.27 (n=56)	-8.47 ±4.45 (n=41)	-0.95 ±1.40 (n=97)	-1.09 ±1.44 (n=56)	-0.76 ±1.33 (n=41)	70.77 ±6.92 (n=96)	71.30 ±6.25 (n=55)	70.06 ±7.75 (n=41)	12.75 ±5.54 (n=97)	12.31 ±6.06 (n=56)	13.35 ±4.76 (n=41)
Total	**-4.51 ±2.03 (n=691)**	**-4.79†† ±1.95 (n=356)**	**-4.22†† ±2.07 (n=335)**	**-7.74 ±3.59 (n=691)**	**-8.30‡‡ ±3.58 (n=356)**	**-7.14‡‡ ±3.51 (n=335)**	**-1.48 ±0.06 (n=689)**	**-1.56 ±1.51 (n=354)**	**-1.40 ±1.55 (n=335)**	**72.42 ±6.92 (n=684)**	**72.08 ±8.35 (n=352)**	**72.78 ±2.07 (n=332)**	**10.67 ±5.93 (n=685)**	**10.94 ±5.70 (n=353)**	**10.38 ±13.71 (n=332)**

Legend: AVA = anteversion angle, IMD = Intermalleolar distance, Q-angle = quadriceps-angle, TFA = Tibiofemoral angle, TTA = Tibial torsion angle, SD = Standard deviation

Frontal plane (FP) measures: Tibiofemoral angle (TFA), intermalleolar distance (IMD), and quadriceps-angle (Q-angle)

The terminal CART nodes for TFA, back-carried with the legs spread around the mother's waist (BC-LS), and age are presented in Figure 1. Node 5 shows the smallest valgus mean for two-year-olds (n=38, TFAmean=-3.39°±3.43°, η^2=0.022). In the five- to nine-year-olds, node 6, shows the second smallest valgus mean and represents a larger nodal percentage of the participants (n=457, TFAmean=-4.44°±1.83°, η^2=0.008). Node 9, shows the largest valgus mean (n=26, TFAmean=-5.98°±2.14, η^2=0.002), representing three-year-old children who were always BC. This CART was significant as shown with ANOVA ($F(5, 690)=7.215$, $p<0.001$). Significant Sheffe post hoc tests were between nodes 5 and 7 (p=0.016), 5 and 9 (p<0.001), 5 and 10 (p=0.009) and 6 and 9 (p=0.011).

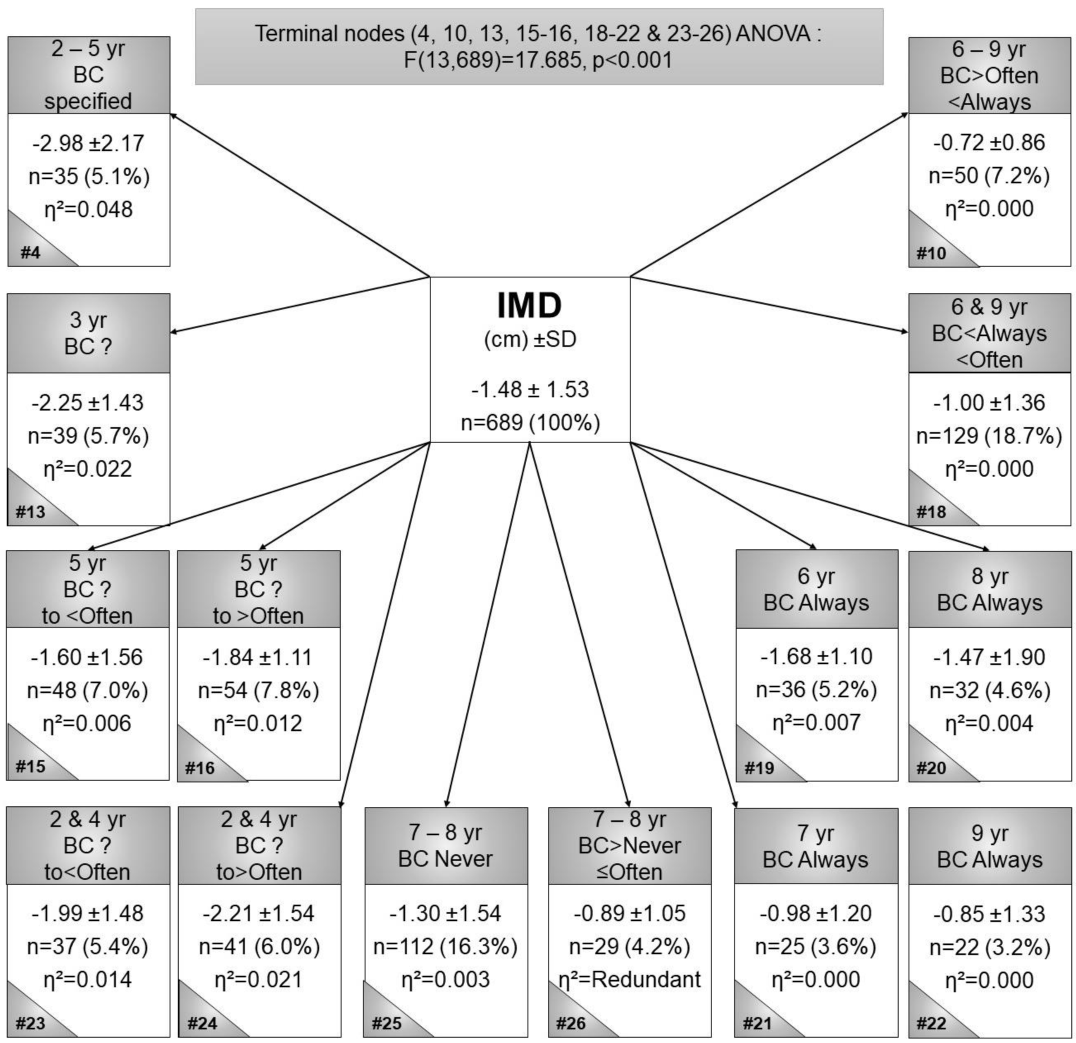
The smallest valgus IMD was found in six- to nine-year-olds (node 10), BC between often and always (n=320, IMDmean=-0.72cm, η^2=0.000), whilst the second smallest valgus distance was observed in nine-year-old children (node 22) who were reportedly always BC (n=22, IMDmean=-0.85cm, η^2=0.000) (Figure 2).



Legend: # = node number, η^2 = partial eta squared, BC = Back-carried, TFA = Tibiofemoral angle, SD = Standard Deviation, yr = year

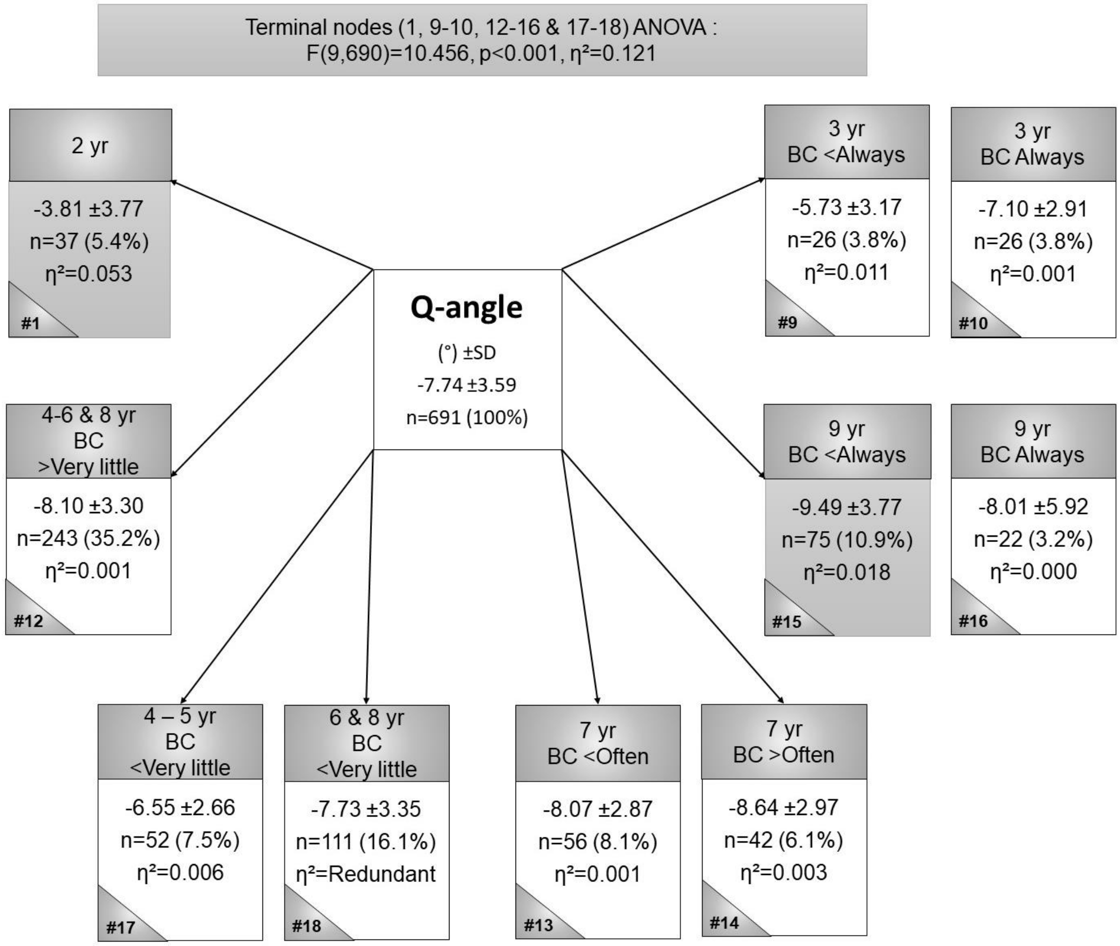
Figure 1: Terminal nodes CART for the tibiofemoral angle (TFA) in black Setswana-speaking children back-carried with legs spread (BC-LS), according to age

The largest valgus IMDs were observed in two- to five-year-olds (node 4), who were BC-LS for specified frequencies (as opposed to unspecified frequencies) (n=35, IMDmean=-2.98cm, η^2=0.048) and a significant ANOVA (F(13, 689)=17.685, p<0.001). Significant post hoc differences were observed for node 4 versus 10, -18, -21, -22, -25 and -26, node 10 versus 13 and 24 and node 13 versus 18. The smallest Q-angles were observed in two-year-old children (node 1 in Figure 3) (n=37, Q-angle mean=-3.81°, η^2=0.053), while the largest Q-angle was found in nine-year-olds who were BC-LS less than always (node 15: n=75, Q-angle mean=-9.49°, η^2=0.018).



Legend: # = node number, η^2 = partial eta squared, BC = Back-carried, IMD = Intermalleolar distance, SD = Standard Deviation, yr = year

Figure 2: Terminal nodes CART for intermalleolar distances (IMD) in black Setswana-speaking children back-carried with legs spread (BC-LS), according to age

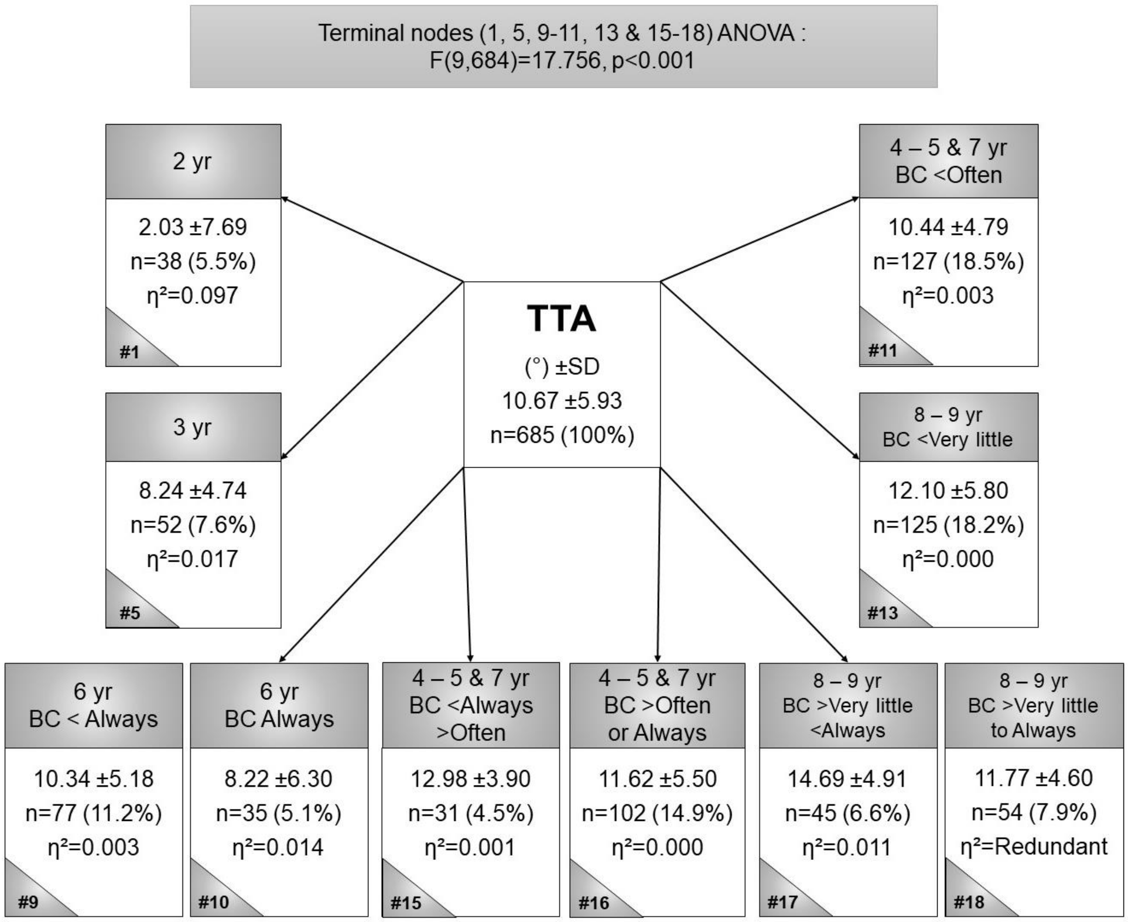


Legend: # = node number, η^2 = partial eta squared, BC = Back-carried, Q-angle = quadriceps-angle, SD = Standard Deviation, yr = year

Figure 3: Terminal nodes CART for quadriceps-angles in black Setswana-speaking children back-carried with legs spread (BC-LS), according to age

Measurement in transverse plane (TP): Tibial torsion (TT) and anteversion (AV)

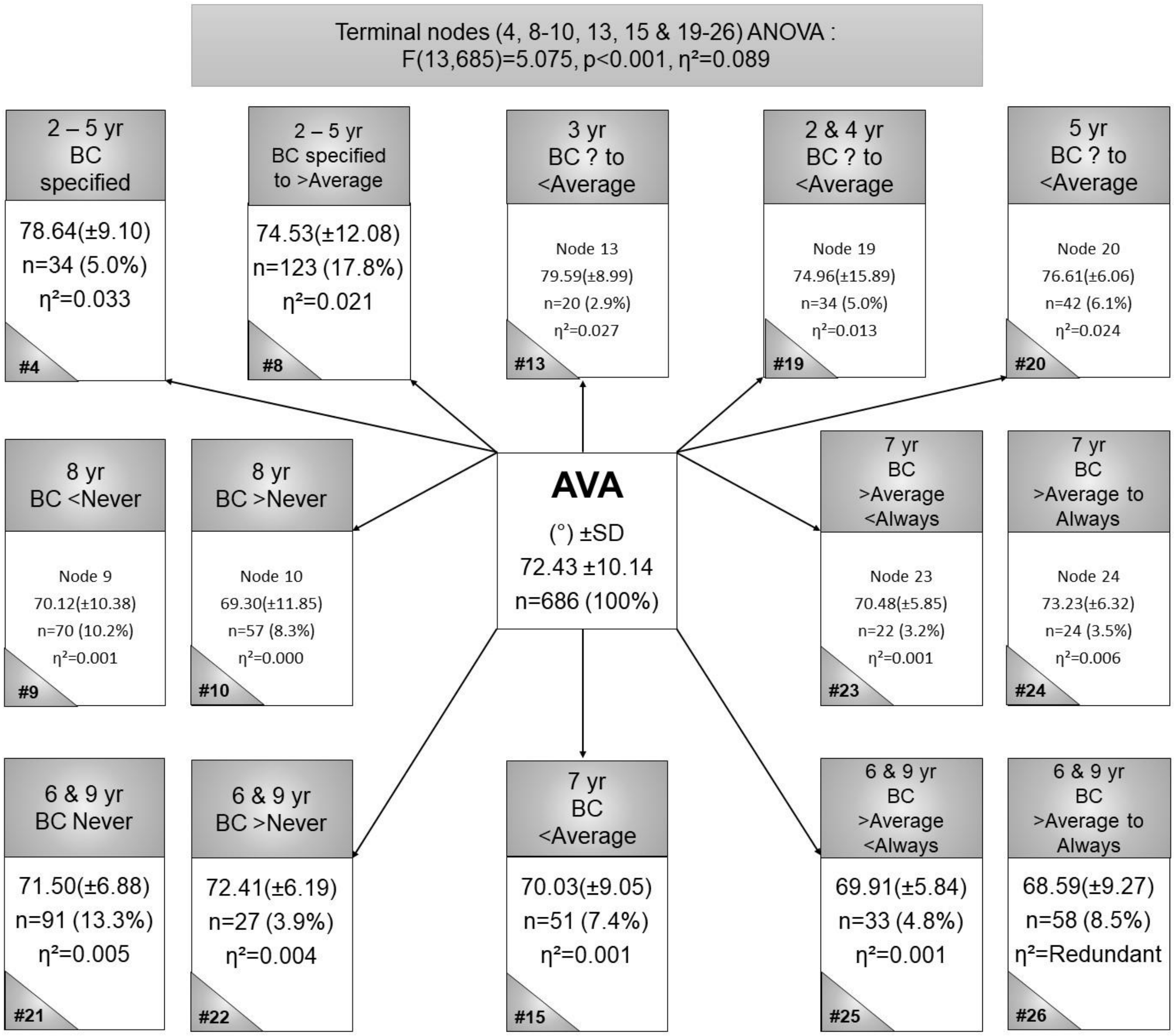
The greatest internal TT (Figure 4) was observed in the two-year-olds (node 1), (n=37, TTAmean=2.03°, η^2=0.097). The second greatest internal TT (n=35, TTAmean=8.22°, η^2=014) was observed in six-year-old children (node 10) who were BC-LS always. The greatest external TT was observed in eight- and nine-year-old children (node 17) who were BC-LS more than very little, but less than always (n=45, TTAmean=14.69°, η^2=0.011). ANOVA indicated statistical significance (F(9, 684)=17.756, p<0.001).



Legend: # = node number, η^2 = partial eta squared, BC = Back-carried, SD = Standard Deviation, TTA = Tibial Torsion Angle, yr = year

Figure 4: Terminal node CART for the tibial torsion angle in black Setswana-speaking children back-carried with the legs spread (BC-LS), according to age

Figure 5 shows node 13 and node 4 as the two largest AVA mean groupings. Node 13 is the highest (n=20, AVAmean=79.59°, η^2=0.027), for three-year-olds who were BC-LS for an unspecified frequency to less than average. The second-largest AVA mean (node 4; n=34, AVAmean=78.64°, η^2=0.033) in two- to five-year-old children who were BC-LS for specified frequencies. Six- and nine-year-old children, BC-LS more than average to always (node 26) represent the smallest AVA (n=58, AVAmean=68.59°, η^2=Redundant). Node 10 is the second lowest AVA (n=57, AVAmean=69.3°, η^2=0.000), in eight-year-old children who were BC-LS (more than never). Statistical significance for these end nodes as calculated by ANOVA (F(13, 685)=5.075, p<0.001).



Legend: # = node number, η^2 = partial eta squared, AVA = Anteversion Angle, BC = Back-carried, SD = Standard Deviation, yr = year

Figure 5: Terminal node CART for the anteversion angle (AVA) in black Setswana-speaking children back-carried with the legs spread (BC-LS), according to age

DISCUSSION

The two objectives of this study were to determine relationships between LL angle measures and BC in black Setswana-speaking children. Firstly, the relationship between frontal plane measures (TFA, IMD or ICD and Q-angle), in BC and non-BC children was determined. The CART analysis of the various LL developmental variables indicated several significant results, which seem to be age-dependent.

When children are always BC (Figure 1), the CART reveals a larger valgus TFA, which corresponds with Golding [4], who observed a constant valgus force at the knee compared to non-BC children. In older children, we expect to see neutral alignment, and this was corroborated in our findings with small IMDs of the older children and larger IMDs in younger children. In younger children, BC more frequently was associated with (statistically non-significant) greater valgus distances. In older children, an opposite relationship was observed, where children who were BC less frequently had larger valgus angles, with the exception of children always BC, the relationship was the same as in younger children. Normally, Q-angles increased with an increase in age, and this trend was also observed in BC children. The post hoc Sheffe test did not indicate any significant differences between nodes 15 and 16, nor between nodes 16 and 18 (Figure 3), thus we assumed that Q-angles are unaffected by BC.

Secondly, the relationship between TP torsion measures (AVA and TTA), in BC and non-BC children is determined. As expected, the greatest internal TTA was observed in the youngest (two-year-olds), whilst the second largest internal TTA was observed in six-year-old children who were BC more than always. This was an unexpected result, as these children are normally in a neutral alignment or slightly externally rotated in terms of TTA. Children who were BC more frequently tended to present with larger internal TTA than those who were BC less frequently. This confirms the observation of Golding [4], where BC would contribute to valgus force at the knee and constant internal TTA force.

Previous studies found greater AVA in younger children that decrease with age [18,19], which was observed in our study, where the youngest children presented with the largest AVA (Figure 5). Children BC more frequently typically present with smaller AVA than children BC less frequently, and children typically older have a lower AVA than the younger children.

The findings of this study should be interpreted against the limitations experienced. Firstly, the sampling was conducted in a relatively small demographic area, however, the North West Province is widespread and further afield consists of rural tribal villages, often inaccessible. Sampling from a larger demographic area in a randomised manner would render the findings more general of developmental trends. Secondly, although a bilingual questionnaire with illustrations of the various carrying methods, was distributed, some parents or guardians still struggled with the interpretation of the questions. Blank or incomplete questionnaires that had to be regarded as missing data were returned and could not be included in this analysis.

In conclusion, results from our analysis classified relationships between BC frequency and specific dependent variables (various LL measures), depending on the correlations between variables grouped per node. BC children presented with larger genu valgum angles, smaller AVA and larger internal TTAs than non-BC counterparts. These relationships between BC children and the development of the LL serves as an impetus for further research into the specific BC practices (duration and age until BC), to determine which, if any, of the BC practices exacerbates LL malalignments.

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CONFLICT OF INTEREST

No conflicts of interest to report.

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CHAPTER 5 : ARTICLE 3

BACK-CARRYING FREQUENCY AND DURATION IN BLACK SETSWANA-SPEAKING CHILDREN INFLUENCE LOWER LIMB DEVELOPMENT

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Declarations of Interest: None

This research article will be submitted for publication to: *Early Human Development.* (Guidelines for authors is available in Appendix E).

ABSTRACT

Background

Many African cultures, including the Batswana, back-carry their children. It is a culturally accepted method of child transport and soothing. One significant benefit of back-carried children, is the lower incidence of developmental hip dysplasia, in black African children, compared to non-back-carried children. No information regarding the relationship between lower limb development and child-rearing practices such as back-carrying-, swaddling- and pram use durations, and frequencies exist.

Aims

To determine the predictor factors contributing and influencing lower limb development, at the hip, knee, and ankle, in two- to nine-year-old black Setswana-speaking children.

Study design

Cross-sectional clinical investigation.

Subjects

Two- to nine-year-old black Setswana-speaking children (N=691).

Outcome measures

The tibiofemoral angle (TFA), intermalleolar distance (IMD), quadriceps-angle (Q-angle), femoral anteversion angle (AVA) and tibial torsion angle (TTA) measures. Child-rearing practices such as back-carrying-, swaddling, and pram use practices were recorded with a questionnaire and data analysed through an automated linear regression analysis.

Results

Various highly significant ($p<0.001$) relationships, between various child-rearing prediction factors and lower limb development was discovered. Frontal plane measures identified seven predictor factors for TFA development ($F(12, 690)=6.750$, $p<0.001$), four IMD ($F(7, 688)=15.098$, $p<0.001$) and six for Q-angle ($F(11, 690)=12.170$, $p<0.001$). For transverse plane measures the AVA had seven predictors ($F(13, 685)=7.856$, $p<0.001$) and TTA six ($F(10, 684)=17.029$, $p<0.001$).

Conclusions

Relationships are present between child-rearing practice frequency and duration factors and lower limb development in the frontal- and transverse planes. Strategies to inform parents/guardians of the associations between back-carrying and lower limb development should be implemented by health care-providers.

Keywords: Lower limb development, Back-carrying, Swaddling, Tibiofemoral angle, Child-rearing practices

INTRODUCTION

Back-carrying (BC)[64] of children with the aid of blankets or towels [1-3], is a culturally accepted practice in most Setswana-speaking families [1, 4, 5]. Setswana-speaking children are often back-carried (BC) for long durations (as long as eight hours per day), for safety, while their mother works or travels on foot [1, 3]. BC poses some developmental benefits and disadvantages to the child [3]. Most significantly, it has been linked to the possible prevention and rarity of developmental dysplasia of the hip (DDH[65]) in BC children [2, 6-8]. Very low occurrences of DDH in the African, BC population have been reported [2, 6-8]. The typical position assumed on the mother's back, with the child's limbs wrapped around the mother's waist, resembles the Pavlic harness, a brace used to treat DDH [7]. In both BC and the Pavlic harness, hip flexion and abduction are maintained [7]. Hence, it was postulated that BC practices contribute to the low incidence of DDH in African children [6-8].

In a South African study investigating the physical motor development in BC children, it was found that BC children are disadvantaged in terms of school readiness due to problems in visual analysis and language synthesis [3]. These analytical problems sprouted from limited head, neck and limb movements while carried on the back and limited discovery opportunities when being BC for long durations. Limited discovery opportunities influence sensorimotor development affecting skills required in school, such as handwriting and the ability to copy gestures, letters or patterns [3].

In terms of lower limb (LL[66]) development in BC children, one study reported a constant knee-valgus- and external torsion pressure on the LL and feet [4], which increased interest to determine the relationship between LL malalignments and BC. Psychomotor factors, such as independent walking age and crawling, were linked to the development of pediatric planovalgus foot (PPVF[67]) [9]. These developmental findings [2, 4] and previous links between LL development and BC [10] raises the question of whether BC frequencies and durations would exacerbate LL development, at the hip, knee, and ankle? This study divulges important information lacking about the relationship of BC factors such as BC frequencies and durations as well as LL angle measures. Consequently, the objective of this study is to determine the contributing factors in the development of and the severity of LL malalignments in black Setswana-speaking children between the ages of two to nine years. Knowledge of LL development predictors will allow the education of mothers in terms of BC, swaddling and pram-use durations, to allow optimal LL development of their children.

[64] BC – Back-carrying, Back-carry, Back-carried
[65] DDH – Developmental dysplasia of the hip
[66] LL – Lower limb
[67] PPVF – Planovalgus foot

MATERIALS AND METHODS

The Health Research Ethics Committee (HREC) of the North-West University (NWU) (NWU – 00094-17-A1) approved this cross-sectional design study and upheld the declaration of Helsinki of 1964.

Participants

All primary schools and crèches based in Potchefstroom and Ikageng, listed and registered with the Departments of Education and –Social Development, were invited to participate. Of the potential 18 crèches and 24 primary schools in Potchefstroom and Ikageng, six schools and eight crèches agreed to participate. Most of the primary schools visited had approximately 180 learners per grade per primary school, rendering a total population of 3 240 children across three grades. Principals of ten schools declined based on the lack of black Setswana-speaking children attending their schools. The crèches visited typically are much smaller with a total of approximately 50 to 80 children attending a crèche. Children with known musculoskeletal disorders, or those younger than one year and five months or older than nine years and six months, were excluded, based on the exclusion criteria. From a total of 724 black Setswana-speaking children tested, 33 were excluded, due to musculoskeletal disorders reported in the questionnaire. Measurements from 691 children were included in the analysis. Exclusion criteria were to limit interference in the data and to allow tracking the development of the LL in apparently healthy, black Setswana-speaking children [11-13]. Participants were grouped according to chronological age, rounded off to the nearest integer.

Procedure

After informed consent and assent were signed by the respective legal guardian and child, the measurements were performed. A self-reported questionnaire was used to determine inclusion criteria, to gather child developmental information, leg deformity observations and to determine BC-practices.

Questionnaire data utilized for this article focused on the BC-practices. The method of BC in terms of leg positioning was obtained. Mothers were, for example, asked if they mostly back-carry their child's legs wrapped around the mother's waist, or did the legs hang down? Did the mothers make use of a carrier device in which the child was front-carried, with their legs hanging down? The frequencies and durations in which a child was BC per day were reported in a Likert scale format. Parents had to indicate whether they back-carry (BC) their child never, very little, little, average, often or always in terms of frequencies (per carrying method or style). The age until which the child was BC, were ranked from one year until five years of age. General activity levels in terms of preference to sit and play quietly versus enjoying to play outside were ranked on a Likert scale with zero indicating no preference and five as high preferences to do the activity, as reported by their guardian, was collected. Similar questions for pram use and swaddling were included. Table 2 summarizes the responses to the questionnaire.

Measurements performed in the frontal plane (FP[68]) and transverse plane (TP[69]) were described previously [12, 14, 15]. The principle researcher identified all anatomical landmarks and performed all measurements. Trained assistants were responsible for ensuring neutral hip rotation and full knee extension of the participants during measurements. Varus angles were reported in positive degrees (or centimeters for intercondylar distance - ICD[70]) and valgus angles as negative degrees (or centimeters for intermalleolar distance - IMD[71]).

Statistical analysis

Demographic data were extracted from the questionnaire. The means of the IMD and the bilateral tibiofemoral angle (TFA[72]), quadriceps-angle (Q-angle[73]), tibial torsion angles (TTA[74]) and hip anteversion angle (AVA[75]) were determined from two to three measurements obtained per limb per variable, for each participant. A third measurement was taken where the angles obtained between the first two measures differed more than 3.0°. Average values were used for two measures, while the median was used where three measures were obtained. The various measurement means were linked to each participant's questionnaire data, indicating their BC-preferences and –frequencies. Missing BC data were excluded from the analysis.

Given the multivariate data gathered, linear models were computed, using an Automatic Linear Modelling (ALM[76]) procedure. The modelling begins by replacing missing values by averages and merging adjacent categories of ordinal variables in an attempt to improve the fit of the model. Forward stepwise regression analysis is used to produce the best-fitting model, (IBM© SPSS©, version 25).

The interaction between the various BC methods (legs down versus legs spread), swaddling, pram use and frequencies of applications, as well as ages until which the mother employed each, was analyzed along with the child's age, age of commencement of walking and activity levels. All of these independent variables were analyzed separately against the dependent variables; TFA, IMD,Q-angle, AVA, and TTA. I n total five linear models were computed, one model per dependent variable.

68 FP – Frontal plane
69 TP – Transverse plane
70 ICD – Intercondylar Distance
71 IMD – Intermalleolar Distance
72 TFA – Tibiofemoral Angle
73 Q-angle – Quadriceps-angle
74 TTA – Tibial Torsion Angle
75 AVA – Anteversion Angle
76 ALM – Automatic Linear Modelling

RESULTS

The descriptive characteristics for height and weight per age and frequencies reported for the various factors such as BC, swaddling and pram use, durations BC, swaddled and pushed in a pram as well as activity levels, are summarised in Table 1.

Frontal plane (FP) measures: Tibiofemoral angle (TFA), intermalleolar distance (IMD), and quadriceps-angle (Q-angle)

The TFA was used as a dependent variable in the first ALM procedure (Figure 1), which yielded the following predictor factors, from most important to least important; participant age (R^2=47%)*, sex (R^2=19%)*, durations swaddled per day (R^2=10%)*, walking age (R^2=9%)*, side or hip carried (R^2=7%)*, BC (β=-0.433, p=0.062, R^2=5%) and/or front-carried (β=-0.637, p=0.071, R^2=4%) with legs hanging down. All figures below display the statistically significant factors (non-significant factors were excluded), affecting LL development.

Different predictor factors were linked to IMD development (Figure 2 excludes non-significant results). Age* explained 75% of the IMD variance, while walking age (R^2=14%)*, irregular sports participation (R^2=6%)* and being BC with the legs spread (R^2=5%)*, were the significant predictors.

Six significant predictors of Q-angle (Figure 3) development were identified, including; participant age (R^2=63%)*, duration swaddled per day (R^2=13%)*, age till which BC (R^2=10%)*, sex (R^2=10%)*, inactivity to average participation in running or hopping activities (β=-0.559, p=0.118, R^2=2%) and very little quiet sitting (β=-0.386, p=0.139, R^2=2%).

Table 1: Descriptive statistics reporting means and standard deviations for height and body mass, and frequencies for back-carrying, activity levels, swaddling, and pram, per age for black Setswana-speaking children

AGE	2 yr	3 yr	4 yr	5 yr	6 yr	7 yr	8 yr	9 yr
N	38	52	54	112	113	98	127	97
Height mean ± SD (m)	0.85 ± 7.51	0.91 ± 6.19	1.02 ± 5.60	1.08 ± 5.46	1.13 ± 5.21	1.19 ± 6.13	1.25 ± 6.12	1.30 ± 6.55
Body mass ± SD (kg)	12.41 ± 1.99	14.08 ± 2.34	16.19 ± 2.61	18.14 ± 3.32	20.05 ± 4.08	21.93 ± 4.56	26.25 ± 7.35	27.41 ± 5.96
FACTORS	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**
BACK-CARRIED								
General	**12 (100)**	**16 (100)**	**16 (100)**	**30 (100)**	**33 (100)**	**25 (100)**	**33 (100)**	**29 (100)**
Not at all	4 (33.3)	3 (18.8)	4 (25.0)	11 (36.7)	9 (27.3)	6 (24.0)	12 (36.4)	9 (31.0)
Very little	1 (8.3)	--	1 (6.3)	--	--	--	--	4 (13.8)
Little	5 (41.7)	5 (31.3)	4 (25.0)	3 (10.0)	4 (12.1)	2 (8.0)	8 (24.2)	4 (13.8)
Average	1 (8.3)	5 (31.3)	6 (37.5)	8(26.7)	13 (39.4)	7 (28.0)	10 (30.3)	7 (24.1)
Often	1 (8.3)	--	1 (6.3)	6 (20.0)	5 (15.2)	4 (16.0)	2 (6.2)	4 (13.8)
Always or very often	--	3 (18.8)	--	2 (6.7)	2 (6.1)	6 (24.0)	1 (3.0)	1 (3.4)
Not defined	26 (--)	16 (--)	38 (--)	82 (--)	80 (--)	73 (--)	94 (--)	68 (--)
Legs-spread	**25 (100)**	**26 (100)**	**28 (100)**	**58 (100)**	**77 (100)**	**73 (100)**	**95 (100)**	**75 (100)**
Not at all	8 (32.0)	11 (42.3)	17 (60.7)	32 (55.2)	39 (50.6)	42 (57.5)	70 (73.7)	53 (70.7)
Very little	2 (8.0)	--	2 (7.1)	1 (1.7)	1 (1.3)	--	1 (1.1)	1 (1.3)
Little	1 (4.0)	2 (7.7)	1 (3.6)	1 (1.7)	5 (6.5)	3 (4.1)	5 (5.3)	2 (2.7)
Average	2 (8.0)	7 (26.9)	2 (7.1)	8 (13.8)	12 (15.6)	6 (8.2)	7 (7.4)	6 (8.0)
Often	1 (4.0)	2 (7.7)	2 (7.1)	6 (10.3)	4 (5.2)	5 (6.8)	2 (2.1)	6 (8.0)
Always or very often	11 (44.0)	4 (15.4)	4 (14.3)	10 (17.2)	16 (20.8)	17 (23.3)	10 (10.5)	7 (9.3)
Not defined	16 (--)	13 (--)	26 (--)	54 (--)	36 (--)	25 (--)	32 (--)	22 (--)
Legs-down	**32 (100)**	**36 (100)**	**37 (100)**	**96 (100)**	**101 (100)**	**83 (100)**	**100 (100)**	**83 (100)**
Not at all	28 (87.5)	32 (88.9)	30 (81.1)	83 (86.5)	85 (84.2)	62 (74.7)	78 (78)	68 (81.9)
Very little	--	--	1 (2.7)	3 (3.1)	4 (4.0)	2 (2.4)	5 (5.0)	--
Little	1 (3.1)	2 (5.6)	--	5 (5.2)	4 (4.0)	7 (8.4)	4 (4.0)	3 (3.6)
Average	--	1 (2.8)	3 (8.1)	2 (2.1)	3 (3.0)	6 (7.2)	3 (3.0)	2 (2.4)
Often	1 (3.1)	1 (2.8)	1 (2.7)	1 (1.0)	3 (3.0)	2 (2.4)	4 (4.0)	3 (3.6)
Always or very often	2 (6.3)	--	2 (5.4)	2 (2.1)	2 (2.0)	4 (4.8)	6 (6.0)	7 (8.4)
Not defined	6 (--)	16 (--)	17 (--)	16 (--)	12 (--)	15 (--)	27 (--)	14 (--)

Legend: kg = kilogram, m = meter, n = number of participants per group, SD = standard deviation, yr = years, % = valid percentage

AGE	2 yr	3yr	4 yr	5yr	6yr	7yr	8yr	9yr
FACTORS	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**
BACK-CARRIED…								
Side carried	**35 (100)**	**39 (100)**	**44 (100)**	**102 (100)**	**113 (100)**	**97 (100)**	**124 (100)**	**97 (100)**
Not at all	35 (92.1)	37 (94.9)	42 (95.5)	100 (98.0)	106 (93.8)	90 (82.8)	118 (95.2)	91 (93.8)
Yes	--	--	--	2 (2.0)	--	--	--	--
Very little	--	--	1 (2.3)	--	1 (0.9)	5 (5.2)	2 (1.6)	2 (2.1)
Little	--	1 (2.6)	--	--	2 (1.8)	1 (1.0)	2 (1.6)	1 (1.0)
Average	--	1 (2.6)	--	--	1 (0.9)	1 (1.0)	2 (1.6)	2 (2.1)
Often	--	--	--	--	1 (0.9)	--	--	--
Always or very often	--	--	1 (2.3)	--	2 (1.8)	--	--	1 (1.0)
Not defined	3 (--)	13 (--)	10 (--)	10 (--)	--	1 (--)	3 (--)	--
Front carried, legs down	**34 (100)**	**38 (100)**	**40 (100)**	**93 (100)**	**98 (100)**	**88 (100)**	**111 (100)**	**85 (100)**
Not at all	30 (88.2)	31 (81.6)	34 (85.0)	72 (77.4)	71 (72.4)	64 (72.7)	86 (77.5)	71 (83.5)
Very little	--	--	2 (5.0)	2 (2.2)	2 (2.0)	1 (1.1)	4 (3.6)	1 (1.2)
Little	1 (2.9)	4 (10.5)	--	4 (4.3)	5 (5.1)	1 (1.1)	2 (1.8)	2 (2.4)
Average	1 (2.9)	--	--	7 (7.5)	5 (5.1)	7 (8.0)	5 (4.5)	3 (3.5)
Often	1 (2.9)	--	2 (5.0)	2 (2.2)	11 (11.2)	6 (6.8)	7 (6.3)	6 (7.1)
Always or very often	1 (2.9)	3 (7.9)	2 (5.0)	6 (6.5)	4 (4.1)	9 (10.2)	7 (6.3)	2 (2.4)
Not defined	7 (--)	14 (--)	14 (--)	19 (--)	15 (--)	10 (--)	16 (--)	12 (--)
AGE TO BACK-CARRIED	**19 (100)**	**25 (100)**	**16 (100)**	**78 (100)**	**88 (100)**	**70 (100)**	**107 (100)**	**77 (100)**
1 yr	11 (57.9)	10 (40.0)	8 (50.0)	30 (38.5)	27 (30.7)	22 (31.4)	37 (34.6)	25 (32.5)
2 yr	4 (21.1)	8 (32.0)	1 (6.3)	16 (20.5)	22 (25.0)	26 (37.1)	26 (24.3)	30 (39.0)
3 yr	2 (10.5)	7 (28.0)	5 (31.3)	18 (23.1)	18 (20.5)	14 (20.0)	26 (24.3)	9 (11.7)
4 yr	2 (10.5)	--	2 (12.5)	12 (15.4)	9 (10.2)	6 (8.6)	16 (15.0)	12 (15.6)
5 yr	--	--	--	2 (2.6)	12 (13.6)	2 (2.9)	2 (1.9)	1 (1.3)
Not defined	22 (--)	27 (--)	38 (--)	34 (--)	25 (--)	28 (--)	20 (--)	20 (--)
WALKING AGE	**35 (100)**	**36 (100)**	**41 (100)**	**95 (100)**	**108 (100)**	**92 (100)**	**119 (100)**	**81 (100)**
Very early, 7-8 mo	9 (25.7)	4 (11.1)	7 (17.1)	16 (16.8)	18 (16.7)	17 (18.5)	16 (13.4)	14 (17.3)
Early, 9-10 mo	5 (14.3)	8 (22.2)	11 (26.8)	23 (24.2)	36 (33.3)	32 (34.8)	48 (40.3)	25 (30.9)
Normal, 11-12 mo	17 (48.6)	20 (55.6)	19 (46.3)	43 (45.3)	47 (43.5)	32 (34.8)	49 (41.2)	36 (44.4)
Little later, 13-14 mo	3 (8.6)	3 (8.3)	2 (4.9)	8 (8.4)	4 (3.7)	10 (10.9)	4 (3.4)	3 (3.7)
Later, 15-16 mo	--	1 (2.8)	1 (2.4)	4 (4.2)	2 (1.9)	--	1 (0.8)	2 (2.5)
Much later, 17-18 mo	1 (2.9)	--	1 (2.4)	1 (1.1)	1 (0.9)	1 (1.1)	1 (0.8)	1 (1.2)
Not defined	3 (--)	16 (--)	13 (--)	17 (--)	5 (--)	6 (--)	8 (--)	16 (--)

Legendd: mo = months, n = number of participants per group, yr = years, % = valid percentage

(continued)

AGE	2 yr	3yr	4 yr	5yr	6yr	7yr	8yr	9yr
FACTORS	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**
ACTIVITY LEVEL								
Enjoys outside play	**32 (100)**	**35 (100)**	**41 (100)**	**92 (100)**	**98 (100)**	**87 (100)**	**99 (100)**	**78 (100)**
Not at all	--	--	--	1 (1.1)	1 (1.0)	1 (1.1)	--	1 (1.3)
Very little	--	--	--	1 (1.1)	6 (6.0)	2 (2.3)	--	--
Little	--	--	--	1 (1.1)	1 (1.0)	3 (3.4)	4 (4.0)	--
Average	4 (12.5)	8 (22.9)	2 (4.9)	5 (5.4)	8 (8.2)	11 (12.6)	7 (7.1)	7 (9.0)
Often	5 (15.6)	2 (5.7)	5 (12.2)	11 (12.0)	8 (8.2)	8 (9.2)	13 (13.1)	10 (12.8)
Always	23 (71.9)	25 (71.4)	34 (82.9)	73 (79.3)	74 (75.5)	62 (71.3)	75 (75.8)	60 (76.9)
Not defined	6 (--)	17 (--)	13 (--)	20 (--)	15 (--)	11 (--)	28 (--)	19 (--)
Likes running and hopping	**32 (100)**	**34 (100)**	**41 (100)**	**94 (100)**	**97 (100)**	**86 (100)**	**102 (100)**	**74 (100)**
Not at all	--	--	1 (2.4)	2 (2.1)	3 (3.1)	2 (2.3)	5 (4.9)	4 (5.4)
Very little	--	--	1 (2.4)	1 (1.1)	3 (3.1)	2 (2.3)	3 (2.9)	2 (2.7)
Little	--	3 (8.8)	--	5 (5.3)	2 (2.1)	4 (4.7)	4 (3.9)	1 (1.4)
Average	3 (9.4)	1 (2.9)	5 (12.2)	10 (10.6)	9 (9.3)	8 (9.3)	11 (10.8)	7 (9.5)
Often	8 (25.0)	8 (23.5)	5 (12.2)	(14.9)	19 (19.6)	21 (24.4)	23 (22.5)	15 (20.3)
Always	21 (65.6)	22 (64.7)	29 (70.7)	62 (66.0)	61 (62.9)	49 (57.0)	56 (54.9)	45 (60.8)
Not defined	6 (--)	18 (--)	13 (--)	18 (--)	16 (--)	12 (--)	25 (--)	23 (--)
Plays street soccer	**32 (100)**	**31 (100)**	**39 (100)**	**89 (100)**	**97 (100)**	**84 (100)**	**97 (100)**	**72 (100)**
Not at all	13 (40.6)	13 (41.9)	7 (17.9)	18 (20.2)	19 (19.6)	15 (17.9)	15 (15.5)	10 (13.9)
Very little	4 (12.5)	2 (6.5)	3 (7.7)	10 (11.2)	3 (3.1)	5 (6.0)	4 (4.1)	2 (2.8)
Little	2 (6.3)	1 (3.2)	6 (15.4)	9 (10.1)	10 (10.3)	8 (9.5)	9 (9.3)	5 (6.9)
Average	3 (9.4)	3 (9.7)	6 (15.4)	16 (18.0)	20 (20.6)	11 (13.1)	14 (14.4)	7 (9.7)
Often	3 (9.4)	4 (12.9)	4 (10.3)	15 (16.9)	16 (16.5)	19 (22.6)	19 (19.6)	11 (15.3)
Always	7 (21.9)	8 (25.8)	13 (33.3)	21 (23.6)	29 (29.9)	26 (31.0)	36 (37.1)	37 (51.4)
Not defined	6 (--)	21 (--)	15 (--)	23 (--)	16 (--)	14 (--)	30 (--)	25 (--)
Attends regular sport	**31 (100)**	**30 (100)**	**35 (100)**	**82 (100)**	**88 (100)**	**83 (100)**	**93 (100)**	**68 (100)**
Not at all	24 (77.4)	21 (70.0)	18 (51.4)	35 (42.7)	28 (31.8)	29 (34.9)	24 (25.8)	17 (25.0)
Very little	1 (3.2)	1 (3.3)	6 (17.1)	11 (13.4)	7 (8.0)	14 (16.9)	8 (8.6)	2 (2.9)
Little	1 (3.2)	1 (3.3)	4 (11.4)	9 (11.0)	12 (13.6)	5 (6.0)	10 (10.8)	7 (10.3)
Average	2 (6.5)	3 (10.0)	4 (112)	12 (14.6)	14 (15.9)	10 (12.0)	16 (17.2)	11 (16.2)
Often	1 (3.2)	4 (13.3)	2 (5.7)	4 (4.9)	15 (17.0)	11 (13.3)	14 (15.1)	13 (19.1)
Always	2 (6.5)	--	1 (2.9)	11 (13.4)	12 (13.6)	14 (16.9)	21 (22.6)	18 (26.5)
Not defined	7 (--)	22 (--)	19 (--)	30 (--)	25 (--)	15 (--)	34 (--)	29 (--)

Legend: n = number of participants per group, yr = year, % = valid percentage

(continued)

AGE	2 yr	3yr	4 yr	5yr	6yr	7yr	8yr	9yr
FACTORS	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**
ACTIVITY LEVEL…								
Likes sitting quietly	**31 (100)**	**33 (100)**	**40 (100)**	**88 (100)**	**90 (100)**	**84 (100)**	**96 (100)**	**70 (100)**
Not at all	8 (25.8)	11 (33.3)	7 (17.5)	38 (43.2)	31 (37.8)	30 (35.7)	43 (44.8)	32 (45.7)
Very little	3 (9.7)	6 (18.2)	6 (15.0)	6 (6.8)	9 (10.0)	8 (9.5)	11 (11.5)	9 (12.9)
Little	3 (9.7)	3 (9.1)	8 (20.0)	13 (14.8)	9 (10.0)	9 (10.7)	7 (7.3)	7 (10.0)
Average	10 (32.3)	6 (18.2)	9 (22.5)	13 (14.8)	18 (20.0)	11 (13.1)	12 (12.5)	11 (15.7)
Often	3 (9.7)	4 (12.1)	3 (7.5)	8 (9.1)	16 (17.8)	12 (14.3)	14 (14.6)	7 (10.0)
Always	4 (12.9)	3 (9.1)	7 (17.5)	10 (11.4)	4 (4.4)	14 (16.7)	9 (9.4)	4 (5.7)
Not defined	7 (--)	19 (--)	14 (--)	24 (--)	23	14 (--)	31 (--)	27 (--)
SWADDLED	**33 (100)**	**37 (100)**	**41 (100)**	**92 (100)**	**100 (100)**	**86 (100)**	**113 (100)**	**84 (100)**
Not at all	5 (15.2)	8 (21.6)	6 (14.6)	18 (19.6)	19 (19.0)	5 (5.8)	17 (15.0)	15 (17.9)
Yes	28 (84.8)	29 (78.4)	35 (85.4)	74 (80.4)	81 (81.0)	81 (94.2)	96 (85.0)	69 (82.1)
Not defined	5 (--)	15 (--)	13 (--)	20 (--)		12 (--)	14 (--)	13 (--)
AGE TO SWADDLED	**29 (100)**	**29 (100)**	**36 (100)**	**78 (100)**	**83 (100)**	**85 (100)**	**101 (100)**	**72 (100)**
0-3 mo	25 (86.2)	25 (86.2)	28 (77.8)	65 (83.3)	66 (79.5)	69 (81.2)	86 (85.1)	55 (76.4)
4-6 mo	3 (10.3)	2 (6.9)	7 (19.4)	10 (12.8)	13 (15.7)	12 (14.1)	8 (7.9)	10 (13.9)
7-9 mo	1 (3.4)	2 (6.9)	1 (2.8)	--	4 (4.8)	4 (4.7)	7 (6.9)	--
Other	--	--	--	3 (3.8)	--	--	--	7 (9.7)
Not defined	4 (--)	23 (--)	18 (--)	34 (--)	30 (--)	13 (--)	26 (--)	25 (--)
PRAM	**30 (100)**	**32 (100)**	**41 (100)**	**93 (100)**	**103 (100)**	**88 (100)**	**110 (100)**	**82 (100)**
Not at all	17 (56.7)	14 (43.8)	15 (36.6)	45 (48.4)	41 (39.8)	40 (45.5)	41 (37.3)	41 (50.0)
Yes	13 (43.3)	18 (56.3)	26 (63.4)	48 (51.6)	62 (60.2)	48 (54.5)	69 (62.7)	41 (50.0)
Not defined	8 (--)	20 (--)	13 (--)	19 (--)	10 (--)	10 (--)	17 (--)	15 (--)
AGE TO IN PRAM	**15 (100)**	**19 (100)**	**25 (100)**	**48 (100)**	**60 (100)**	**48 (100)**	**70 (100)**	**43 (100)**
9-10 mo	7 (46.7)	8 (42.1)	10 (40.0)	12 (27.3)	27 (45.0)	18 (37.5)	32 (45.7)	21 (48.8)
11-12 mo	2 (13.3)	7 (36.8)	5 (20.0)	9 (18.8)	15 (25)	12 (25.0)	16 (22.9)	7 (16.3)
1-2 yr	5 (33.3)	4 (21.1)	10 (40.0)	25 (52.1)	14 (23.3)	13 (27.1)	19 (27.1)	12 (27.9)
3-4 yr	1 (6.7)	--	--	2 (4.2)	4 (6.7)	5 (10.4)	3 (4.3)	3 (7.0)
Not defined	3 (--)	33 (--)	29 (--)	64 (--)	53 (--)	50 (--)	57 (--)	54 (--)

Leged: mo = months, n = number of participants per group, SD = standard deviation, yr = years, % = valid percentage (continued)

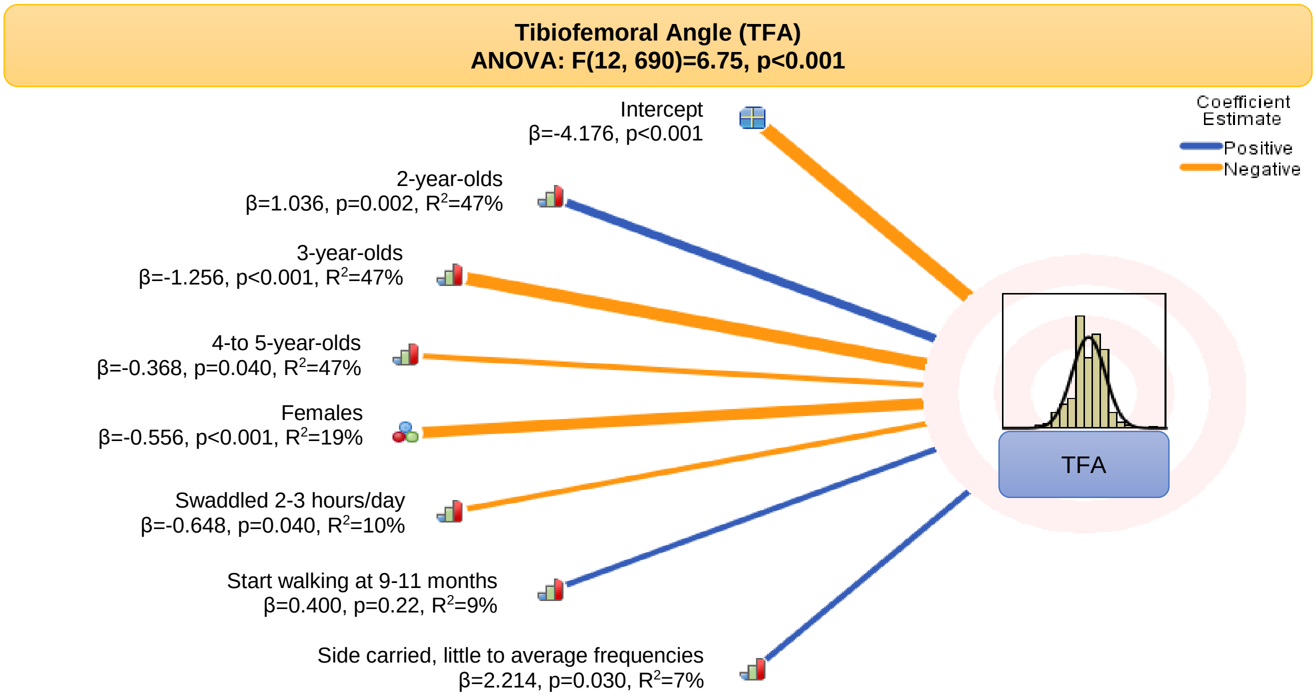

Figure 1: Statistically significant predictor factors for the development of the tibiofemoral angle (TFA) and their importance

The TFA is the dependent variable in this ALM graphic presentation, while age, sex, swaddling duration, walking age, and side-carrying are all independent variables. Line thicknesses represent the importance of each independent variable, with thicker lines representing greater importance. Negative correlations are indicated in yellow and positive correlations are indicated in blue.

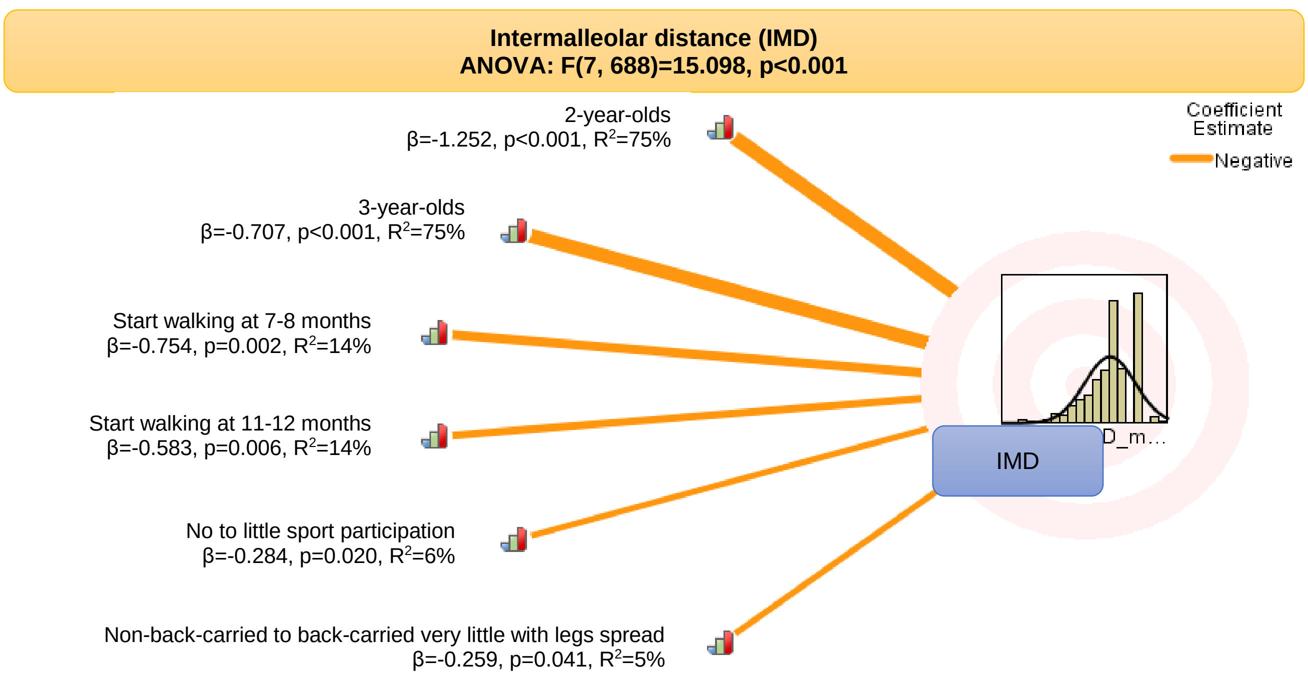

Figure 2: Statistically significant predictor factors for intermalleolar distance (IMD) development and their importance

The IMD is the dependent variable in this ALM graphic presentation, while age, walking age, sport participation and very little back-carrying with the legs spread are all independent variables. Line thicknesses represent the importance of each independent variable, with thicker lines representing greater importance. Negative correlations are indicated in yellow.

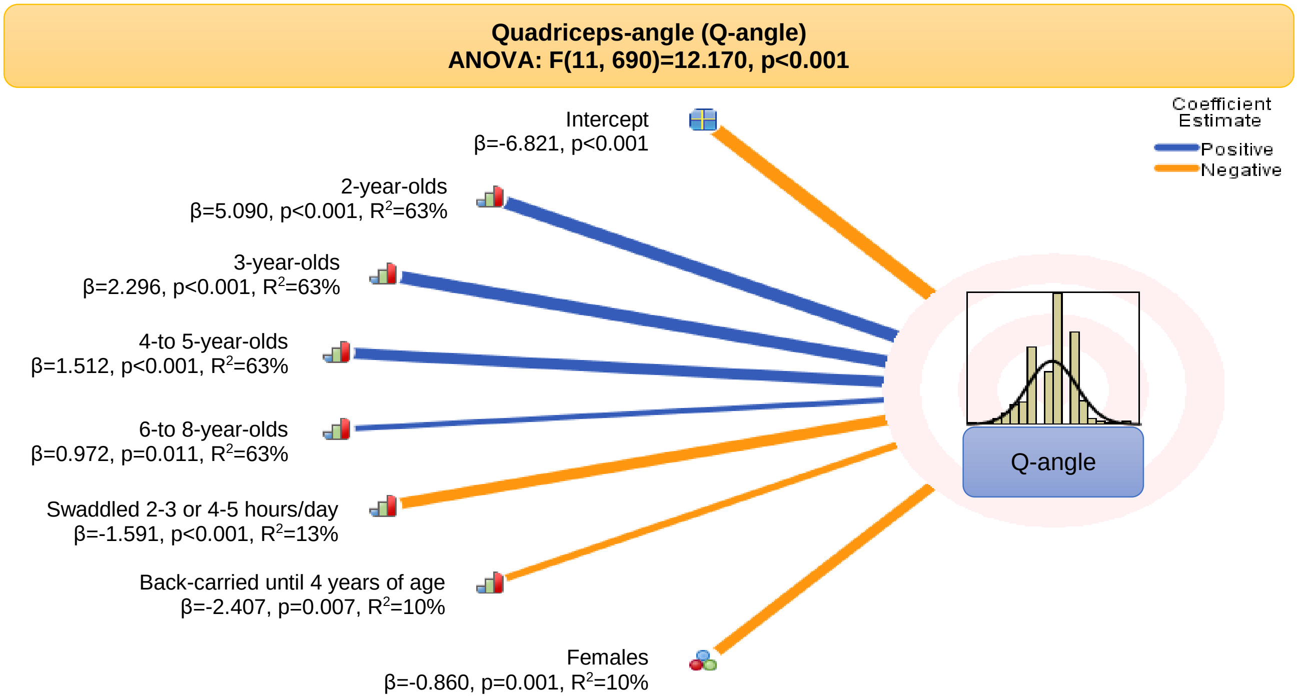

Figure 3: Statistically significant predictor factors for quadriceps-angle (Q-angle) development, and their importance

The Q-angle is the dependent variable in this ALM graphic presentation, while age, swaddling duration, back-carrying age, and sex are all independent variables. Line thicknesses represent the importance of each independent variable, with thicker lines representing greater importance. Negative correlations are indicated in yellow and positive correlations are indicated in blue.

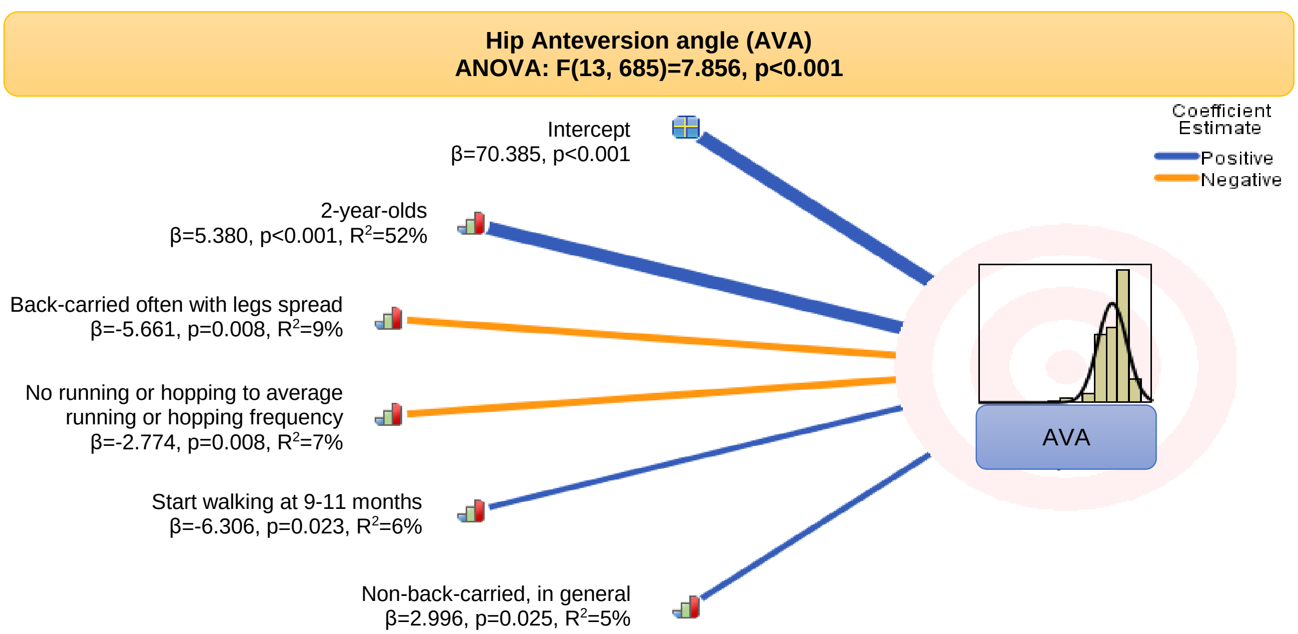

Figure 4: Statistically significant predictor factors for hip anteversion angle (AVA) development, and their importance

The AVA is the dependent variable in this ALM graphic presentation, while age, back-carrying with legs spread, hopping or running frequency, walking age and non-back-carrying are all independent variables. Line thicknesses represent the importance of each independent variable, with thicker lines representing greater importance. Negative correlations are indicated in yellow and positive correlations are indicated in blue.

Transverse plane (TP) measures: Hip anteversion (AV) and tibial torsion (TT)

The ALM with hip anteversion (AV) (Figure 4) as the dependent variable yielded eight predictor factors. Participant age (R^2=52%)*, BC with the legs spread (R^2=9%)*, daily BC durations per day of less than an hour or more than two hours (β=-1.330, p=0.575, R^2=9% and β=-4.370, p=0.088, R^2=9% respectively), running and hopping activity (R^2=7%)*, swaddled for less than three hours or swaddled between four to five hours per day (β=-1.441, p=0.318, R^2=7% and β=1.663, p=0.362, R^2=7% respectively), no to very little activity or preferential quiet sitting for frequencies between average to always (β=-0.630, p=0.523, R^2=6% and β=2.077, p=0.125, R^2=6% respectively), walking age (R^2=6%)* and general BC practices (R^2=5%)*. Five predictors of TTA (Figure 5) were identified: participant age (R^2=83%)*, front carried with the legs down (R^2=5%)*, active, playing outside (R^2=5%)* and pushed in a pram (R^2=5%)*.

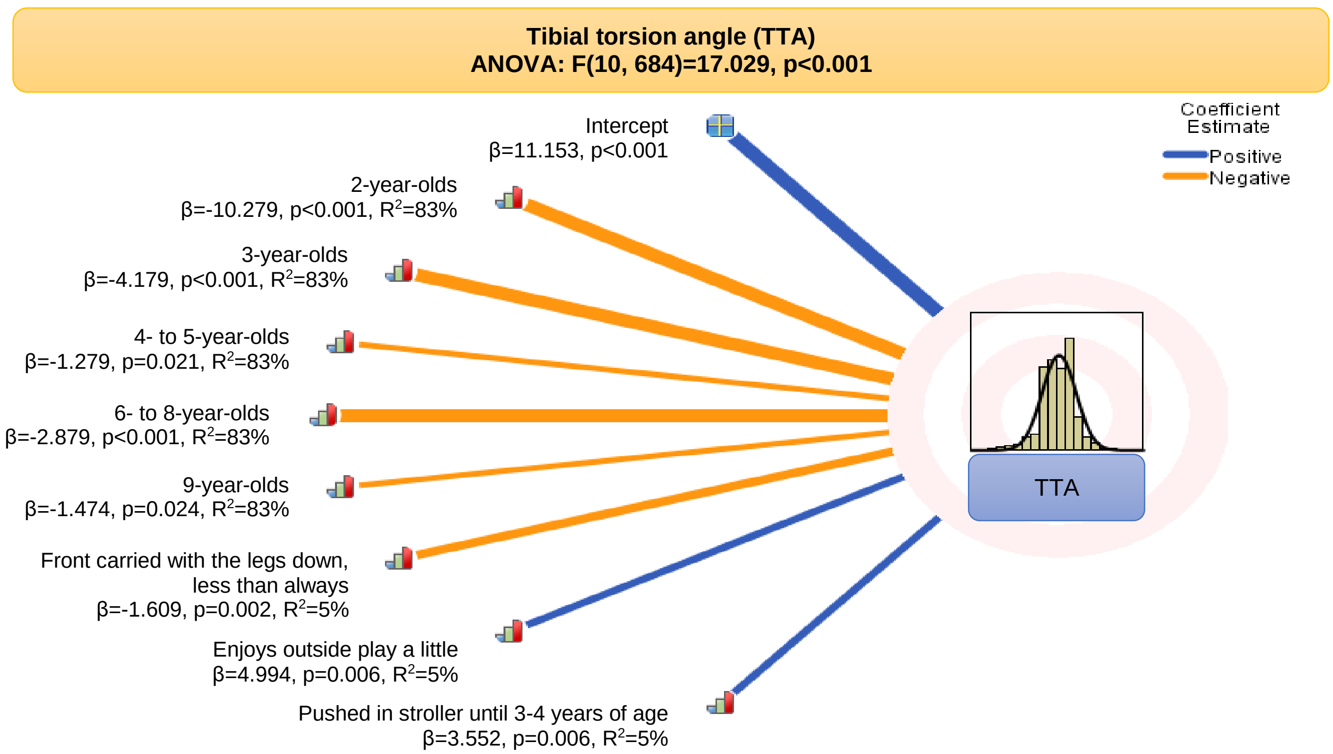

Figure 5: Statistically significant predictor factors for tibial torsion angle (TTA) development, and their importance.

The TTA is the dependent variable in this ALM graphic presentation, while age, front-carrying with the legs down, outside playing and being pushed in a pram are all independent variables. Line thicknesses represent the importance of each independent variable, with thicker lines representing greater importance. Negative correlations are indicated in yellow.

DISCUSSION

The objective of this study is to determine the contributing factors in the development of and the severity of deviation in LL alignments in black Setswana-speaking children between the ages of two- to nine years. LL alignments were assessed from the FP (TFA, IMD, and Q-angle) and the TP (AVA and TTA) perspectives. Each of the LL alignment measures was compared with postulated predictor factors, such as BC, swaddling or pram use methods, durations, and frequencies, commencement of independent walking age as well as activity levels of the child. Previous research report LL measures such as the TFA, IMD, AVA and TTA change with an increase in age, and differs slightly between children from different ethnicities [12, 16, 17], explaining why participant age is consistently the most significant predictor of LL development in the current study.

In terms of the TFA, participant age was the most prominent and essential predictor, at R^2=46%, of the TFA, with the maximum TFA observed in two-year-olds and the minimum mean TFA in three-year-olds. Similar observations were made in previous studies, where infants and two-year-olds presented with varus to neutral TFAs [12, 16, 18]. The greatest valgus TFAs were associated with children who were swaddled between two- and three hours per day. Smaller valgus angles were found when children were swaddled for longer than four hours or shorter than two hours. We argue that infants (younger than two years) would mostly be swaddled for long durations, which explains the relationship between smaller valgus angulation in longer swaddled (more than four hours) children. Bone growth and adaptation are guided by Wolff's law [19] or the current, more commonly accepted bone functional adaptation theory, whereby external- and internal mechanical forces control the shape and structure of the bone [20]. At these young ages, the functional adaptation of bone is pronounced, whereby activity or then inactivity, greatly affects bone adaptation in comparison to adults [21]. Slightly less valgus TFAs were observed with increased commencement of independent walking age, while greater valgus TFAs were found when the walking age was 12 months or later. The closer to varus TFA at early walking ages is expected, since previous research reported a greater association of infantile Blount's disease (inward bowing of the lower leg, and genu varum) in children who start walking earlier, than the usual 11- to 12-month interval [22-24].

Children who were side-carried (or hip-carried) often, had the greatest valgus TFAs, while those side-carried for little to average frequencies, presented with less valgus TFAs than those not side-carried to side-carried very little. Children both BC with legs hanging down and front-carried with legs down groups reflected negative non-significant relationships with TFA development and presented with greater valgus TFAs. The last three findings explain one another from the perspective that the last two carrying positions are fairly similar, with the child's legs closer together than in the side-carrying position.

The IMD is often used in support of TFA measures, and usually not applied as a standalone measure, due to various methodological reasons, such as the child's size affecting measurements [25, 26].

IMD measures correlate with TFA measures since both these measures determine genu varum or genu valgum in the FP [11, 12]. Different predictor factors were however linked to IMD development than for TFA development (Figure 2), all of which had negative relationships with IMD development. Those who started independent walking at older ages had gradually smaller valgus (closer to neutral) angles, which is in agreement with normal physiological development factors [22, 23]. Similar to commencement of walking age, smaller valgus angles were observed with an increase in sport participation. It can be argued that those who did not participate in sport regularly, assumed more sedentary postures, or were mostly younger than two- or three years of age. Table 2 shows two- and three-year-olds with the lowest regular (always) sports attendance, in comparison to the older children. Two- and three-year-olds both presented with greater valgus IMDs. The last and least important predictive factor for IMD development is BC with legs spread. Decreased valgus angles were associated with an increased frequency in BC with the legs spread, while greater valgus was associated with very little frequencies of BC. The legs spread BC technique, can be seen as the opposite position from legs hanging down BC position, or swaddling, where the limbs are placed together. TFA and IMD are usually measured in conjunction with another to represent FP tibiofemoral development. Greater valgus TFAs were found in children BC with the legs down, thus supporting the opposite finding in IMD.

Participant age was the greatest predictor for Q-angle development, showing an increase in the Q-angle with an increase in age. This increase in the Q-angle with age (to adolescence) is a normal developmental pattern [27]. Swaddling durations were the second greatest predictor and presented highly similar patterns to TFA. Maximal Q-angles were associated with swaddling duration of two- to five hours per day and decreased Q-angles in those swaddled either shorter than two-hour periods or longer than five-hour periods. Similarly, the maximum Q-angle was observed in those BC until four years of age, while smaller Q-angles were found in children BC to ages younger than three- or older than four years. Rationalising why those BC more than four years would present decreased Q-angles angles is difficult. Any explanation at this stage is speculation, but may be linked to underestimation of BC age, by the guardians of the four-year estimates group. Hvid and Andersen [28] found that the Q-angle may be linked to the AVA where Q-angles less than 15° are related to femoral retroversion. Those who were often BC, presented with decreased AVAs, but not decreased enough to indicate femoral retroversion. Maximum Q-angles were observed in those swaddled between two- to five hours per day, with the Q-angle gradually decreasing in those who were swaddled beyond five years of age. Although absolute LL positions are opposite in BC versus swaddled positions, both positions are characterised by increased valgus forces at the knee, as applied by the blanket [4]. Similar to TFA development, Q-angle measures were greater in females than in males. Very little information on young child Q-angles are available [27], but in adult populations, females normally present with greater Q-angles than males [28-30], which could explain this study's finding.

In the TP, hip AVAs were decreasing while the frequency of BC with the legs spread increased. Those who were BC with the legs spread, for frequencies less of than often, had greater hip AV means. Excessive hip AV is often observed along with greater external TTA [31, 32]. Yet, in black Setswana-speaking children, greater internal TTAs were found in BC children [10]. Maximal hip AVAs were found in non-BC children, and these angles steadily decreased as BC frequency increased. Those BC for longer than two hours per day presented lower AVA than those BC for less than one hour per day. No statistically significant differences were found between the various BC duration groups. In terms of activity, those less active (did not like running or hopping) and more inactive (likes sitting quietly) had lower AVAs than those who were more active. This finding supports the previous two findings, as those BC often and those BC for longer durations would have less time to be active and participate in running or hopping activities. Similar reasoning can be applied to the last predictor factor, general BC practices, where the non-BC group showed a significant, positive relationship with AVAs, thus non-BC children had greater AVAs than those who were BC.

TTAs in children are lower than in adults and far more varied with age [12, 15, 33, 34]. Far greater internal TTAs were observed in black Setswana-speaking [35] children, than reported in three prior studies [12, 33, 36], which progressed toward neutral and slight external TT in older children. Internal TTAs coexist with greater genu valgum angles, which have been shown in a previous study [35]. Those who were never front-carried with the legs hanging down, had the greatest internal TTAs, while those always front-carried, presented with lower internal TTAs. Activity levels were measured and reported in a questionnaire on a Likert scale, from not active at all, to always active. Less active (did not enjoy outside play), and very active children both presented with greater internal TTAs than those who enjoyed outside play a little. Explanation of this observation is complicated, but may be attributed to the over-estimation of activity levels by the caregiver. An alternative explanation could be more variable postures assumed in those "little active", varying from sitting, standing and running. Further investigation into this is required, and we recommend more objective measures of activity levels to accompany such an investigation. In children who were pushed in a pram or stroller, internal TTAs were observed in both the groups; less than two-year group and the three- to four-year group. Although not statistically significant, the group who were in a pram between three- to four years, presented with greater internal TTAs. Greater internal TTA in children who were pushed in a pram might be linked to the results obtained for swaddling, since children's legs are likely together in the pram. Epiphyseal plates develop differently in response to different loading types including;

longitudinal-, perpendicular- and torsional loading [24]. Epiphyseal plates are the least resistant to torsional loading resulting in torsional deformities (TT), due to the presence of abnormal forces [24] and possibly explains the significant findings.

Asencio, Medina-Alcántara *et al.* [2019] [9] performed a study, similar in research design to this study. They hypothesised psychomotor factors such as the independent walking age will influence paediatric planovalgus foot (PPVF) development. They reported an increased risk for the development of PPVF along with obesity, in the left foot of males who started independent walking at a later age than others. They could not provide causal explanations for the association between PPVF and walking age, which calls for further longitudinal investigations into psychomotor- and child-rearing factors and LL development. The current study shows that general child-rearing methods such as swaddling, BC practices, and child activity levels, can predict LL development in children. In a prior study, investigating the relationship between LL development and BC, greater genu valgum, greater internal TTA, and smaller AVA were consistently observed in children BC more frequently than children BC less frequently [10]. The results should be interpreted against the limitations of the study. Several factors are still unexplained or poorly explained and require further investigation. This was a cross-sectional design study, and a longitudinal investigation would render more meaningful results. The use of retrospective questionnaires to gather child-rearing information is always less reliable than an observational study and in the case of the present study, a longitudinal study would render greater reliability. However, the duration and technical requirements for such a long study is very demanding. Individual interviews, preferably held in mother-tongue langue will render more reliable data. However, this is a time-consuming task, and impossible to conduct with such a large population, as in this study.

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Declaration of interest:

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Author contributions:

MvA has contributed to the conception and design of the work, data collection, statistical interpretation and drafted the paper.

SC, the promoter of MvA, contributed to the work by supporting the conception, statistical interpretation, designing and revising the work critically.

SM, the co-promoter, contributed to the work by supporting the conception and revising the work critically.

FS was responsible for statistical analysis.

All authors read and approved the final paper.

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CHAPTER 6 : ARTICLE 4

KINEMATIC GAIT COMPARISON BETWEEN BACK-CARRIED- AND NON-BACK-CARRIED BLACK SETSWANA-SPEAKING CHILDREN

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This research article will be submitted for publication to: *Gait and Posture.* (Guidelines to authors available in Appendix E).

The results of this paper were presented by SH Czyz, at the 12th International Conference on Kinanthropology, held between the 7th and 9th of November 2019, at Masaryk University in Brno, Czech Republic (Appendix K).

ABSTRACT

Purpose:

Dynamic differences during gait are expected at the tibiofemoral joint between back-carried and non-back-carried black Setswana-speaking children, based on static relationships found previously, at the joint in back-carried children. This study aimed to compare the kinematic gait pattern differences between back-carried black Setswana-speaking children with non-back-carried black Setswana-speaking children between seven to nine years of age.

Methods:

Results for 12 (n=12) non-back-carried- (mean age=8.00±0.95 years) and 14 (n=14) back-carried (mean age=8.01±0.73 years) children, selected from a larger (N=691) study, were included. Analysis of tibiofemoral joint kinematics, using the Qualisys Track Manager software, were performed in the three cardinal planes, at heel-strike, mid-stance, and toe-off gait phases, in the three cardinal planes. Groups were compared using an independent Bayesian t-test, which tests the likelihood of data being supported by either the null- or alternative-hypotheses. The null-hypothesis, postulates the absence of differences between back-carried and non-back-carried children at the tibiofemoral joint, while the alternative-hypothesis proposes the presence of differences between the groups. The Bayesian factor was used to test the strength of the evidence for or against either hypothesis.

Results:

The data supported the null-hypothesis in comparisons of the heel-strike in all three planes, comparisons of mid-stance in the transverse plane, and comparisons of toe-off in the sagittal and transverse planes. In all these cases the Bayesian factor values were above 1 and below 3, providing inconclusive evidence. In the analysis of mid-stance in the sagittal- and frontal planes and toe-off in the frontal plane, the data supported the alternative-hypothesis, with Bayesian factors above 0.33, rendering inconclusive evidence.

Conclusions:

The results were inconclusive, i.e. the differences between tibiofemoral angles in back-carried and non-back-carried were not large enough to provide convincing evidence for either of the hypotheses. The value of this study is that the results of Bayesian analysis may be used as prior in future studies investigating the relationship between tibiofemoral angles and back-carrying.

Keywords: back-carrying, kinematic gait analysis, lower limb development, Bayesian analysis, tibiofemoral joint

INTRODUCTION

In South Africa, there is a strong cultural tradition of mothers back-carrying (BC) their children, sometimes for extensive durations, sometimes as long as eight hours per day [1, 2]. One researcher linked BC to lower incidences of tibia vara in West-African children [3]. Similar relationships between BC-practices and static lower limb (LL) development measures were found, during a prior study investigating clinical LL development [4]. Children that were back-carried (BC) more often in the study, presented with greater genu valgum as represented by the tibiofemoral angle (TFA) in the frontal plane (FP), compared to less frequently or non-back-carried (non-BC) children. Larger internal tibial torsion angles (TTA) and smaller femoral anteversion angles (AVA) were also observed compared to less frequently- or non-BC children. The question is whether these static relationships observed in BC children compared with non-BC children will translate into kinematic differences between the groups, during gait. Should kinematic differences exist between BC and non-BC children, it could indicate greater risk for injury in the BC group, which would mean BC mothers will need to be informed of the possible consequences of their actions.

In two separate studies static- and dynamic measures of genu varum malalignment, in young adolescents (12- to 19-year-olds), were investigated and compared to healthy controls [5, 6]. Sagittal plane (SP) and FP kinematic gait discrepancies were observed between children with varus malalignment and healthy controls [5]. Adolescents with genu varum presented with significantly reduced knee extension angles in the terminal stance phase of gait but no significant temporal-spatial gait parameter differences were observed in comparison with those with normal alignment [5]. In a later study, the researchers compared static varus measures to dynamic varus measures and found increased endorotation (toeing-in) of the foot along with increased internal tibial rotation in the transverse plane (TP) during the stance phase, in the adolescents with genu varum, compared to controls [6]. Static discrepancies in the TP measures were not observed between groups; thus the dynamic differences observed, were attributed to compensation mechanisms [6]. Based on their findings, the authors argued that varus malalignment should not be solely assessed with static measures [5, 6]. In contrast, a study investigating kinematic differences in six-year-old children with genu valgum compared to a normal reference group found increased knee adduction in the FP along with slower walking speeds and lower cadences in children with genu valgum [7].

Motor development is classified as a continuous process of movement pattern and skill acquisition [8]. There are five potential factors affecting child motor development, including; the child's neuromuscular maturation status, his/her physical growth and behavioural characteristics, the tempo of physical growth, the child's biological maturation and behavioural development, previous movement experiences and lastly, new movement experiences of the child [8]. In addition to these factors, the physical and socio-cultural environment of the child will affect their development and motor ability [8]. Children learn through experimentation and the context of the environment(s) in which they experiment, such as at home, playgrounds in the community, the crèche or preschool, all contribute to skill development and physical ability [8]. Cross patterning skills are affected in BC children, due to the restrictions of the carrying method to their upper- and LL and head [1], which directly impacts their neuromuscular maturation status [8]. The question is whether there is a difference in the kinematic gait between seven- to nine-year-old children who were BC as an infant and or toddler compared to those who were not BC.

Various authors have postulated that BC contributes to the prevention of developmental hip dysplasia in children [9-11]. None of these researchers, however, have specifically investigated the differences in static LL development measures, nor did they directly investigate the kinematic gait differences between BC and non-BC children. Therefore, this study compared tibiofemoral joint (TFJ) angles, during three phases of gait, heel-strike (H-S), mid-stance (M-S) and toe-off (T-O), between BC, seven- to nine-year-old black Setswana-speaking children and their non-BC counterparts.

MATERIALS AND METHODS

This cross-sectional design study was approved by the Faculty of Health Research Ethics Committee of the North-West University (NWU) (NWU – 00094-17-A1) and upheld the declaration of Helsinki of 1964.

Participants

Thirty-four (n=34) healthy children, between the ages of seven- to nine years old, who participated in a larger (N=691) clinical study on LL development, were invited to participate in this study. Only 17 of the seven- to nine-year-old participants (n = 322) from the larger study, indicated that they were not BC and were automatically invited to participate in this study, however only 12 (n=12) non-BC, and 14 (n=14) BC of the invited participants agreed to participate. Of the 26 final participants, data for two of the BC participants were excluded in the final analysis, due to missing data points. The selection of BC participants from the larger participant pool was performed using the random function in Microsoft Excel® using participant numbers (Table 1).

The decision for the older age category was selected based on a suggestion in the literature that adult-like kinematics are established at the age of four years and thereafter minimal discrepancies in kinematic gait are observed between children older than four years of age [12, 13]. Only older children (seven- to nine years of age) were selected to allow more participants per age group and improve statistical power. The inclusion of participants was based on the availability of a complete data set (clinical measures and questionnaire data) and was performed in such a way to ensure equal numbers of participants for each age category. Both male and female participants were invited to participate, and we aimed to include equal numbers of males and females from the three indicated age categories. Only those whose parents agreed to their participation and who provided assent to participation themselves were included in this study.

Procedure

For the kinematic analysis reflective markers (50 mm spheres) were placed on each lower extremity at 13 anatomical landmarks, using the *Calibrated Anatomical Systems Technique* (CAST) *Six-Degrees-Of-Freedom* (6-DOF) protocol [14]. This protocol uses clusters to track the thigh and shank (lower leg) (Figure 1). Markers were placed on the following landmarks for static data collection: Anterior superior iliac spine (ASIS), posterior superior iliac spine (PSIS), greater trochanter, thigh cluster (four markers), lateral femoral condyle, medial femoral condyle, shank cluster (four markers), lateral malleolus, medial malleolus, calcaneus, first distal first metatarsal head, proximal third metatarsal head, distal fifth metatarsal head. During dynamic data collection, the markers remained the same, but the greater trochanter, medial- and lateral femoral condyles and malleoli markers were removed, to allow for normal walking.

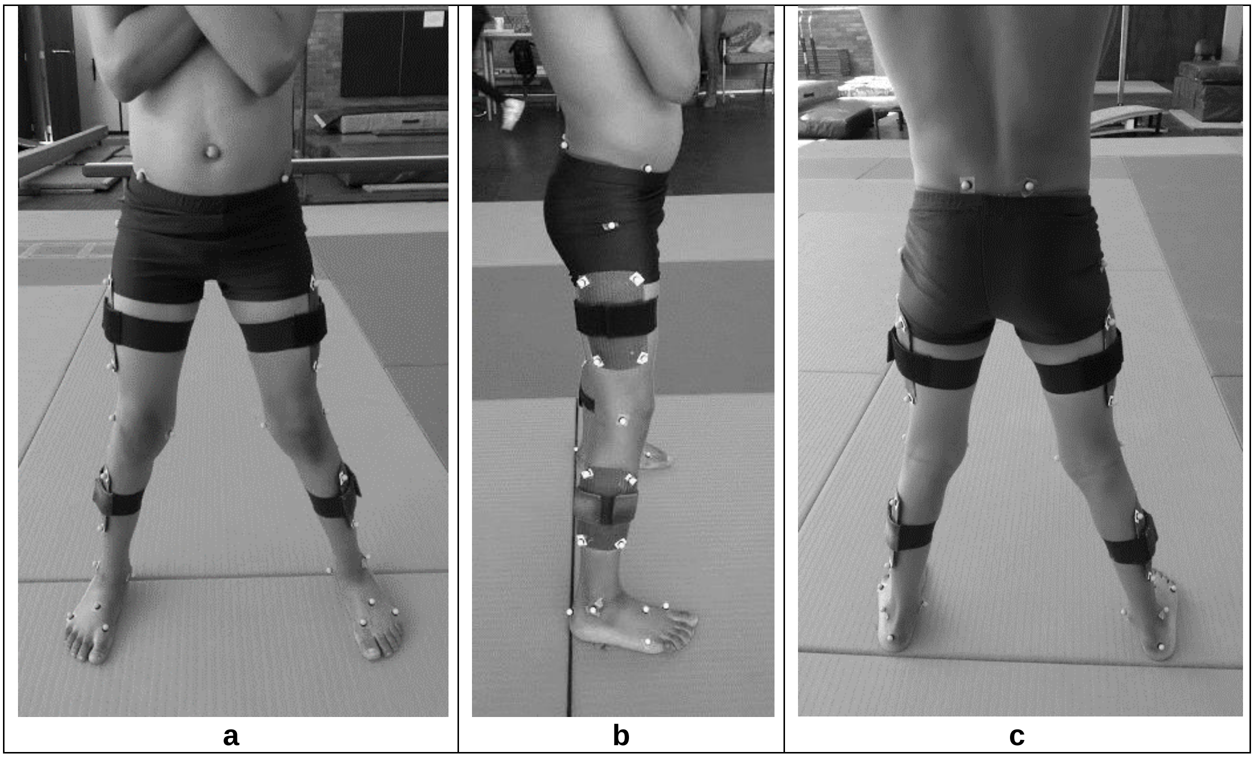

Figure 1: Static marker sets applied: (a) Anterior view, (b) Lateral view and (c) posterior view

Participants walked barefoot, following a circular route, within a 24-m^3 calibrated volume. The circular walking route started within the calibrated volume, within the main line of sight of the cameras. Walking circuits were initiated within the calibrated volume for 3.0 m before turning followed by 3.0 m outside the calibrated volume, and turning back to the start. This was done to allow the attainment of normal walking patterns and walking speed. Participants completed between five- to ten circuits, passing through the calibrated volume, walking at a self-selected speed. Trials containing hopping, skipping, limping or running, were eliminated from the analysis.

Data management

Marker trajectories were tracked using the Qualisys Track Manager (QTM, Qualisys AB, Sweden) software and six wall-mounted cameras (OQUS 3+, Qualisys AB, Sweden). A horizontal X-, vertical Y-, and mediolateral Z-axis coordinate system were used for kinematic analysis in the static- and dynamic measures [15, 16]. Marker trajectories were collected at 100 samples per second during, barefoot level walking at self-selected walking speeds. Camera resolution was set to 1280 x 1224 pixels. Kinematic data were collected at 200-240Hz. Calibration was based on marker coordinates in the anatomical zero position (from each participant). Three-dimensional (3D) marker trajectories were labelled manually before digitisation and remodelling in the programme and a gap-filling tool and smoothing tool were applied to missing marker frames. Coordinate systems for the pelvis, thigh, shank, and foot were located through the reflective marker sets [12, 15, 16]. The average values obtained from the best quality marker trajectories from five walking trials were used for analysis. Bilateral analysis was performed in all three cardinal planes (SP, FP, and TP), to investigate differences in peak TFJ angles at H-S, M-S and T-O gait phases (Table 2).

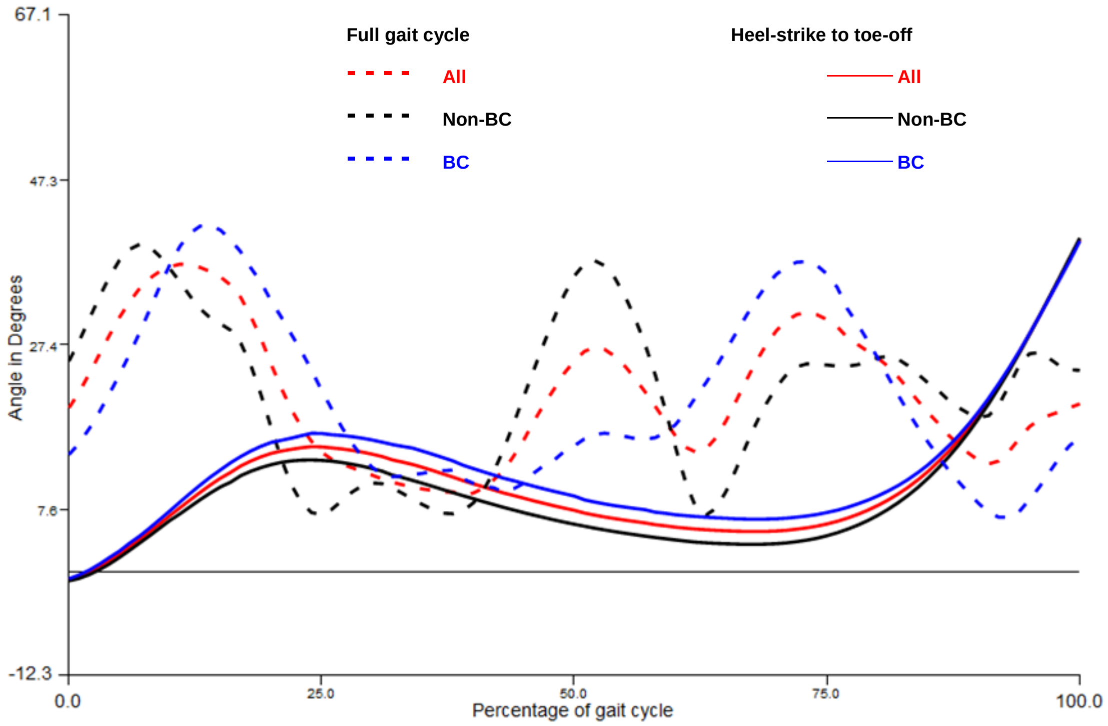

Figure 2: Sagittal plane (SP) joint excursion angles (°) of the knee during the full gait cycle and between heel-strike (H-S) and toe-off (T-O) for back-carried (BC) versus non-back-carried (non-BC) versus all participants

Statistical analysis

Bilateral kinematic data were obtained for all three planes and three gait phases, for the left and right LL. The t-test (Bonferroni adjustment for multiple comparisons were applied) showed no significant differences between left- versus right limb measures, thus only left limb measures were used for statistical analysis. Similarly, both male and female data and age group data showed non-significant differences and were pooled. Given the number of comparisons (9 tests, 3 planes x 3 angles) planned, we decided to use the Bayesian approach. The Bayesian approach tests the null-hypothesis (H_0) against the alternative-hypothesis (H_1). In this study, the H_0 stating an absence of differences between the BC and non-BC children groups versus the H_1 stating differences between the groups. The Bayesian approach quantifies the evidence in favour of one of the hypotheses, whereas the frequentist approach confirms or falsifies only the H_1. Moreover, the significance of the findings in the Bayesian and frequentists approach is similar in terms of the directions of the effect: where p-values < 0.05 yield evidence against H_0, and p-values > 0.05 yield evidence against H_1, similarly to the Bayes factor (BF) [17]. What these approaches do not agree on is the strength of the evidence: where 70% of p-values in the 0.01 to 0.05 interval yield evidence that is, according to BF cut-off points, only "anecdotal" [17]. Therefore, we decided to apply the Bayesian independent sample t-test [18] to compare the TFJ kinematics of the BC to non-BC groups.

Since there is no previous research on the topic, the H_1 was conservatively advanced as the population means are not equal, i.e. H_1 proposes the presence of a difference in TFJ angle kinematics between BC and non-BC children. The H_0 postulates the absence of a difference. A Cauchy scale parameter of 0.707 (prior) [18] was assigned for the effect size. In other words, the assumption is that a difference is expected (either positive or negative) in the observed TFJ angles in BC- compared to non-BC children, and the size of the difference is relatively vague - half of the prior mass is on small-to-moderate effect sizes of Cohen's *d*, and half of its prior mass is on effects sizes that are larger.

The evidence categories for BF were set as proposed by Jeffreys [1998] [19] (also see Wetzels, Matzke *et al.* [2011] [17]. The BF robustness was checked, i.e. we displayed the BF as a function of the width of the Cauchy prior on effect size. The scale of the Cauchy prior is varied between 0 and 1.5, creating progressively more uninformative priors. The Bayesian statistics was performed using JASP (version 0.10.2).

RESULTS

The means and the static measurements of the demographic information of the participants for the BC and non-BC children are presented in Table 1. No statistically significant differences were found between the static measures for BC and non-BC children.

Table 1: Demographic information and static lower limb (LL) development measures in back-carried (BC) versus non-back-carried (non-BC) children

Measure	non-BC mean ± SD (n=12)	BC mean ± SD (n=14)	p-value	Cohens *d*
Age (years)	8.0 ±0.9	8.1 ±0.7	0.835	0.085
Body Mass (kg)	23.8 ±7.5	27.9 ±7.6	0.185	0.537
Height (cm)	120.9 ±6.6	126.4 ±6.7	0.048*	0.821
Tibiofemoral angle (°)	-4.5 ±1.7	-4.4 ±1.7	0.881	0.059
Quadriceps-angle (°)	-9.3 ±3.7	-7.9 ±3.3	0.338	0.388
Intermalleolar distance (cm)	-0.9 ±1.0	-1.8 ±2.2	0.169	-0.583
Tibial torsion angle (°)	12.3 ±3.6	13.8 ±5.8	0.881	0.323
Anteversion angle (°)	75.7 ±6.8	75.0 ±5.1	0.760	-0.124

*Legend: ° = degrees, BC = back-carried, cm = centimetre, non-BC = non-back-carried * Non-significant after Bonferroni correction (0.288)*

Figure 2 represents the mean differences in SP TFJ angles, between BC and non-BC and all of the participants, during both the full gait cycle (dashed lines) and between H-S (0%), M-S (50%) and T-O (100%) (solid lines). Minimal discrepancies are observed between the BC (blue) and non-BC (black) groups during the shortened gait phase from H-S to T-O (solid lines), while the discrepancies are more pronounced between the groups during the full gait cycle (dashed lines).

Table 2: Kinematic results for the tibiofemoral joint (TFJ) in the three cardinal planes, at heel-strike (H-S), mid-stance (M-S), and toe-off (T-O) gait phases

Knee angles in non-back-carried (non-BC) vs back-carried (BC) participants						Bayesian t-test	
Plane	**Gait phase**	**non-BC mean (°) ±SD (n=12)**	**SE**	**BC mean (°) ±SD (n=12)**	**SE**	**BF_{01}**	**Error %**
Sagittal Plane (SP)	**H-S**	-1.566 ±4.786	1.382	-1.429 ±4.494	1.297	2.674	0.016
	M-S	5.109 ±3.581	1.034	8.801 ±3.738	1.079	0.340	0.000
	T-O	36.745 ±3.403	0.982	38.383 ±4.611	1.331	1.878	0.019
Frontal Plane (FP)	**H-S**	-2.855 ±1.944	0.561	-3.693 ±3.659	1.056	2.240	0.017
	M-S	-2.558 ±1.988	0.574	-4.631 ±3.692	1.066	0.952	0.000
	T-O	-1.396 ±3.728	1.076	-6.798 ±7.854	2.267	0.543	0.002
Transverse Plane (TP)	**H-S**	-1.657 ±6.270	1.810	-1.972 ±10.876	3.140	2.672	0.016
	M-S	2.860 ±6.381	1.842	5.518 ±10.176	2.938	2.163	0.017
	T-O	2.292 ±7.004	2.022	4.518 ±8.830	2.549	2.259	0.017

Legend: BC = back-carried, BF_{01} = bayesian factor for the alternative-hypothesis, FP = frontal plane, H-S = heel-strike, M-S = mid-stance, non-BC = non-back-carried, T-O = toe-off, TP = transverse plane, SD = standard deviation, SE = standard error, vs = versus
Negative values represent knee flexion in the sagittal plane, knee adduction in the frontal plane and internal rotation in the transverse plane.

Before applying the Bayesian t-test (Table 2), we checked the assumption. The equality of variances was tested using Levene's test for all comparisons performed (9 tests). In all of the tests, the results were insignificant ($p>0.05$). We tested the normality using the Shapiro-Wilk test for each of the compared groups (18 tests). In three cases, the test yielded significant p-values ($p<0.05$); however, after applying Bonferroni adjustments, all the comparisons were insignificant.

Explanations of Figures 3 to 5:

In the right column, the prior and posterior distribution of the effect size are represented. The dotted line represents the prior distribution under the alternative-hypothesis (scaled Cauchy distribution at 0.707). The solid line represents the posterior distribution. The posterior distribution represents the knowledge about the parameter after seeing the data (observed data). The Savage-dickey density ratio (i.e. equal to BF in our case) is the ratio of the height of the posterior and prior distribution at the location of the H_0. These heights are represented by two grey points. In the left column, BF robustness plots are shown.

In three comparisons of H-S (Figure 3 to Figure 5, subfigures a and b) in all three planes (SP, FP, TP), the observed data supported the H_0. However, the BF reached values above 1.0 and below 3.0 providing inconclusive (anecdotal) evidence. This means the observed data was only one to three times more likely under the H_0, which postulates the absence of a difference between BC and non-BC on TFJ angles. The H_1 postulates the presence of the difference.

The observed data supported the H_1 while analyzing M-S in the SP (Figure 3, subfigures c and d) and FP (Figure 4, subfigures c and d). The BF was above 0.33. In the TP (Figure 5, subfigure c and d), the observed data supported H_0, however, the BF was below 3.0. These values, similar to the previous results, yielded inconclusive evidence.

Analysis of T-O, did not provide stronger evidence either. In the SP (Figure 3, subfigure e and f) and TP (Figure 5, subfigures e and f), the BF was below 3.0 and the data supported H_0, whereas in FP observed data supported H_1, although the BF was above 0.33.

We also performed a robustness check test. We tested our hypothesis using different priors. We used JASP specified wide and ultra-wide priors in order to examine the extent to which our conclusions depend on our prior specification [20]. In Figure 3 (b, d, and f) to Figure 5, we presented values of BF for wide and ultra-wide prior distribution. As it can be observed, our results did not change substantially, leading to the same conclusions as described before.

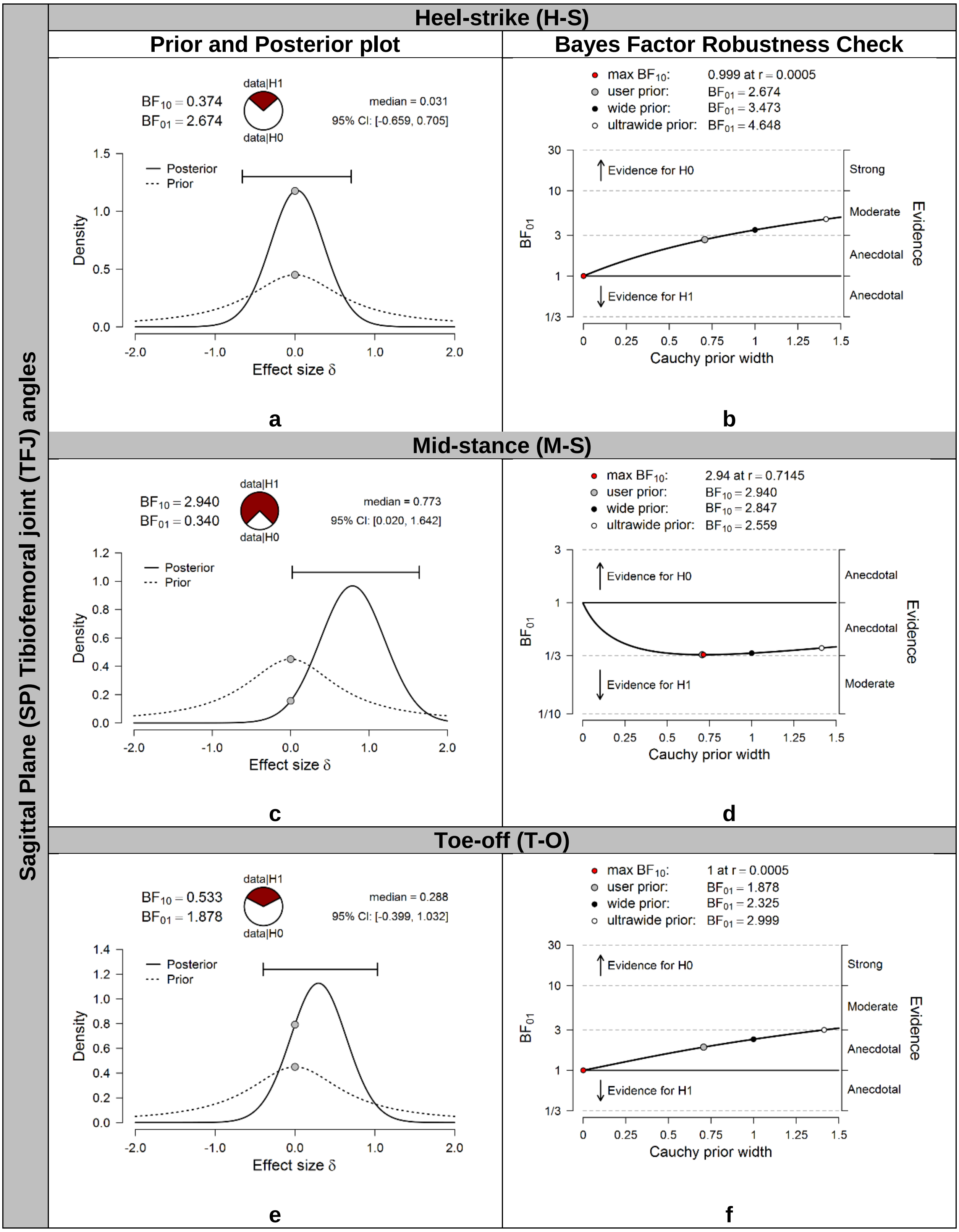

Figure 3: Inferential plots of sagittal plane (SP) kinematics at the knee, during: (a-b) Heel-strike (H-S), (c-d) Mid-stance (M-S) and, (e-f) Toe-off (T-O) gait phases

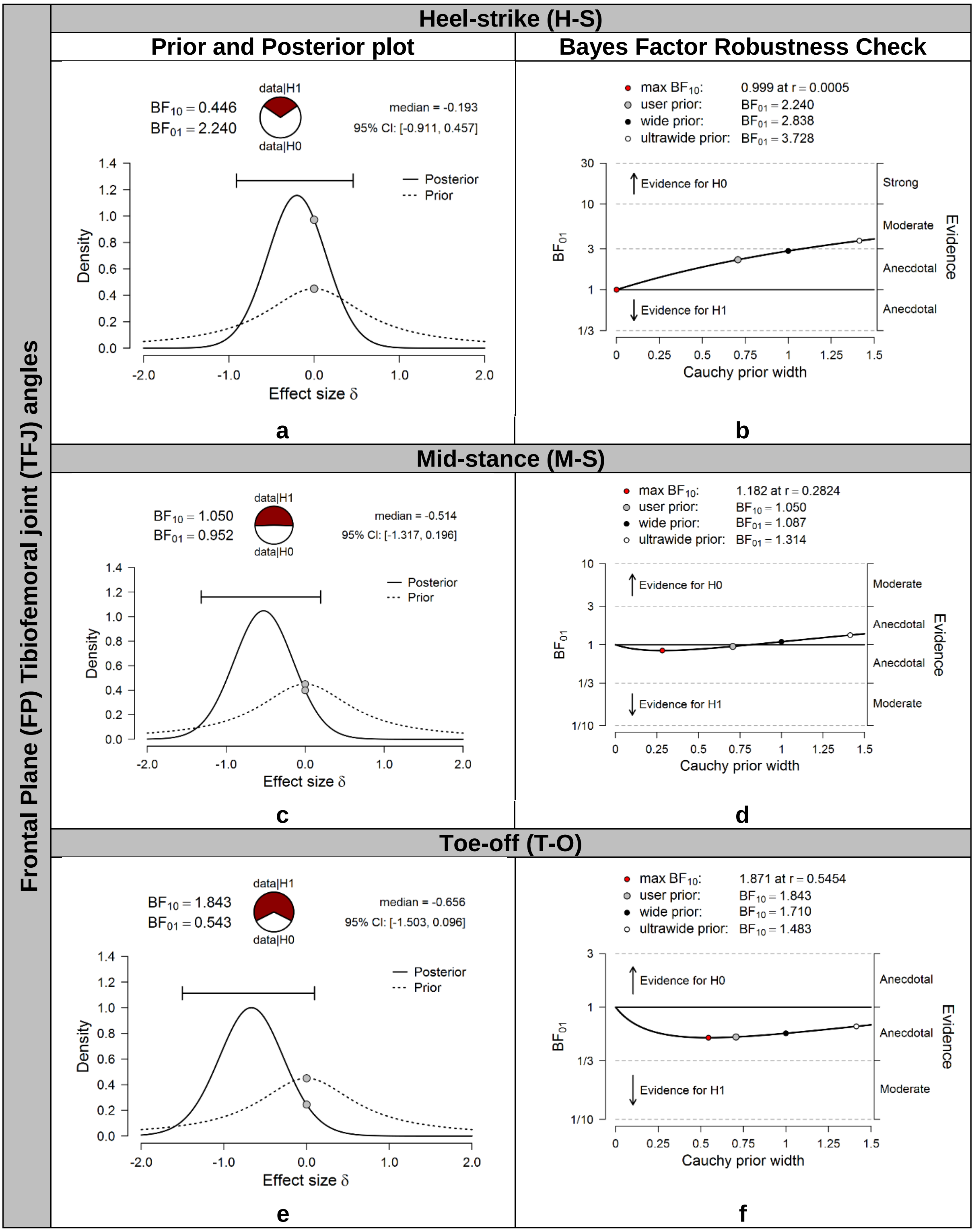

Figure 4: **Inferential plots of frontal plane (FP) kinematics at the knee, during: (a-b) Heel-strike (H-S), (c-d) Mid-stance (M-S) and, (e-f) Toe-off (T-O) gait phases**

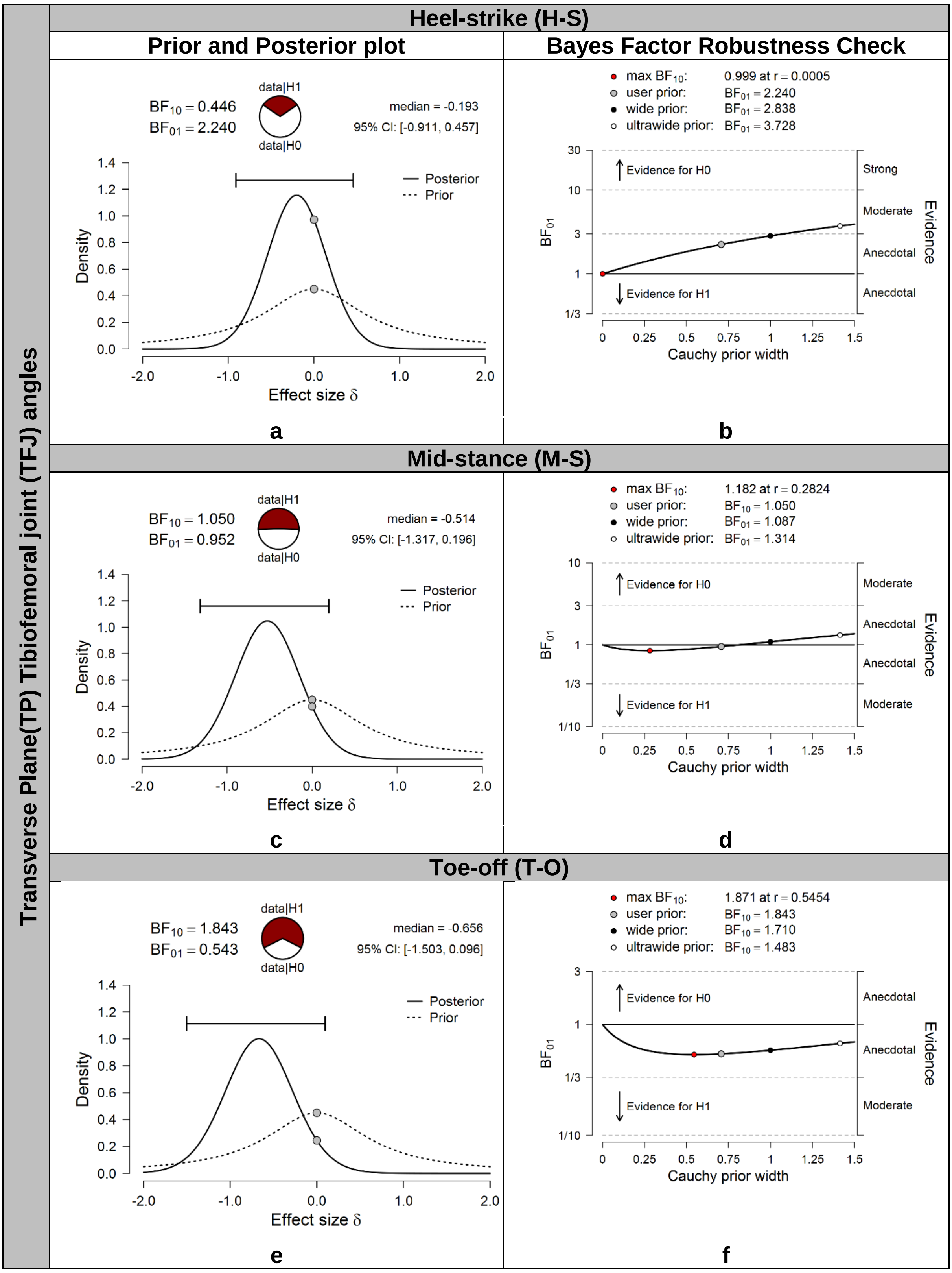

Figure 5: **Inferential plots of the transverse plane (TP) knee kinematics, during: (a-b) Heel-strike (H-S), (c-d) Mid-stance (M-S) and, (e-f) Toe-off (T-O) gait phases**

DISCUSSION

The objective of our study was to compare kinematic differences at the TFJ, during self-selected walking speeds between seven- to nine-year-old BC-, and non-BC children, during three phases of gait at H-S, M-S and T-O. The evidence from the observed data is inconclusive with regards to the presence of differences between BC and non-BC children. Support for either the H_0 or H_1 in any of the kinematic gait angles at the TFJ, in any of the cardinal planes, at the three gait phases which were investigated. Kinematic differences were expected, based on previous evidence from a larger clinical study, which established relationships between static TFJ angle measures in more frequently BC children compared to less frequently BC children [4]. More frequently BC children, presented with greater genu valgum angles in the FP, than children who were BC less frequently or not BC at all [4].

The greatest support for differences in knee kinematics between BC and non-BC children in the SP was during the M-S phase of the gait cycle. In this phase, the mean knee angle in non-BC children was relatively smaller (thus closer to full knee extension) than those observed in BC children (Figure 3, c-d). A greater relationship with genu valgum in BC children was observed in the previous larger clinical study [4] and another study found greater knee extension angles in older adolescents with genu varum, in comparison to those with neutral TFJ alignments [5]. Although the non-BC participants did not present with genu varum, their TFA were greater than those of the BC participants, therefore the findings in the current study agree with those of Stief, Böhm *et al.* [2011] [5].

The TFJ forms part of the LL kinetic chain and correlated motions such as external tibial torsion (TT) is associated with genu valgum, while internal TT is associated with genu varum [21]. In both the TP and FP, anecdotal evidence for greater support of the H_1 is seen at the TFJ during T-O. In the TP greater internal rotation of the knee is seen in the non-BC sample than in the BC sample during H-S. Although none of the participants in neither our study nor the larger clinical study presented with genu varum, the non-BC sample presented with less genu valgum than the frequently BC sample [4]. Although Stief, Böhm *et al.* [2014] [6], did not observe static differences in TT between children with genu varum and their healthy counterparts, they did observe a greater yet statistically non-significant internal knee rotation during the stance phase of gait between the groups. They argued the observed internal knee rotation is a compensatory motion found in those with genu varum [5, 21], while in those with genu valgum, external TT is a correlated motion [21]. Greater external knee rotation angles were observed in our study, during both the M-S and T-O phases in BC children, who in general had greater genu valgum angles. In contrast, smaller external knee rotation angles were found in children with genu valgum in comparison to children with neutral TFJ alignment [22]. The researchers reasoned this observation was a compensatory mechanism for the slightly increased external foot progression angle observed in the participants with genu valgum [22].

In the FP, we found a greater mean knee adduction angle in BC children than in non-BC children. It could arguably be attributed to greater genu valgum relationships in BC children than in non-BC children found observed in the larger static clinical investigation [4]. In six-year-old children with genu valgum, greater knee adduction angles were observed in the stance phase in comparison to children with normal knee alignment [7]. However, in studies investigating the dynamic kinematic- and kinetic differences between children and adolescents with- and without genu varum, significantly greater knee adduction was found in the stance phase, in patients with genu varum [5] and greater internal rotation of the knee in the TP [6]. Drawing inferences between our study and previous research is hard, due to different statistical approaches (Bayesian versus frequentist approach) utilised, but it seems that the results of our study are in contradiction with the study by Stief, Böhm *et al.* [2011] [5] and in agreement with the study by Pretkiewicz-Abacjew [2003] [7].

We chose a sample of older children (seven- to nine-year-olds) from the larger clinical study participants consisting of two- to nine-year-olds. Although more children were reportedly not BC in the younger participant sample from the larger study [4], we believe the inclusion of these younger (two- to six-year-old) children, would have been problematic based on immature gait patterns previously reported in younger children [8, 12, 13, 23]. While investigating SP kinematic and kinetic gait parameters in three- to 13-year-old children, some temporal-spatial differences between the youngest and eldest age categories were found, which were attributed to differing body sizes, proportions and walking schemes [23]. Significant shorter cycle times combined with higher cadences were seen in the youngest age groups (three- to four-year-olds and five- to six-year-olds) when compared to the eldest groups (seven- to eight-year-olds and nine- to 13-year-olds). Older children walked with greater walking velocities, but only differed significantly between the youngest and eldest groups. Most researchers agree that paediatric gait is immature and only changes into adult-like patterns due to growth and central nervous maturation, between 3.5 years-to four years of age [13, 23].

Previous researchers did not report significant differences during gait, in the sagittal hip, -knee or -ankle angles, signifying adult-like joint angle patterns emerged from three years of age [23]. Similar findings were reported in a different study, where adult-like kinematic gait patterns were found in seven-year-old children [12]. The seven-year-olds had a statistically nonsignificant trend toward decreased peak dorsiflexion angles. Lower dorsiflexion angles were associated with kinetic differences in plantar-flexor moments, leading to the conclusion that children lack neuromuscular maturity observed in adults. If clear differences were expected to be seen in our study, the expectation was to observe them in the SP at the TFJ, as this is reported to be the easiest joint to observe differences [13].

The results of our study should be interpreted against the background of the limitations encountered. Information on whether children were BC or not were obtained from a questionnaire, collected in the larger study. Self-reported BC methods, frequencies, and durations are problematic, as it relies on the parent or guardian's memory recall. Often Setswana-speaking children are raised by their grandparents, who often raise multiple children simultaneously, which further challenges memory-recall. During data collection, technical influences resulted in the loss of data from two of the participants and therefore their results were excluded. The small sample size in our study is possibly a contributing factor for the inconclusive evidence in favour of either of the hypotheses for BC and non-BC gait patterns. The decision for sample size was based on sample sizes included in previous research but was also dependent on the number of non-BC participants for this age group, who participated in the larger study [4]. In this age group, only 17 children from 322 seven- to nine-year-olds, were reportedly not BC as infants or toddlers. In addition, the static TFA measures for the sample participants in this study did not render similar relationships as found in the larger clinical study [4], which is attributed to the smaller sample used in this study. Furthermore, we chose a completely random BC from the larger sample, while non-BC children were automatically included, provided they consented to participation. A more specific selection of children who were BC for longer durations or greater frequencies, might render different results.

In summary, we found inconclusive evidence for differences between the TFJ angles of BC compared to non-BC children. The value of our study is that it is the first study comparing kinematic gait differences between BC and non-BC children, furthermore, the results of our Bayesian analysis may be used as prior knowledge in future studies investigating relationships between TFJ angles and BC. Significant differences were found in static LL developmental measures between BC and non-BC children, with greater genu valgum angles in more frequently BC children. However, these genu valgum angles were still within normal limits. Combined with the lack of evidence for differences in TFJ kinematics, we conclude that from an orthopaedic perspective, mothers may continue with their BC practices.

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The results of this paper were presented at the 12th International Conference on Kinanthropology, held between the 7th and 9th of November 2019, at Masaryk University in Brno, Czech Republic. (Appendix K)

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CHAPTER 7 : SUMMARY, CONCLUSION, LIMITATIONS AND RECOMMENDATIONS

7.1. INTRODUCTION

This chapter aims to present the summary and conclusions drawn, in regard to the development of the lower limb (LL) and the gait kinematics of back-carried (BC) black Setswana-speaking children. Development profiles of LL for the black Setswana-speaking child population were lacking, and a summary will be provided, comparing their development to those observed in other child populations. The relationships found between LL development and BC children and the factors contributing to changes in LL alignment will be summarised, before discussing the kinematic comparisons and differences observed between the BC and non-back-carried (non-BC) sample. The conclusions of the study will be drawn based on the hypothesis tested. The contribution that the study makes to the current body of knowledge will be highlighted. The limitation against which the study findings should be interpreted will be indicated, together with recommendations for future research.

7.2. SUMMARY

In this study, we set out to investigate the problem, that the act of children being BC by their mother, might influence the child's static and kinematic LL development. Since no information on LL development in Setswana-speaking children was found, we researched available literature on LL development in children of other ethnicities, which were presented in Chapter two. The Batswana (all Setswana-speakers residing in and around Botswana and the North-West province of South Africa), have a strong culture of back-carrying (BC) and a lack of information regarding BC and the relationship with LL development, may be detrimental with negative long-term consequences. The tibiofemoral angle (TFA) in children of various ethnicities, progressed from genu varum at birth, to knock-knees in toddler ages (between three- and four years) and back toward neutral in older children (between seven- to eight years of age). The general progression was found to be similar in children of various ethnicities, but differences were observed in the ages where the various transitions between genu varum, neutral and genu valgum took place. Hip anteversion angles (AVA) steadily decreased in European children (Cheng *et al.*, 1991), while tibial torsion angles (TTA) increased (Staheli *et al.*, 1985:43; Cheng *et al.*, 1991:158-160; Jacquemier *et al.*, 2008:188). Limited data were found for the development of the quadriceps-angle (Q-angle) in young children, while more data was found for Q-angle development in older adolescents and adults. Most importantly, it is evident that the measurement of Q-angles should follow a strict protocol, to ensure reliability and validity.

Since limited information on the behaviours such as BC impacting the psychomotor- and the kinematic gait differences in children, is available, Chapter two aimed to present the available information for children of other ethnicities. The work presented in the second Chapter served as a critical analysis of the current literature. In parallel South-African studies, some detriments of BC to school readiness, peripheral vision and in turn cognition, were found (Pretorius *et al.*, 2002a:586; Pretorius *et al.*, 2002b:175). Benefits to the mother are having her hands free to perform her daily duties and the knowledge that her child is kept safe (Graham *et al.*, 2015:59). Benefits to the child include, but are not limited to, improved emotional bonding between mother and infant and decreased fussiness of the child due to the soothing environment provided by the mothers' warmth. The greatest orthopaedic benefit to the child, being the possible prevention of developmental dysplasia of the hip (DDH) due to the abducted- and flexed hip position attained on the mother's back (Graham *et al.*, 2015:59). Due to the association between DDH prevention and BC, the question arose as to whether BC would influence the development of the LL of the BC child, at the hip-, knee- and ankle level, and in turn whether there would exist any kinematic gait differences at the tibiofemoral joint (TFJ), between BC and non-BC children.

Finally, in the literature review, the kinematic gait development patterns and differences in very young children (one- to four-year-olds) in comparison to older children (older than four years of age) and adults were presented. Most researchers agree that kinematic adult-like gait patterns emerge from as early as three years old. In order to asses kinematic gait in children, multiple variables should be included during the analysis, with an emphasis on careful methodological planning, involved in kinematic gait studies.

Based on the literature indicating that LL development follows certain progressions, differing between children of different ethnicities, a study with a cross-sectional design was developed, investigating LL development in black Setswana-speaking children between two- to nine years of age. Overall three investigations were combined to address the five objectives. Firstly LL development was measured clinically. Secondly, a questionnaire was used to investigate the psychomotor factors or child-rearing methods in terms of BC. Thirdly, walking gait was investigated through a kinematic analysis. In the first investigation, goniometry was used to measure the TFA and Q-angle with the child in a standing, neutral posture while the AVA and TTA were measured with the child in prone. Intermalleolar distance (IMD) was measured with a measuring tape with the child standing. The clinical results are presented in Chapter three, entitled; *The profile and development of the lower limb in black Setswana-speaking* *children between the ages of two- to nine years.* It showcases the development of the TFA, IMD, Q-angle, AVA, and TTA in two to nine-year-old black Setswana-speaking children. One-year-olds and younger were excluded because all the measurements performed, were done with the child in standing, most children younger than 12 months, have not reached the milestone for walking yet. It was evident that children mostly attain neutral TFA alignment at seven years of age, but since no research was available for the black Setswana-speaking population, it was decided to include children up to nine years of age, to investigate whether this trend would also be true for the black Setswana-speaking population. We recruited 724 participants for this study, of which 33 were excluded, rendering a total sample of 691 (N=691) participants. All measures were performed by a registered biokineticist, trained to perform the measures. In the black Setswana-speaking population, TFA and IMD were found to develop and follow a similar progression as those reported for children of other ethnicities. Similar to the findings for AVA in European children, the AVA of black Setswana-speaking children also declined with an increase in age, however, the absolute values were higher for the black Setswana-speaking population than reported in Europeans. Development of the TTA in black Setswana-speaking children was similar to those reported in Chinese children, where the angle progresses from internal tibial torsion (TT), toward neutral, slightly external TT in older children. Limited child data was obtained for Q-angle development in children of other ethnic groups, where the Q-angle decreased with age in older children (nine years and older) but a steady increase in the Q-angle was found in black Setswana-speaking children, between two- to nine years old. The results presented in this Chapter can be used by medical professionals such as physiotherapists, occupational therapists, and biokineticists as developmental limits for referral to medical doctors for further diagnosis of LL malalignments.

The profiling data obtained in Chapter three was required to allow the investigation of the relationship between BC and LL development in the frontal plane (FP) (objective two) and the transverse plane (TP) (objective three), in Chapter four. The title of Chapter four is; *Back-carrying in black Setswana-speaking children related to lower limb development.* For this Chapter, a questionnaire was developed to determine BC practices employed by the mothers of the participants. The questionnaire data obtained was compared to the developmental LL data obtained in the first article, Chapter three. Chapter four drew comparisons between LL development patterns in BC and those of non-BC children. A *Classification and Regression Tree* (CART) analysis was performed for this Chapter, which grouped the significant relationships between BC and LL development, according to BC, ages, and sexes. Overall, greater genu valgum, greater TTA, and smaller AVA were observed in children who were BC more frequently. Chapter four proved that relationships exist between BC and frontal- and TP LL development exist, which allowed the natural progression into Chapter five.

The fifth Chapter addressed the fourth objective; to determine if predictor factors exist, forecasting the development and severity of LL alignment deviations in black Setswana-speaking children. This Chapter is entitled; *Back-carrying frequency and duration in black Setswana-speaking children influence lower limb development.* The LL data obtained and reported in Chapter three, and questionnaire data obtained and reported in Chapter four were used for this study. The five dependent LL alignments TFA, IMD and Q-angle, AVA and TTA were tested using an Automatic Linear Modelling (ALM) analysis, against various independent psychomotor factors, of which 11 yielded significant contribution in LL alignment status. Age was unsurprisingly, consistently the greatest significant predictor of LL development, owed to the definite developmental progression observed in terms of TFA-, IMD-, AVA- and TTA reported for black Setswana-speaking child populations and other ethnicities. The most significant psychomotor behaviours ($R^2 \leq 10\%$) predicting the dependent LL development variables are summarised here. The most significant psychomotor behaviours predicting TFA development were swaddling of children for two- to three hours per day, while in the age where independent walking was attained predicted IMD development strongest. Two psychomotor factors were found to affect Q-angle development; swaddling of children for two- to three hours- or four- to five hours per day, and those BC until four years of age. For AVA BC with the legs spread (wrapped around the mother's waist), was the greatest predictor, although R^2 was only 9%, which means only 9% of the data variability can be explained by this predictor exclusively. None of the psychomotor factors were in proximity with 10%, for TTA development, however the most noteworthy is less than always front-carrying with the legs down. This Chapter shows significant, yet weak ($10\% < R^2 < 15\%$) relationships between psychomotor or child-rearing methods such as BC, swaddling, and independent walking ages and LL development.

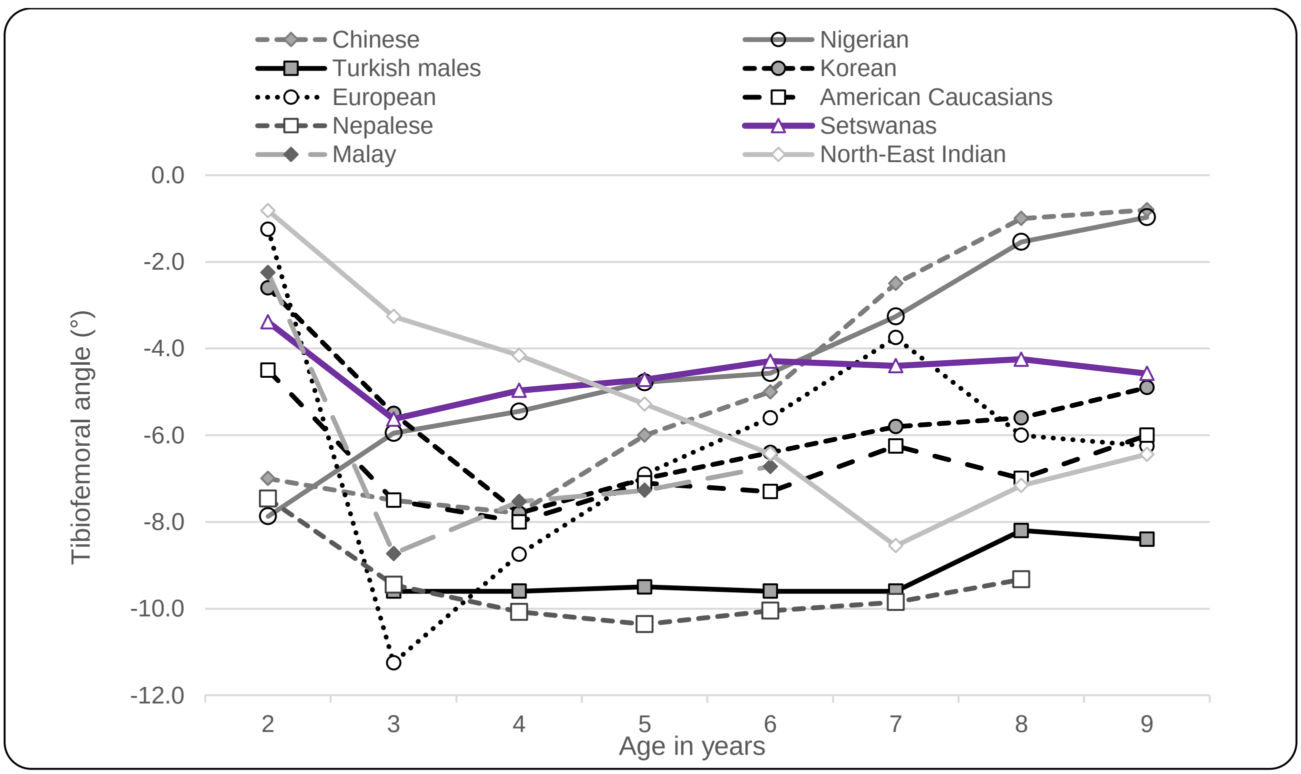
The preceding Chapters three to five, all investigated static LL development measures in BC and non-BC black Setswana-speaking children. Based on the abovementioned relationships between static LL developmental measures and BC, it is of interest to determine if the relationships present in static will be present during gait. Chapter six, entitled: *Kinematic gait comparison between back-carried-, and non-back-carried black Setswana-speaking children,* describes the angles observed at the TFJ, during kinematic gait of BC and non-BC children between seven- to nine years of age. Bayesian statistics were applied for this Chapter, which tests the plausibility of the observed data under prior distribution. The Bayesian approach also allows to test the null-hypothesis (H_0) and the alternative-hypothesis (H_1) against one another. The two-sided H_0 describes the lack of evidence for differences between BC and non-BC children, whereas the H_1 describes evidence for differences between the mentioned groups. Due to the overall focus of the thesis on the TFJ in the FP between BC and non-BC children, the analyses of the kinematic investigation only analysed differences at the

TFJ, although analysis include all three cardinal planes. The conclusions of the study are drawn based on the hypotheses tested.

7.3. CONCLUSION

The study aimed to answer the research question: What are the impacts of BC on static- and kinematic LL development of black Setswana-speaking children at different ages (between two- to nine years old), compared to their non-BC black Setswana-speaking counterparts? In order to answer this question, five objectives were formulated. The conclusions of the study will be based on the hypotheses tested for each of the objectives.

The first objective of the study did not require hypothesis testing, since the objective was to determine the profile and development of the TFA and rotational angles affecting the femur and tibia in black Setswana-speaking children between the ages of two- to nine years.

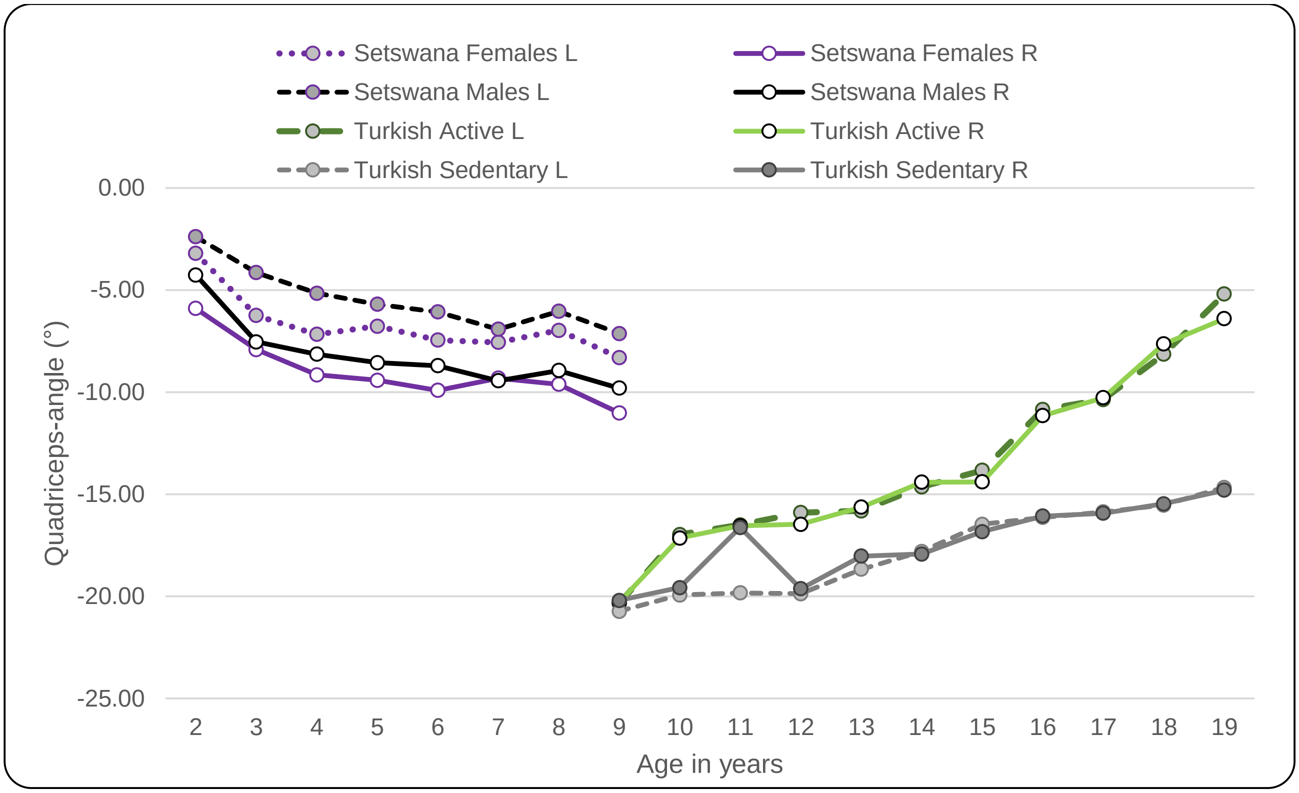


Legend: Negative values (-) = valgus angles, Positive values = varum angles, ° = degrees
<u>Comparative references:</u>
Chinese (Cheng et al., 1991:157)
Turkish (Arazi et al., 2001:265-266)
European (Salenius et al., 1975:260)
Nepalese (Prajapati, 2018:24)
Malay (Mohd-Karim et al., 2015:11)
Nigerian (Bafor et al., 2012:1248)
Korean (Yoo et al., 2008)
American whites (Heath et al., 1993:261)
North-East Indian (Baruah et al., 2017:343)

Figure 7-1: Development of the tibiofemoral angle (TFA) in children from different ethnicities, compared to black Setswana-speaking children

In figure 7-1 the results for black Setswana-speaking children are compared to results presented by other researchers, for children of different ethnicities. The Korean study performed radiological measurements, and still show great compatibility with black Setswana-speaking children. The Chinese- and Nigerian studies shows greater variation, especially in older children, where they observed closer to neutral TFA compared to all other ethnic groups. This study was largely based on the methods employed by the Chinese study, thus the differences noted in black Setswana-speaking children versus the Chinese is attributed to ethnic differences. IMD measures supported the overall progression of the TFA and are in agreement with the findings reported in other studies. The researchers found the measurement of the IMD slightly more difficult and less reliable than the TFA and suggest that future researchers use this measure in addition to the TFA and never as a stand-alone measure. Overall, the differences in the findings are attributed to ethnic discrepancies. Therefore, this study indicates that during LL developmental there is a general progression from close to neutral angulation, or more varus angulation at birth, toward a maximal valgus angle in toddlers, before a gradual return toward neutral, in older children, which shows agreement with the findings of other studies in terms of the TFA.

Clinical measurements using goniometry is problematic, due to possible measurement error by clinicians. On the other hand, testing children with radiographic equipment unnecessarily, expose children to radiation. Therefore a choice of the testing method is not only an ethical dilemma, but also a costly one. Various researchers have assessed the reliability and validity of clinical measures in comparison to radiographic measures. Most researchers agree the radiographic studies are the gold standard, but that clinical studies can be reliable and valid, provided the researcher follows a strict protocol. Body and limb positioning affects the presence and severity of genu varum or -valgum and it is recommended that clinicians follow a standardised protocol when performing both clinical and radiographic measurements to establish genu varum or –valgum. An externally rotated foot during measurements, contribute to the underestimation of the genu varum alignment, whilst an internally rotated foot will lead to an overestimation of the severity of the genu varum alignment. In this study, care was taken to physically position the participant in a neutral position, where necessary, especially with the younger children. An assistant helped to hold the child’s LL in place, while ensuring to not disrupt the neutral position. The younger the participants are, the harder it is to perform accurate measurements, due to young participants fidgeting or with the two-year-olds, poor balance is troublesome, leading to the child often changing foot position. An alternative measurement method for genu varum determination is to use interpopliteal distances as a clinical measurement instrument. Infants can be measured in prone, while those who are ambulatory can be measured in a standing position. The alternative interpopliteal protocol uses the dimple of the popliteal fossa as an anatomical landmark and this distance is measured with the medial malleoli of the ankles touching. The current study did not utilise the interpopliteal distance method, as the landmark used is deemed more problematic than using the distance between the medial malleoli.

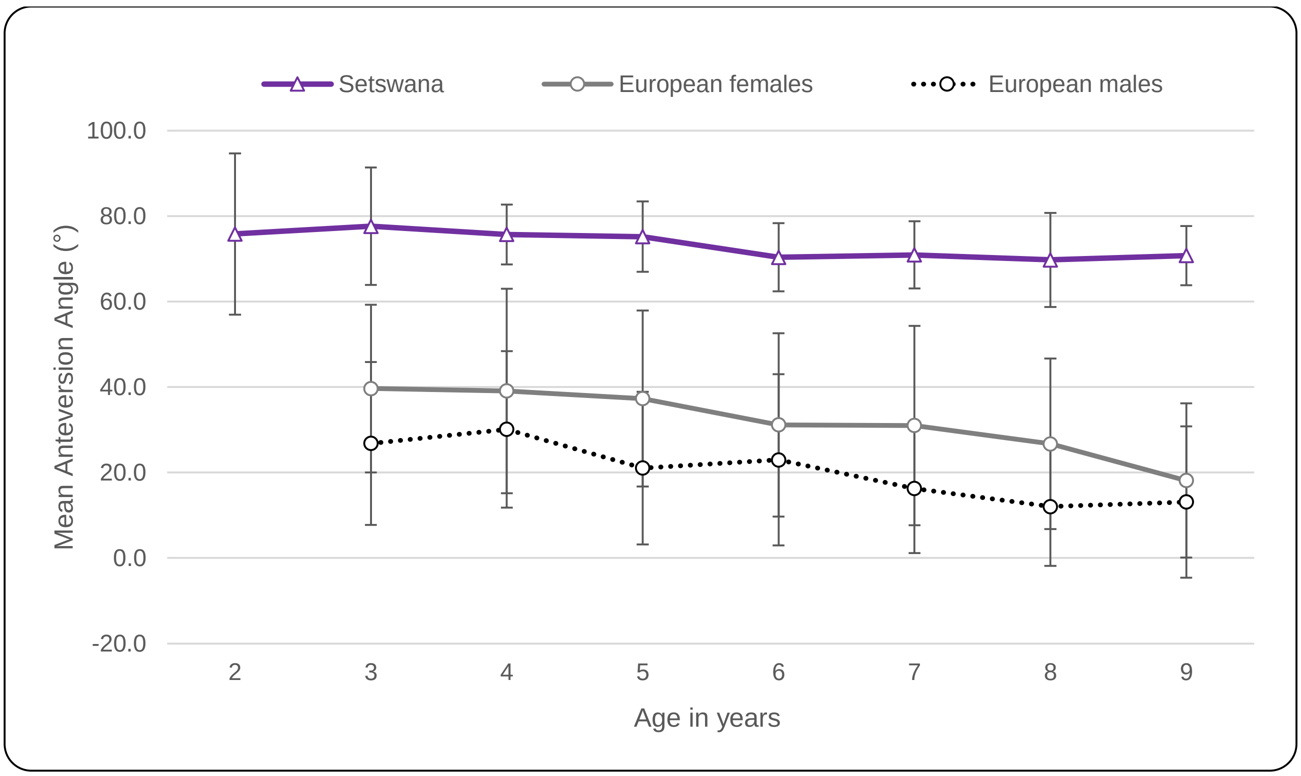


Legend: L = left limb, negative values (-) = valgus angles, postivie values = varus angles, R = right limb, Q-angle = quadriceps-angle, ° = degrees
Comparative reference: *Turkish (Bayraktar* et al.*, 2004:757-756)*

Figure 7-2: Bilateral comparison of the quadriceps-angles (Q-angle) observed in black Setswana-speaking children, compared to active and sedentary Turkish children

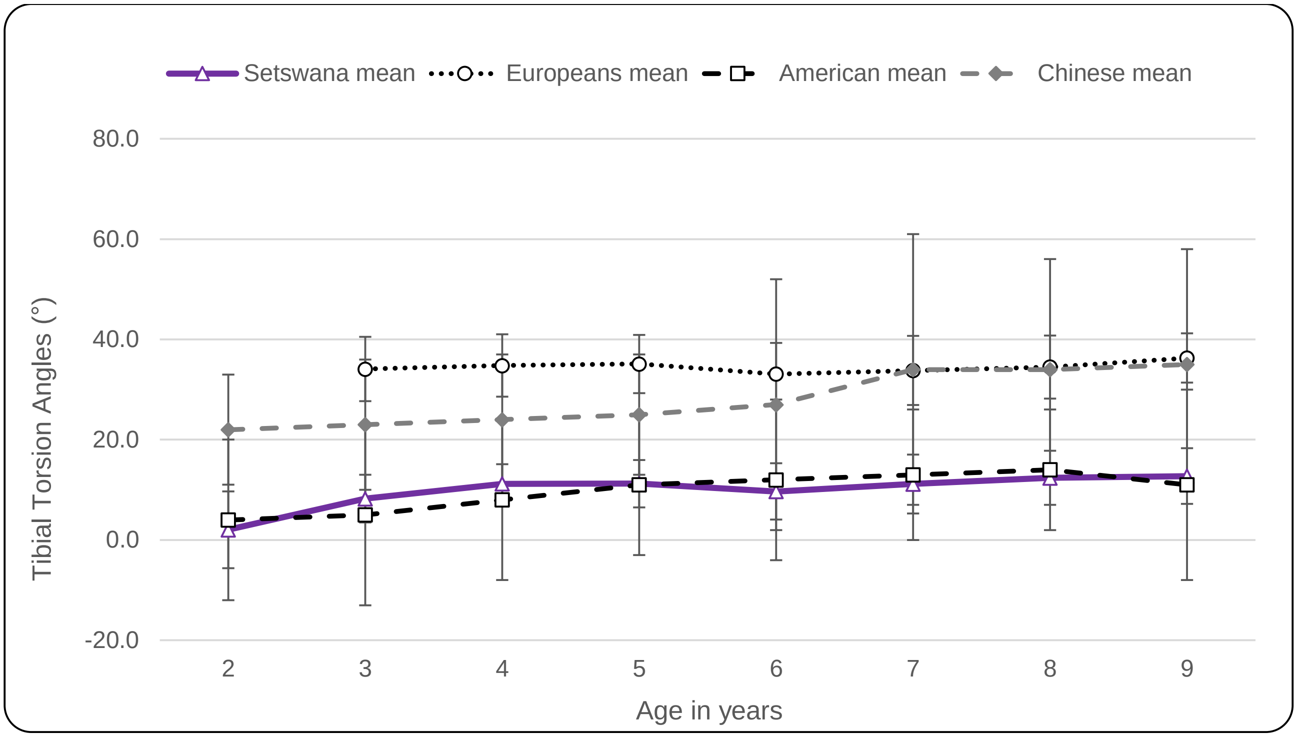
Studies on the development of the Q-angle in young children are lacking. Most of the studies performed on young children utilise small sample sizes which lead to pooling of age groups. This makes a comparison of the Q-angles observed in Setswana-speaking children with children of other ethnicities problematic. The Q-angle became increasingly greater in a valgus direction, with an increase in age, while in Turkish children the Q-angle became increasingly less valgus with an increase in age (Figure 7-2) The discrepancy observed between the two ethnic groups of children is attributed to the younger ages of black Setswana-speaking children measured compared to the Turkish population. It seems plausible that the Q-angle increases with age until adolescence, whereafter it decreases toward adult values.

The development of the AVA in black Setswana children, shows the greatest variation when compared to children of other ethnicities (Figure 7-3). Far greater AVA was found in black Setswana-speaking children than reported in studies performed on European, Chinese and American children. In three-year-old European females, an AVA of 40° ±20° was reported. In a seven-year-old, Norwegian child patient population with known in-toeing, maximal AVA of 42° ±6° was observed. The values obtained for black Setswana-speaking children in this study, border on pathological angles reported by others for children. A decline in the AVA, although marginal, is noted with an increase in age, in black Setswana-speaking children, while in the European children it dramatically decreases with an increase in age, to near adult-like values. It is noteworthy that in this study, increased AVA was found in back-carried children and was also associated with increased internal TTAs. Normally this combination is regarded as torsional malalignment syndrome. When comparing the development of the TTA in black Setswana-speaking children, once again a greater internal TTA is noted than in Chinese- and European children, but compares well with the TTAs found in American children (Figure 7-4). When compared to the internal torsion angles observed in children with torsional malalignments, the black Setswana-speaking group's TTA is normal.



Legend: ° = degrees, Error bars = Standard deviation reported
<u>Comparative reference:</u> European children (Jacquemier et al., 2008:189)

Figure 7-3: Development of the anteversion angle (AVA) in black Setswana-speaking- and European children



Legend: ° = degrees, Error bars = Standard deviation reported
Comparative references:

American children (Staheli et al., 1985:43)
European children (Jacquemier et al., 2008:189)
Chinese children (Cheng et al., 1991:160)

Figure 7-4: Development of tibial torsion angles (TTA) in black Setswana-speaking children compared to European-, American- and Chinese children

Hypothesis Two:

In terms of the tibiofemoral- and quadriceps-angles, significantly greater genu varum angles will be observed in black two- to nine-year-old Setswana-speaking children who were back-carried during infancy and toddler ages than in their black non-back-carried Setswana-speaking peers.

CART analysis for the TFA revealed greater genu valgum in children reportedly always BC. ANOVA showed highly significant groupings for these end nodes at $F(5, 690)=7.215$, $p<0.001$. The greatest valgus TFA mean was observed in three-year-old children who were always BC (-5.98° ± 2.14°, $\eta^2=0.002$). Partial eta-squared (η^2) is the calculated effect size and an effect size of 0.002 means the effect size is very small and not worth mentioning. Similarly, the CART analysis for IMD revealed highly significant groupings for the end nodes at $F(13, 689)=17.685$, $p<0.001$. For younger children (two- and four-year-olds), more frequent BC was associated with (statistically non-significant) greater valgus distances (-2.21 cm ± 1.54 cm, $\eta^2=0.021$) as opposed to those BC less frequently (-1.99 cm ± 1.48cm, $\eta^2<0.001$). In older children, the CART analysis age groupings made it exceedingly complex to establish definite relationships. Generally, opposite relationships were observed (six- to nine-year-olds) where less frequently BC children had smaller valgus angles (-1.00 cm ± 1.36 cm, η^2<0.001) than children BC more frequently (-0.72 cm ± 0.86 cm η^2<0.001) except children always BC, the relationship was the same as in younger children. In six-year-olds always BC the valgus angle was greater than both those BC less frequently and more frequently (-1.68 cm ± 1.10 cm, η^2=0.007), while the always BC nine-year-olds had smaller valgus distances (-0.85 cm ± 1.33 cm, η^2<0.001). In older children, neutral alignment is expected, and this was corroborated in our findings with small IMDs of the older children and larger IMDs in younger children. No significant relationships or -differences were observed between less frequently BC- and more frequently (always) BC children, leading to the assumption that Q-angles were unaffected by BC. Overall, considering TFA and IMD, virtually no genu varum angles were observed at any point in time, whether BC or non-BC. Based on these results, this hypothesis is **rejected**.

Hypothesis Three:

Both femoral retroversion- and medial tibial torsion angles, will be significantly greater in two- to nine-year-old black Setswana-speaking children who were back-carried between infancy and toddler ages than in their black non-back-carried Setswana-speaking peers.

Terminal nodes of the CART analysis for AVA presented high statistical significance with ANOVA (F(13, 685)=5.075, p<0.001). Smaller AVA was consistently observed in children who were BC more frequently than children BC less frequently. The highest AVA was observed in three-year-olds, who were those BC with their legs wrapped around the mother or carrier's back, for an unspecified frequency to less than average (n=20, AVAmean=79.59°, η^2=0.027). Two- to five-year-olds, BC similarly, had the second-largest AVA mean (n=34, AVAmean=78.64°, η^2=0.033). Six- and nine-year-old children, carried this way, for frequencies more than average to always, signified the smallest AVA (n=58, AVAmean=68.59°, η^2=Redundant). A reduction in AVA with an increase in age was observed. Thus, the AVA is highest in younger children, yet those BC more frequently typically presented with smaller AVA than children BC less frequently. This finding leads to the first section of the hypothesis for AVA being **rejected**. Although smaller AVA means a move toward (closer to) femoral retroversion, the generally high AVA found, is still too far from retroversion of the hip.

The second part of this hypothesis is **accepted,** since greater internal (medial) TTA were observed in children BC more frequently than those BC less frequently. Greater internal TTA (n=35, TTAmean=8.22°, η^2=014) was observed in six-year-old children who were always BC with the legs spread, while greater external TTA was observed in eight- and nine-year-old children who were BC similarly, but for frequencies of less than always (n=45, TTAmean=14.69°, η^2=0.011). The ANOVA for this CART analysis indicated statistical significance ($F(9, 684)$=17.756, $p<0.001$). The greatest internal TTAs were observed in the youngest (two-year-olds), while the second-largest internal TTA was observed in six-year-old children BC always.

Hypothesis Four:

Certain factors will yield significant correlations with deviations of lower limb development, in back-carried black Setswana-speaking children between the ages of two- to nine years.

As mentioned for hypothesis two, children BC more often presented with greater genu valgum (decreased TFA), decreased AVAs and increased medial TTAs, in comparison to those BC less often or not at all. Overall 11 highly significant ($p<0.001$) relationships, between various child-rearing prediction factors and LL development, was discovered. In an attempt to condense and summarise the findings, child age, the most prominent predictor for all of the LL measures is ignored here. Furthermore, only the predictors describing more than 10% of the variance for each dependent variable will be described.

Seven predictor factors for TFA development ($F(12, 690)$=6.750, $p<0.001$) were identified, with swaddling duration explaining 10% of the variance (β=-0.648, p=0.040, R^2=10%), although independent walking age explained less than 10% of the variance, it is worth mentioning here (β=0.400, p=0.22, R^2=9%). Swaddling children for long hours (four- to five hours) led to greatest valgus angles, while longer than five hours of swaddling was associated with smaller valgus angles. Four IMD ($F(7, 688)$=15.098, $p<0.001$) predictor factors were identified of which independent walking age explained 14% of the IMD variance. Similar to TFA development and its association with the commencement of independent walking age, the IMD decreased to closer to neutral angulation in later independent walkers. For the Q-angle ($F(11, 690)$=12.170, $p<0.001$) there were six significant predictors with swaddling duration explaining 13% of the Q-angle variance and BC age explained 10% thereof. The Q-angle and swaddling presented similar associations to swaddling durations as found in the TFA, where maximal Q-angles (most valgus) were seen in those swaddled between two- to five hours, and decreased Q-angles were seen in those swaddled less than two hours or more than five hours. A BC period to an age of four years is associated with maximal valgus Q-angles. In those BC for periods shorter- than, or longer than four years, are associated with less valgus, Q-angles.

In the TP seven AVA predictor factors ($F(13, 685)=7.856$, $p<0.001$) were identified, but all factors were lower than 10%. Being BC with the legs spread was the closest factor ($\beta=-5.661$, $p=0.008$, $R^2=9\%$) where AVA decreased with an increase in BC frequency. BC frequencies of less than often were associated with greater hip AV means. The six TTA predictor factors ($F(10, 684)=17.029$, $p<0.001$) which were found all had variances were much lower than 10% and are thus not discussed here. Based on the above results, the hypothesis is **accepted**.

Hypothesis Five:

There will be conclusive evidence for differences between the kinematic gait patterns of seven- to nine-year-old black Setswana-speaking children that were back-carried, compared to their black Setswana-speaking not back-carried peers.

In the comparisons of heel-strike (H-S) in all three planes, the observed data supported the H_0, which postulates the absence of differences between H-S patterns of BC and non-BC children. This is still inconclusive evidence due to the Bayesian factor (BF) reaching values above 1 and below 3. For mid-stance (M-S) in the sagittal- and FP the H_1 is, with the BF above 0.33. The H_0 was supported in the TP, but since the BF was below 3, it means results for M-S observations were inconclusive too. Toe-off (T-O) in the SP and TP, yielded a BF below 3 in support of the H_0, whereas data for the FP supported the H_1, although the BF was above 0.33. Overall this means inconclusive evidence for either H_0 or H_1 was found and the TFJ angles of BC children do not differ from those in non-BC children. The observed data is similarily likely under H_0 and H_1, thus the answer to the fifth hypothesis is **inconclusive**.

Based on the findings from the hypotheses testing it is clear that overall, the LL measures observed statically, differ from the overall dynamic observations. No genu varum was found in BC children as hypothesised, instead, greater genu valgum was associated with BC practices in the FP. The researchers of this study argue that greater valgus forces are applied to the knee, simultaneously with internal TT forces, by the blanket used to secure the infant or child to the mother's back, during BC. As a result, the increased valgus forces applied, contribute to greater genu valgum and greater internal TT. Normally, greater AVA are associated with increased external TT angles. Although a decrease in the AVA was observed with both an increase in age and an increased BC frequency, the AVA was still high in the black Setswana-speaking population, in comparison to other studies.

In terms of psychomotor development and child-rearing factors associated with LL development; swaddling duration and independent walking ages affected FP development at the TFA, IMD, and Q-angle, while BC with the legs spread affected the AVA in the TP. Swaddling for long periods has been found by others to be detrimental to hip development and one of the causes of DDH. Four-hour swaddling durations were associated with maximal genu valgum angles. Longer than four-hour swaddling durations were associated with slightly greater valgus angles than shorter than four-hour swaddling durations. It is expected that infants, who also have the greatest genu valgus angles, would be swaddled for the longest durations, due to constant applied valgus forces at the hip and knee. This explains the association between lower valgus angles in those swaddled for longer durations. Older infants, start to progress toward greater valgus angles and are less likely to be swaddled for increased durations. Functional bone adaptation as guided by Wolff's law is greatest at this age, whereby bone adapts due to forces applied and their activity or then inactivity levels. Independent walking age was also associated with TFA development. As the age of independent walking increased (very early to normal range), the TFA increased and became less valgus. This is in agreement with observations that younger independent walkers are at greater risk to develop infantile Blount's disease. In those who started walking at 12 months or later, greater valgus TFA angles were found.

A BC period to an age of four is associated with maximal valgus Q-angles, shorter- or longer BC periods, are associated with decreased, less valgus, Q-angles. Reasons for this finding is speculative, but possibly linked to underestimations of BC periods by guardians and parents for the four-year age group. Previously a link between Q-angles below 15° and femoral retroversion has been found, and although AVA decreased in children who were BC often, these angles were still far from femoral retroversion. Two- to five-hour swaddling durations were associated with maximal Q-angles in a valgus direction while the angle became less valgus as it decreased with an increase in the swaddling duration. Increased valgus angulations at the knee were found in both swaddling and BC. The absolute LL positions differ greatly in swaddling and BC, yet the blankets used in swaddling and BC increases the applied valgus forces at the knee (Golding, 1994:181). Factors that may influence development is sitting-position and muscle tone and –length, but these were not assessed. Sitting with the legs in a "W" position, place the tibia in external torsion which in turn potentially predisposes the knees toward excessive valgus angulation. This sitting position was not included in the questionnaire, and could potentially be a co-factor contributing to the large amount of genu valgum found in this study. In addition, muscle tone, -strength and –length might affect both static and dynamic LL development. For instance, as quadriceps muscles develop in strength, the Q-angle steadily decreases and in turn, affects the static and dynamic Q-angle. The kinematic analysis rendered inconclusive results and contrary to the expectation, no kinematic gait differences were found between BC and non-BC children. Motion patterns in the paediatric population show great inter-individual- and age-related variability, especially in younger (one- to four-year-old) children. Kinematic gait matures due to the improvement of neuromuscular control and maturity.

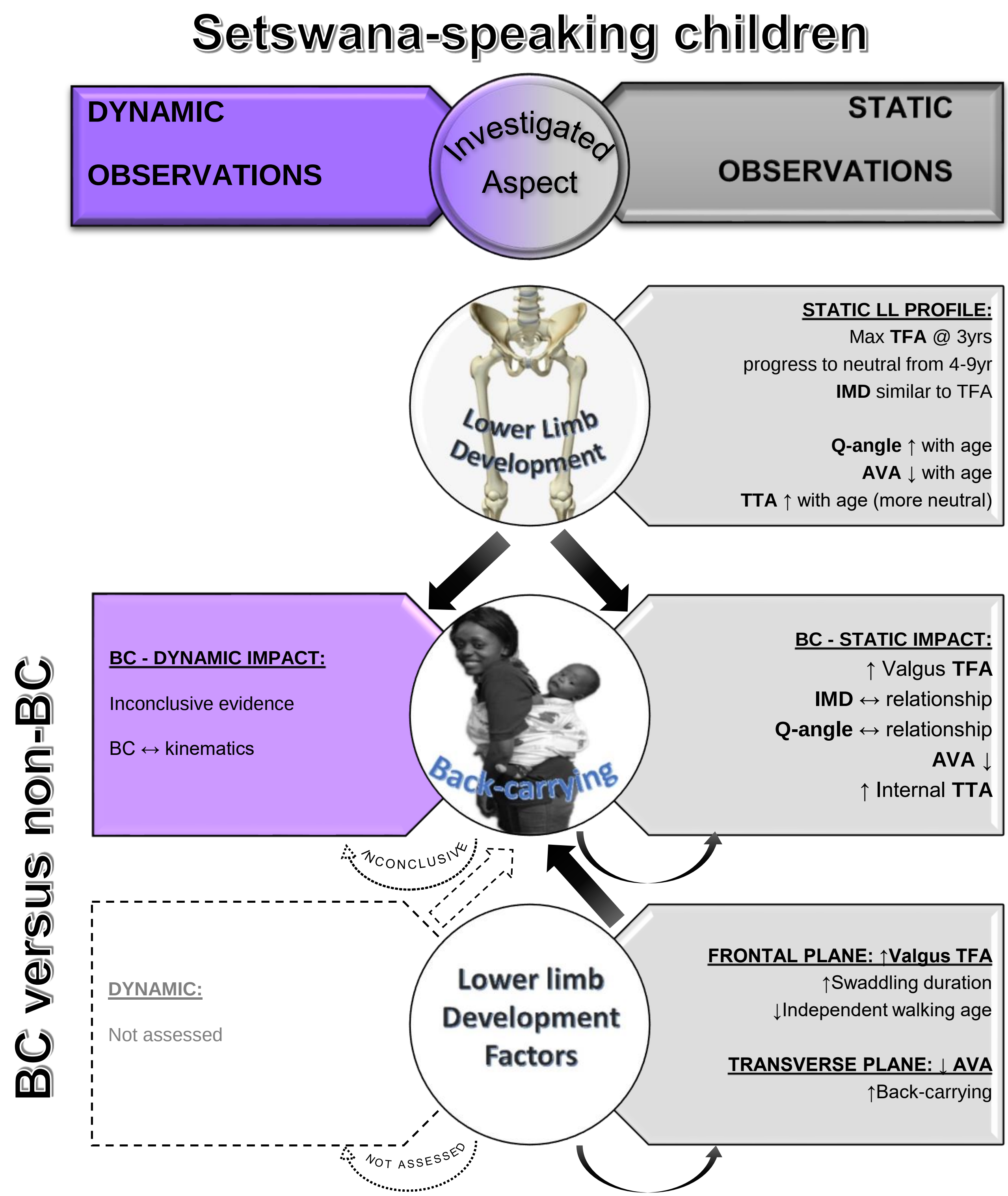
Therefore, the answer to the first posed research question: *"What is the impact of back-carrying on the development of the lower limb of the child at the hip, knee, and ankle?"* is there is a minimal static impact, rendering genu valgum in BC children, which remain within normative values. The answer to the second posed research question: *"What is the kinematic gait differences at the tibiofemoral joint, between back-carried children and non-back-carried children?",* is inconclusive.

7.4. CONTRIBUTION TO CURRENT KNOWLEDGE

The findings from this study give a clear indication of the LL development in black Setswana-speaking children, which can now be applied by medical professionals. The profiles developed for static LL development were lacking for this population and necessary. The population-specific profiles were required in order to avoid unnecessary intervention applications, such as orthotics. Thus, should the medical professional apply the norms set for children of other ethnicities, the intervention may have been unnecessary. This is the first study to describe LL developmet for the black Setswana-speaking population and from the findings and it is clear that this population have a slightly different LL development patterns compared to other ethnic groups. As is illustrated in Figure 7-5, the contribution of this study to the current knowledge indicates that static LL development of the TFA and IMD is maximal at three years of age and progresses to neutral between four- to nine years of age. Q-angles and the TTA increase with age, while the AVA decreases with age. The main finding of the study is that BC contributes to the development of genu valgum and not the postulated genu varum. When children are BC more frequently, they present with greater valgus TFAs and internal TTAs and decreased AVAs, while the IMD and Q-angle remain unchanged. In terms of psychomotor factors affecting LL development, increased swaddling durations and earlier independent walking is associated with greater valgus TFAs and increased BC is associated with decreased AVAs. Furthermore, kinematic gait patterns at the TFJ do not differ between BC and non-BC children. Thus, although BC shows several associations with static LL measures, it does not hold true in dynamic TFJ movement. Finally, no kinematic gait differences exist between BC- and non-BC children, which is why the psychomotor factors (such as commencement of independent walking age and carrying methods) which could theoretically influence gait kinematics, were not investigated.

Based on the results presented, the following reflections and recommendations in terms of psychomotor behaviors and LL development are pertinent. Self-reported time spent BC children may be a significant source of bias in this study. Recall bias is a strong possibility, especially in chronologically older caregivers (such as the grandparents) of the children. Culturally, it is very common for the grandparents of black Setswana-speaking individuals, to take care and rear their grandchildren, rather than the child's mother and father. It is easy to "get carried away" (pun intended) for a parent when performing housework, and time goes past without notice. The cultural Batswana way for a parent with young infants or children is to back-carry them, while they perform their house chores. The parent might have perceived themselves as for argument sake, only spending mornings performing house chores (thus approximately three- to four hours), but in actual fact, they may have spent more than just the morning performing house chores, and thus back-carry (BC) their child or infant.

The researchers suggest that parents should not swaddle their child for durations longer than four hours per day, to avoid the association with increased genu valgum development. As parents, there is not much to be done about the attainment of independent walking ages in children. Children develop in their own time. The only suggestion to parents would be, to not try to force earlier independent walking, as this was associated with infantile Blount's disease by previous studies. Clearly, the LL forms part of the kinetic chain and what happens at the hip, affects the knee and ultimately the ankle. More frequent BC shows relationships with increases in genu valgum, however, the angles observed in the FP are still within normal ranges. Overall great AVAs were observed in the black Setswana-speaking population and BC was associated with a decrease in the AVA and an increase in the TTA. Although TTA were still lower than for European children, it corresponds with the angles observed in American children. The static angles did not differ significantly between the BC and non-BC sample, who participated in the kinematic investigation, nor was evidence found for differences in TFJ angles during gait. Based on the abovementioned, from an orthopaedic LL perspective, BC is accepted and no education is required in changing behaviors of mothers and caregivers.



Legend: AVA = anteversion angle, BC = back-carrying, DDH = developmental dysplasia of the hip, ICD = intercondylar distance, IMD = intermalleolar distance, LL = lower limb, non-BC = non-back-carried, Q-angle = quadriceps-angle, TFA = tibiofemoral angle, TTA = tibial torsion angle

Figure 7-5: Influence of back-carrying (BC) on the development of the lower limb (LL)

7.5. LIMITATIONS AND RECOMMENDATIONS

Although this study is the first to investigate and show various associations between static- and dynamic LL development in black Setswana-speaking children, the results should be interpreted against the background of the limitations experienced.

- **Limitation:** The sample obtained was not random, but rather based on the willingness of schools to participate and the number of black Setswana-speaking children attending the various schools.
  - **Recommendation:** Stratified random sampling of schools, from a larger area, would be more convincing in terms of approximation results to the whole population. .
- **Limitation:** Field tests were applied to measure the LL characteristics.
  - **Recommendation:** *Magnetic Resonance Imaging* (MRI)- or *Computed Tomography* (CT) scan- or radiographic studies should be incorporated to confirm clinical measures. When performing very large investigations, smaller random samples from the larger participant pool can be screened with a radiographic measure to determine measurement reliability.
- **Limitation:** The cross-sectional study design and recall bias is a potential downfall in the collection of milestone attainment data from older primary caregivers.
  - **Recommendation:** Consider following children's development longitudinally, assess them from birth at six-month intervals and continuously ask parents to provide feedback regarding psychomotor development factors, milestone attainment, and rearing practices.
- **Limitation:** The sample obtained for the kinematic investigation was limited by the number of non-BC children available in the seven- to nine-year-old participant pool. The BC sample was chosen randomly to allow equal numbers per age group and equal numbers of males and females per age group. BC frequencies were not considered during the random selection.
  - **Recommendation:** Inclusion of more frequently BC children, rather than the inclusion of any BC frequencies might render greater discrepancy between the groups.

7.6. FUTURE RESEARCH

Although this study was the first to provide information on the development of the LL in black Setswana-speaking children, future studies should consider to investigate the following: Firstly, how will different BC and front-carrying positions affect the attainment of crawling motor milestones? Secondly, how will smaller hip abduction angles (such as during front-carrying) be more conducive toward crawling, or are larger angles of hip abduction (such as during typical BC) more conducive? Such a study should still consider the durations of babywearing along with whether the babywearing or –carrying is intermittent or continuous in nature.

The two studies on cognition and peripheral vision in BC children were the only ones found for BC effects on child development (Pretorius *et al.*, 2002a; Pretorius *et al.*, 2002b). and included relatively small sample sizes, thus future researchers could repeat similar studies on larger sample sizes. Furthermore, it should be determined if there exists a dose-response between BC duration and school readiness, peripheral vision, and cognition? The typical African or Setswana mother is not likely to stop the practice of BC, since it is so convenient and economic to them, hence it should be investigated whether the detrimental effects of BC could be counteracted by exercises or games performed by the child, once they are not on the mother's back anymore, either through daily exercises in-between BC episodes, or then only once the child is older and not BC at all anymore.

Based on the findings that peripheral vision, fine motor skills, midline-crossing skills and ultimately cognition is impaired in BC children, the question is whether intervention in the form of gross motor exercises will eliminate or at least reduce the detrimental effects of BC on cognition? Furthermore, it should be determined if there is a difference in the application of the intervention gross motor exercises, applied at an earlier age in comparison to at a later age.

Although a relatively large sample size was included in this study, we were only able to investigate children between the ages of two- to nine years of age, in a cross-sectional design study. Future researchers should consider performing a longitudinal study and follow their sample until the age of at least 18 years, when skeletal growth and maturation is nearly complete. This is important as very few cases of genu varum (none excessive) were observed in this study after the age of five years. Previous studies have found that after the age of 14 years, did males start to present a substantial decrease in their valgus angle and by 16 years of age the males presented with greater genu varum angles ("*were more bow-legged*") than females. When performing these studies, careful attention should be paid to sport participation, since an association has been shown between specifically soccer participation and genu varum.

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APPENDIX A: ETHICAL APPROVAL

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Web: http://www.nwu.ac.za

Research Ethics Regulatory Committee
Tel: +27 18 299 4849
Email : Ethics@nwu.ac.za

ETHICS APPROVAL CERTIFICATE OF STUDY

Based on approval by **Health Research Ethics Committee (HREC)** on 04/12/2017, the North-West University Research Ethics Regulatory Committee (NWU-RERC) hereby **approves** your study as indicated below. This implies that the NWU-RERC grants its permission that provided the special conditions specified below are met and pending any other authorisation that may be necessary, the study may be initiated, using the ethics number below.

Study title: **The development of *genu varum* and the tibiofemoral joint profile in back-carried Setswana children**

Study Leader/Supervisor: Dr SH Czyż
Student: M van Aswegen-20383800

Ethics number:

N	W	U	-	0	0	0	8	4	-	1	7	-	A	1
Institution				Study Number						Year			Status	

Status: S = Submission; R = Re-Submission; P = Provisional Authorisation; A = Authorisation

Application Type: Single study
Commencement date: 17/08/2017
Risk: 2. Greater than Minimal

Approval of the study is initially provided for a year, after which continuation of the study is dependent on receipt of the annual (or as otherwise stipulated) monitoring report and the concomitant issuing of a letter of continuation.

General conditions:

While this ethics approval is subject to all declarations, undertakings and agreements incorporated and signed in the application form, please note the following:

- *The study leader (principle investigator) must report in the prescribed format to the NWU-RERC via HREC:*
  - *annually (or as otherwise requested) on the monitoring of the study, and upon completion of the study*
  - *without any delay in case of any adverse event or incident (or any matter that interrupts sound ethical principles) during the course of the study.*
- *Annually a number of studies may be randomly selected for an external audit.*
- *The approval applies strictly to the proposal as stipulated in the application form. Should any changes to the proposal be deemed necessary during the course of the study, the study leader must apply for approval of these amendments at the HREC, prior to implementation. Should there be any deviations from the study proposal without the necessary approval of such amendments, the ethics approval is immediately and automatically forfeited.*
- *The date of approval indicates the first date that the study may be started.*
- *In the interest of ethical responsibility the NWU-RERC and HREC retains the right to:*
  - *request access to any information or data at any time during the course or after completion of the study;*
  - *to ask further questions, seek additional information, require further modification or monitor the conduct of your research or the informed consent process.*
  - *withdraw or postpone approval if:*
    - *any unethical principles or practices of the study are revealed or suspected,*
    - *it becomes apparent that any relevant information was withheld from the HREC or that information has been false or misrepresented,*
    - *the required amendments, annual (or otherwise stipulated) report and reporting of adverse events or incidents was not done in a timely manner and accurately,*
    - *new institutional rules, national legislation or international conventions deem it necessary.*
- *HREC can be contacted for further information or any report templates via Ethics-HRECApply@nwu.ac.za or 018 299 1206.*

The RERC would like to remain at your service as scientist and researcher, and wishes you well with your study. Please do not hesitate to contact the RERC or HREC for any further enquiries or requests for assistance.

Yours sincerely

Prof. Refilwe Phaswana-Mafuya
Chair NWU Research Ethics Regulatory Committee (RERC)

APPENDIX B: PROOF OF LANGUAGE EDITING

NELDA MOUTON (BA, HONS (ENGLISH)), MASTERS (ENGLISH),

PHD (ENGLISH LITERATURE)

PHD (EDUCATION MANAGEMENT)

Language Services

Hattingh street 3G

Declaration

This is to declare that I, Nelda Mouton, have edited the study by

Mariaan van Aswegen

20383800

with the title

Lower limb development and gait kinematics of back-carried Setswana children

22 November 2019

NELDA MOUTON DATE

APPENDIX C: INFORMED CONSENT DOCUMENTS

Informed Consent into Clinical Investigation – English Version

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS

Health Research Ethics Committee
Faculty of Health Sciences
NORTH-WEST University
(Potchefstroom Campus)
2017 -12- 06
HREC Stamp

INFORMED CONSENT DOCUMENTATION FOR YOUR CHILD'S PARTICIPATION IN A RESEARCH STUDY

TITLE OF THE RESEARCH STUDY: The development of genu varum and the tibiofemoral joint profile in back-carried Setswana children.

ETHICS REFERENCE NUMBERS: NWU – 00094-17-A1

PRINCIPAL INVESTIGATOR: Dr. Stanislaw Czyz

POST GRADUATE STUDENT: Mrs Mariaan van Aswegen

ADDRESS:
Mail: North-West University, Private Bag X6001, 2520, Potchefstroom, North West Province, South Africa; Internal box #481
Physical address: PhASRec, building K3, 1st floor, room 111; Fanie du Troit Sports Field; C/o Thabo Mbeki & Meyer Street, Potchefstroom (Die Built); 2531; North West Province; South Africa
Email: stanislaw.czyz@nwu.ac.za

CONTACT NUMBER: (018) 285 2625

You are being invited to take part in a **research study** that forms part of my Doctoral degree in Human Movement Science. Please take some time to read the information presented here, which will explain the details of this study. Please ask the researcher or person explaining the research to you any questions about any part of this study that you do not fully understand. It is very important that you are fully satisfied that you clearly understand what this research is about and how your child might be involved. Also, your child's participation is **entirely voluntary** and you are free to say no to participate. If you say no, this will not affect you or your child negatively in any way whatsoever. You are also free to withdraw from the study at any point, even if you do agree to take part now.

This study has been approved by the **Health Research Ethics Committee of the Faculty of Health Sciences of the North-West University (NWU-00094-17-A1)** and will be conducted according to the ethical guidelines and principles of Ethics in Health Research: Principles, Processes and Structures (DoH, 2015) and other international ethical guidelines applicable to this study. It might be necessary for the research ethics committee members or other relevant people to inspect the research records.

What is this research study all about?

- *This study will be conducted at crèches and Primary schools in Ikageng and Potchefstroom, in a private and secure room at the school and will involve the primary caregiver of the child (person who looks after the child for most of the day) to complete a questionnaire. Experienced health researchers, trained in Biokinetics, will measure your child's knee-angles at their school. 400 participants will be included in this study.*
- *We plan to investigate how knee development occurs in Setswana children, between the ages of 2 to 9 years of age. From there we are going to investigate if there is a relationship between back-carrying of children and their knee development. Should we find a relationship, we are going to investigate which factors contribute to making it worse (or better). Lastly we are going to compare the walking patterns of back-carried children, to the walking patterns of non-back-carried children in a secondary study to which your child may be invited later.*

Why has your child been invited to participate?

- *Your child has been invited to be part of this research because your child is between the ages of 2 to 9 years, and your child is a black, Setswana speaking individual.*
- *Your child also fit the research because he/she is healthy and can walk unassisted.*
- *Your child was or wasn't carried on the primary caregiver's back when he/she was an infant or toddler.*
- *Your child has (or doesn't have) hip joint problems (developmental dysplasia of the hip).*

- *Your child will not be able to take part in this research if he/she cannot walk unassisted, is non-Setswana or of any other ethnicity.*
- *If your child is younger than 2 years old, or older than 9 years.*
- *If your child has any known bone-, muscle-, nerve- or ligament disorders, except for hip joint problems (developmental dysplasia of the hip).*
- *If your child or direct family members (mother, father, brother/sister, grandfather/grandmother) has a known disorder such as bone joint problems (skeletal dysplasia), brain injury before or at birth (cerebral palsy), foot deformities and or calcium-, iron-, vitamin D- deficiencies (metabolic diseases such as Rickets)*

What will be expected of you?

- *You will be expected to ask the primary care giver (person who takes care of the child for most hours of the day, e.g the nanny, grandmother, mother or aunt), to complete the attached questionnaire. The completed questionnaire must then be sent back to school with your child in the envelope provided. We request the contact information of the primary care giver to appear on the separate information sheet. This is necessary should the researcher want to confirm answers, or to allow the researcher to contact the care giver if there is missing information. Please make sure that no one's name or contact details appear on the* *questionnaire itself, as this will ensure anonymity. Once the researchers are satisfied with the information provided on the questionnaire, we will destroy the contact detail information.*

- *The researchers will visit your child's school/crèche on a day suited to them, in a private room or venue on the school premises. Your child will be brought to the room where they will be asked to remove their shoes and socks. Two researchers will do four measurements on the child including; height and weight, 8 tests to determine the knee angle, 2 tests to determine rotation of the thigh bone, a test to measure rotation of the lower leg and a test to determine leg lengths. These measurements will not cause them any physical or emotional harm and should not take longer than 30 minutes. Photographs will be taken of your child's legs to supplement our investigation. His/Her face will not appear on the photograph.*
- *Whilst the clinical investigation is underway, the 3rd researcher will go through the questionnaire, making sure there aren't any missing information. This researcher will then contact the primary care giver telephonically to complete any missing information, if necessary. Once the researcher is satisfied with the information, they will destroy the primary care giver's contact details form.*

Will you or your child gain anything from taking part in this research?

- *The gains for you if you take part in this study will be that the clinical investigation will be done free of charge and you will receive a report on your child's knee angles in the form of a general information leaflet about knee angles. These assessments normally cost between R400 to R500, but we will conduct it free of charge.*
- *The other gains of the study is toward the Setswana community in the knowledge that we will gain as to the development of Setswana children's knee angles and whether or not back-carrying affects the development of their knees. This knowledge will enable us to provide guidelines to child care givers on how to best carry a child on the back, and the duration that is best to do so.*

Are there risks involved in you taking part in this research and what will be done to prevent them?

- *There are no conceivable risks in your child's participation in this study, other than the risks associated with activities of daily living and walking.*
- *The clinical investigation will be done in a safe, secure and private room on the school premises. Your child will not suffer any bodily harm or injustice, however if he/she perceives any discomfort at any point in time, he/she should tell the researchers.*
- *If your child requires it, we will stop all tests and he/she may withdraw from the study and return to their classroom.*
- *The teacher or another third party will be present to observe that the clinical investigation is performed in an appropriate way.*
- *If you as parent or guardian choose to be present during the investigation, you are most welcome.*
- *The gains of your child participating in this study, outweighs the risk.*

How will we protect your and your child's confidentiality and who will see your findings?

- *Anonymity of your child's findings will be protected by assigning a numbered code to each child, which is only known to the researcher, your child's name will not appear on any documentation. Only the researchers will be able to look at your child's findings. Findings will be kept safe by locking hard copies in locked cupboards in the researcher's office and electronic data will be password protected. (As soon as data has been analysed it will be deleted from the recorders.) Data will be stored for 7years.*

What will happen with the findings?

- *The findings of this study will be used for this study and subsequent or secondary studies to build and support our knowledge on back-carrying practices and knee development. The anonymised data will be analysed in South Africa by the investigators and statisticians, if necessary.*

How will you know about the results of this research?

- *We will give you the results of this research once analysis has been completed by the end of 2018.*
- *You will be informed of any new relevant findings through information leaflets that will be distributed at your child's school or crèche.*

Will you or your child be paid to take part in this study and are there any costs for you?

No, you or your child will not be paid to participate in this study, but refreshments will be available to your child after their clinical investigation was completed at school.
There will be no monetary cost to you, should you agree to participate.
There will be some disruption of your child's school curricular activities, but we will do our very best to limit this and the inconvenience posed to your child's teacher(s).

Is there anything else that you should know or do?

- You can contact Mrs Mariaan van Aswegen at +27 18-389 2897 if you have any further questions or have any problems.
- You can also contact the Health Research Ethics Committee via Mrs Carolien van Zyl at 018 299 1206 or carolien.vanzyl@nwu.ac.za if you have any concerns that were not answered about the research or if you have complaints about the research.
- You will receive a copy of this information and consent form for your own purposes.

Declaration by participant

By signing below, I (parent/guardian's name and surname)_______________________________________ agree to allow my child (name and surname)_______________________________________ to take part in the research study titled: The tibiofemoral angle profile and development of genu varum in back-carried Setswana children.

I declare that:

- I have read this information/it was explained to me by a trusted person in a language with which I am fluent and comfortable.
- The research was clearly explained to me.
- I have had a chance to ask questions to both the person getting the consent from me, as well as the researcher and all my questions have been answered.
- I understand that taking part in this study is **voluntary** and my child and I have not been pressurised to take part.
- My child and I may choose to leave the study at any time and will not be handled in a negative way if we do so.
- I give permission for the tests to be performed on my child, and for photographs to be taken of my child.
- I may be asked to leave the study before it has finished, if the researcher feels it is in the best interest, or if I do not follow the study plan, as agreed to.

Signed at (*place*) ______________________________ on (*date*) ___________ 20__

_________________________________......   _________________________
Signature of participant   **Signature of witness**

Declaration by person obtaining consent

I *(name)* ___________________________________ declare that:

- I clearly and in detail explained the information in this document to ____
- I did/did not use an interpreter.
- I encouraged him/her to ask questions and took adequate time to answer them.
- I am satisfied that he/she adequately understands all aspects of the research, as discussed above
- I gave him/her time to discuss it with others if he/she wished to do so.

Signed at (*place*) ___________________________ on (*date*) ____________ 20__

____________________________________ ___________________________
Signature of person obtaining consent   **Signature of witness**

Declaration by researcher

I *(name)* ___________________________________ declare that:

- I explained the information in this document to ________________________
- I did/did not use an interpreter
- I encouraged him/her to ask questions and I was available should he/she want to ask any further questions.
- The informed consent was obtained by an independent person.
- I am satisfied that he/she adequately understands all aspects of the research, as described above.
- I am satisfied that he/she had time to discuss it with others if he/she wished to do so.

Signed at (*place*) __________________________ on (*date*) ___________ 20__

_______________________________...... ______________________

Signature of researcher **Signature of witness**

Informed Consent into Clinical Investigation – Setswana Version

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS

Health Research Ethics Committee
Faculty of Health Sciences
NORTH-WEST University
(Potchefstroom Campus)
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TOKOMANE YA KITSISO YA MAITLAMO YA BOTSAYAKAROLO JWA NGWANA WA GAGO MO THUTONG YA PATLISISO

SETLHOGO SA PATLISISO: Tlhabololo ya porofaele ya digoro le tokololo ya lengole mo go belegeng bana ba Batswana

NOMORO KAELO YA MAITSHOLO: NWU-00094-17-A1
MOTLHOTLHOMISIMOGOLO: Dr. Stanislaw Czyz
MOITHUTI WA THUTO E KGOLWANE: Mrs Mariaan van Aswegen

ATERESE
Romela ka Poso: North-West University, Private Bag X6001, 2520, Potchefstroom, North West Province, South Africa; Internal box #481
Aterese ya mogae: PhASRec, building K3, 1st floor, room 111; Fanie du Troit Sports Field; C/o Thabo Mbeki & Meyer Street, Potchefstroom (Die Built); 2531; North West Province; South Africa
Imeile: stanislaw.czyz@nwu.ac.za
NOMORO IKGOLAGANYO: (018) 285 2625

O lalediwa go tsaya karolo mo thutong ya patlisiso e e leng karolo ya dikirii ya me ya Bongaka mo Saeseng ya Motsamao ya Setho. Ka kopo tsaya nako go buisa tshedimosetso e e tlhagisitsweng fa, e e tlaa tlhalosang ka botlalo ka ga thuto e. Ka kopo botsa potso nngwe le nngwe ka ga karolo nngwe le nngwe e o sa e tlhaloganyeng ka botlalo mabapi le thuto e go mmatlisisi kgotsa mongwe yo o e tlhalosang. Go botlhokwa gore o tlhaloganye gore patlisiso e bua ka ga eng le gore ngwana wa gago o ya go amega jang. Gape, itse fa ngwana wa gago a ithaopa mme o letleletswe go ka gana. Fa o gana se ga se ne se go ama, wena le ngwana wa gago ka mokgwa mongwe o o sa siamang. O letleletswe gape go ka ikgogela morago le fa o ne o setse o dumetse go ka tsaya karolo jaanong.

Thuto e e dumeletswe semmuso ke Komiti ya Boitekanelo ya Patlisiso ya Maitsholo ya Legoro la Disaense ya Boitekanelo ya Yunibesithi ya Bokone Bophirima (NWU-00094-17-A1.) e tlaa dirwa go ya ka ditsamaiso le mekgwa ya Maitsholo mo Patlisisong ya Boitekanelo: Ditheo, Tirego le Dipopego (DoH, 2015) le tsamaiso ya maitsholo a boditšhabatšhaba a a maleba mo thutong e. Go ka nna botlhokwa fa maloko a komiti ya maitsholo kgotsa batho ba ba maleba go tlhatlhoba direkoto tsa patlisiso.

Patlisiso ya thuto e e ka ga eng??

- *Thuto e e tlaa dirwa mo dikheretšheng le dikolopotlana tsa Ikgageng le Potchefstroom, mo phaposing e e kgethegileng e bile e bolokesegile mo sekolo mme e tlaa akaretsa motlhokomedimogolo wa ngwana (motho yo a tlhokometseng ngwana letsatsi lotlhe) go tlatsa potsolotso. Babatlisisi ba ba itekanetseng ba na le maitemogelo, ba katisitswe mo thutong ya go dirisa motsamao, ba tlaa meta tshokamo ya mangole kwa sekolong sa bona. Batsayakarolo ba le 400 ba tlaa dirisiwa mo thutong e.*
- *Re rulaganya go tlhotlhomisa gore tlhabololo ya lengole e diragala jang mo baneng ba Batswana, ba bogolo ba magareng a dingwaga di le 2 go ya go 9. Go tlhoga foo re tlaa tlhotlhomisa fa go na le kgolagano magareng go belegega bana le tlhabololo ya mangwele a bona. Fa re ka fitlhela kgolagano, re tlaa tlhotlhomisa gore ke dintlha dife tse di dirang gore a nne maswe (kgotsa botoka). Sa bofelo re tlaa tshwantshanya dielo tsa metsamao ya bana ba ba belegwang go dielo tsa metsamao ya bana ba ba sa belegweng mo thutong e kgolwane e ngwana wa gago a tlaa lalediwang moragonyana.*

Goreng ngwana wa gago a lalediwa go tsaya karolo?

- *Ngwana wa gago o laleditswe go tsaya karolo mo thutong e gonne a le magareng a dingwaga di le 2 go ya go 9, gape ngwana wa gago ke montsho yo o buang Setswana ka boena.*
- *Ngwana wa gago o lekanetse thuto e gonne a itekanetse e bile a sa tlhoke thuso fa a tsamaya.*
- *Ngwana wa gago o ne a sa belegwe ke motlhokomedimogolo fa e ne e le ngwana kgotsa lesea.*
- *Ngwana wa gago o na (ga ana) mathata a noka (bogole ba letheka)*
- *Ngwana wa gago a ka se tseye karolo mo patlisisong e fa a sa tsamae a tshegediwa, e se Motswana kgotsa merafe e mengwe*
- *Fa ngwana wa gago a kwa tlase ga dingwaga di le 2 kgotsa a feta di le 9.*
- *Fa ngwana wa gago a na le bothata bo bo itsegeng ba marapo, tshika kgotsa mosifa, tshika kwantle ga mathata a noka (bogole ba letheka)*
- *Fa ngwana wa gago kgotsa maloko a losika ka tlhamalalo (mme, rre, nkgonne/kgaitsadi, rremogolo/mmemogolo) ba na le bothata bo bo itsegeng jaaka mathata a tokololo ya lerapo, bogole ba marapo), kgobalo ya tlhaloganyo pele kgotsa ka nako ya pelegi (go swa mfama), leoto le le sa tshwaneng le kgotsa tlhaelo ya khalisiamo, mooko, dikotla tsa D (malwetse a go nyemetlhana jaaka digoro)*

Go solofelwa eng mo go wena?

- *Go solofelwa go botsa motlhokomedimogolo (motho yo o tlhokomelang ngwana bontsi jwa nako, sekao- mmelegi, mmemogolo, mme kgotsa rakgadi) go tlatsa dipotsolotso tse di momaganyedisweng. Potsolotso e e tladitsweng e ka busetswa kwa sekolong ka ngwana wa gago e le mo enfelopong e o e neetsweng.re kopa dintlha tsa go ikgolaganya le motlhokomedimogolo mo letlhareng le le arogantsweng la kitsiso. Se se botlhokwa gore fa mmatlisisi a batla go netefatsa dikarabo, kgotsa go letla mmatlisisi go ikgolaganya le motlhokomedimogolo fa go na le dintlha tse di tlogetsweng. Ka kopo netefatsa gore go se tlhagelele ka gope leina kgotsa dintlha tsa kgolagano mo potsolotsong, jaaka se se netefatsa go sa itsiwe. Fa mmatlisisi a kgotsofetse ka kitsiso e e neetsweng mo potsolotsong re tlaa tlosa dintlha tsa kitso tsa kgolagano.*

- *Mmatlisisi o tlaa etela sekolo/kheretšhe ya ngwana wa gago ka letsatsi le le ba siametseng, mo phaposing e e kgethegileng kgotsa lefelo mo dikagong tsa sekolo. Ngwana wa gago o tlaa tsenngwa mo phaposing e batlaa kopiwang go rola ditlhako le dikousu. Babatlisisi ba babedi ba tlaa ba meta gane go akaretsa bogodimo le boima, diteko di le 8 go tlhomamisa tshokamo ya lengole, diteko tse pedi go tlhomamisa go tikologo ya lerapo la serope, teko go meta tikologo ya leoto kwa tlase le teko ya go tlhomamisa boleele ba leoto. Meto o ga o ne o utlwisa ngwana botlhoko go ya ka mmele le maikutlo e bile o ka se fete metsotso e le 30. Ditshwantsho di tlaa tsewa go oketsa tlhotlhomiso ya rona. Sefatlhego sa gagwe ga se ne se tlhagelela mo setshwantshong.*
- Fa tlhotlhomiso ya kalafi e ntse e tsweletse, mmatlisisi wa boraro o tlaa tlhatlhoba potsolotso, go netefatsa fa go sa tlogelwa sepe. Mmatlisisi yo o tlaa ikgolaganya le motlhokomedimogolo ka mogala go tlaleletsa tshedimosetso e e tlogetsweng, fa go tlokega. Fa fela mmatlisisi a kgotsofetse ka tshedimosetso, ba tlaa phimola dintlha tsotlhe tsa kgolagano mo foromo ya motlhokomedimogolo

A wena kgotsa ngwana wa gago le tlaa boelwa ke sengwe go tswa mo go tseyeng karolo mo thutong e?

- *Poelo ya gago mo go tseyeng karolo ke gore tlhotlhomiso ya kalafi e tlaa dirwa ntle le tuelo mme o tlaa amogela pegelo ka ga ditshokamo tsa mangole a ngwana wa gago ka mokgwa tshedimosetso ya kakaretso ya pampitshana ka ga tshokamo ya mangole. Ditlhatlhobo tsegantsi di duela magareng a R400 – R500, mme rona re tlaa di dira ntle le tuelo.*
- *Poelo e nngwe gape ya thuto ke ya gore baagi ba Batswana ba tlaa nna le kitso ka ga tlhabololo ya tshokamo ya mangole a bana ba Batswana lefa kgotsa go sa belege go sa ame tlhabololo ya mangole a bona. Kitso e e tlaa thusa go neela dikaelo go batlhokomedi ba ngwana mo gore ba ka belega bana jang mo mekwatleng ya bona, le nako e e siameng ya go dira jalo.*

A go na le go ka tsena mo diphatseng mo go tseyeng karolo mo patlisisong e le gore go ka dirwa eng go di thibela?

- *Ga gona diphatsa dipe tse di akantsweng mo go tseyeng karolo ga ngwana wa gago mo thutong e, kwa ntle ga diphatsa tse di tsamaelanang le ditirwana tsa letsatsi la go phela le go tsamaya.*
- *Tlhotlhomiso ya kalafi e tlaa dirwa mo go bolokesegileng, babalesegile le mo phaposi e e kgethegileng mo dikagong tsa sekolo. Mmele wa ngwana wa gago o ka se utlwisiwe botlhoko kgotsa le go siamololelwa le fa go ka nna jang fa a bona a sa nnisege ka dinako tsotlhe a ka bolelela babatlisisi.*
- *Fa a e kopa, re tlaa emisa ka diteko tsotlhe mme a ka ikgogela morago go tswa mo thutong a boela morago kwa diphaposing tsa bona.*
- *Morutabana kgotsa mongwe wa boraro o tlaa nna teng go lebelela gore tlhotlhomiso ya kalafi e dirwa ka mokgwa o o maleba.*
- *Fa wena o le motsadi kgotsa motlhokomedi o tlhopha go nna teng ka nako ya tlhotlhomiso, o amogetswe.*
- *Dipoelo tsa ngwana wa gago mo go tseyeng karolo mo thutong e, di feta botlhokwa ba go tsena mo diphatseng.*

Re tla sireletsa jang ngwana wa gago le sephiri sa gagwe le gore ke mang yo o tlaa bonang ditshwetso?

- *Tlhokaina la ditshwetso tsa ngwana wa gago le tla sireletswa ka go neela khoutu ya nomore go ngwana mongwe le mongwe yo a itseweng ke mmatlisisi, leina la ngwana wa gago ga le* *kitla le tlhagelela gope mo nngweng ya ditokomane. Ke mmatlisisi fela yo a tla lebelelang ditshwetso tsa ngwana wa gago. Ditshwetso di tla bolokwa ka dipampiri mo kobotlong e e notletsweng mo phaposing ya mmatlisisi le dinewa tsa mafaratlhatlha a thekenoloji di tlaa sireletswa ka pulamolomo. (Fa dinewa di se na go sekwasekwa e tlaa tloswa mo direkotong). Dinewa di tlaa bolokwa mo nakong ya dingwaga di le 7.*

Go tlaa diragalang ka ditshwetso?

- *Ditshwetso tsa thuto e di tla dirisiwa mo thutong e gape morago ga moo kgotsa dithuto tse kgolwane go aga le go tshegetsa kitso ya rona mo tirisong ya go belega bana ka fa morago le tlhabololo ya lengole. Dinewa tse di sa bontshiwang di tlaa sekwasekwa mo Aforikaborwa ke motlhotlhomisi le baitseanape wa dipalo, fa go tlhokega.*

O tla itse jang ka ga dipholo tsa patlisiso e?

- *Re tla go neela dipholo tsa patlisiso e fa fela tshekatsheko e feditswe mo bofelong ba ngwaga wa 2018.*
- *O tla bolelelwa ka ditshwetso dingwe tse dintšwa ka pampitshana ya tshedimosetso e e tlaa phatlhalatswang kwa sekolong kgotsa kheretšhe ya ngwana wa gago.*

A wena kgotsa ngwana wa gago o tlaa duelwa mo go tseyeng karolo mo thutong e le a go na le ditshenyegelo dingwe go wena?

Nnyaya, wena kgotsa ngwana wa gago ga le kitla le duelwa go tsaya karolo mo thutong e, fela dijonyana go ngwana wa gago morago ga tlhotlhomiso ya bona ya kalafi di tlaa nna teng mo sekolong. Ga go ne go nna le thulaganyo ya madi a ditshenyegelo go wena fa o ka dumela go tsaya karolo.
Go tlile go nna le tlhakatlhakanonyana mo ditirwaneng tsa kharikhula ya sekolo sa ngwana wa gago, mme re tla leka ka bojotlhe ba rona go fokotsa se le mathata a a ka tlholwang mo mo(ba)rutabaneng ba ngwana wa gago.

A go na le sengwe se o batlang go se itse kgotsa go se dira?

- O ka ikgolaganya le Mme Mariaan van Aswegen mo go +27 18 389 2897 fa o na le dipotso tse dingwe kgotsa mathata mangwe.
- O ka letsetsa gape Komiti ya Boitekanelo ya Patlisiso ya Maitsholo ka Mme Carolien van Zyl mo 018 299 1206 kgotsa carolien.vanzyl@nwu.ac.za. Fa o na le le tshwenyego e sa arabiwang go ya ka patlisiso kgotsa o na le ngongorego ka ga patlisiso.
- O tlaa amogela khophi ya tshedimosetso e le foromo ya maitlamo go ya ka maikaelelo a gago.

Tlhomamiso ka motsayakarolo

Ka go saene fa tlase, Nna(leina la motsadi/motlhokomedi
Sefane______________________________________ Ke dumelela ngwanake
leina le sefane)______________________________________ go tsaya karolo mo setlhogong sa patlisiso ya thuto: Tlhabololo ya porofaele ya digoro le tokololo ya lengole mo go belegeng bana ba Batswana

Ke bolela gore

- Ke buisitse tshedimosetso e kgotsa ke e tlhaloseditswe ke motho yo o tshepegang ka puo e ke itseng e bile ke le phuthulogile ka yona.
- Patlisiso e tlhalositswe sentle mo go nna.
- Ke nnile le tetla ya go botsa dipotso go batho ba babedi bao ba neng ba amogela maitlamo mo go nna gape le mmatlisisi le dipotso tsotlhe di arabilwe.
- Ke tlhalogantse gore go tsaya karolo mo thutong e ke boithaopo mme nna le ngwanake ga ra patelediwa go tsaya karolo.
- Nna le ngwanake re ka tlhopha go tlogela thuto ka nako nngwe le nngwe e bile ga re ne re tshwarwa ka mokgwa o o sa siama fa re dira jalo.
- Ke neetse tetla ya go dira diteko le go tsaya ditshwantsho mo ngwaneng wa *me.*
- *Nka kopa go tlogela thuto pele e fetswa, fa mmatlisisi a bona go tshwanela kgotsa fa ke sa sale thulaganyo ya thuto morago jaaka go dumelwane.*

Saennwe kwa (Lefelo) _____________________ *ka (Letlha)* ___________ *20*__

________________________________......   ________________________
Tshaeno ya motsayakarolo   **Tshaeno ya mosupi**

Tlhomamiso ka moamogedi wa tumelano

Nna(*Leina*)*)* _________________________________ bolela gore:

- Ke bontshitse sentle le go tlhalosa ka botlalo kitso e e mo pampiring go ____
- Ke dirisitse/ga ka dirisa motšhomolodi.
- Ke mo rotloeditse go botsa dipotso le go tsaya nako ya gagwe mo go di arabeng
- Ke kgotsofetse gore o tlhalogantse dintlha tsotlhe tsa patlisiso sentle jaaka ditlhalositswe fa godimo
- Ke mo neetse nako ya go buisana le ba bangwe fa a batla go dira jalo.

Saennwe kwa (*lefelo*) ________________________ka (Letlha) ____________ 20__

__________________________________   __________________________
Tshaeno ka moamogedi wa tumalano   **Tshaeno ka mosupi**

Tlhomamiso ka mmatlisisi

Nna(*Leina)*___________________________________ bolela ka:

- Ke tlhalositse kitso mo pampiring e go ________________________
- Ke dirisitse/ga ka dirisa motšhomolodi.
- Ke mo rotloeditse go botsa dipotso le go nna teng fa a ne a batla go botsa ka dipotso tse dingwe.
- Tumalano ya maitlamo e amogetswe ke motho yo o ikemetseng
- Ke kgotsofetse gore o tlhalogantse dintlha tsotlhe tsa patlisiso jaaka di tlhalositswe fa godimo
- Ke kgotsofetse gonne o nnile nako ya go buisana le ba bangwe fa a ne a batla go dira jalo.

Saennwe kwa (*Lefelo*)_________________________ka (*Letlha*) ___________ 20__

_______________________________ ...... ______________________

Tshaeno ya mmatlisisi **Tshaeno ya mosupi**

Informed Consent into Kinematic Investigation – English Version

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS

Health Research Ethics Committee
Faculty of Health Sciences
NORTH-WEST University
(Potchefstroom Campus)
2017 -12- 06
HREC Stamp

INFORMED CONSENT DOCUMENTATION FOR YOUR CHILD'S PARTICIPATION IN A RESEARCH STUDY

TITLE OF THE RESEARCH STUDY: The development of genu varum and the tibiofemoral joint profile in back-carried Setswana children.

ETHICS REFERENCE NUMBERS: NWU – 00094-17-A1

PRINCIPAL INVESTIGATOR: Dr. Stanislaw Czyz

POST GRADUATE STUDENT: Mrs Mariaan van Aswegen

ADDRESS:
Mail: North-West University, Private Bag X6001, 2520, Potchefstroom, North West Province, South Africa; Internal box #481
Physical address: PhASRec, building K3, 1st floor, room 111; Fanie du Troit Sports Field; C/o Thabo Mbeki & Meyer Street, Potchefstroom (Die Built); 2531; North West Province; South Africa
Email: stanislaw.czyz@nwu.ac.za

CONTACT NUMBER: (018) 285 2625

Your child is being invited to take part in a **research study** that forms part of my Doctoral degree in Human Movement Science. Please take some time to read the information presented here, which will explain the details of this study. Please ask the researcher or person explaining the research to you, any questions about any part of this study that you do not fully understand. It is very important that you are fully satisfied that you clearly understand what this research is about and how your child might be involved. Also, your child's participation is **entirely voluntary** and you are free to say no to participate. If you or your child say no, this will not affect you or your child negatively in any way whatsoever. You and your child are also free to withdraw from the study at any point, even if you do agree to take part now.

This study has been approved by the **Health Research Ethics Committee of the Faculty of Health Sciences of the North-West University (NWU............)** and will be conducted according to the ethical guidelines and principles of Ethics in Health Research: Principles, Processes and Structures (DoH, 2015) and other international ethical guidelines applicable to this study. It might be necessary for the research ethics committee members or other relevant people to inspect the research records.

What is this research study all about?

- *This study will be conducted in the biomechanics laboratory in the PhASRec building K3, Fanie du Toit Sports Field, c/o Thabo Mbeki & Meyer street, Potchefstroom (Die Bult), 2531 and will involve markers being placed on your child's skin with double sided tape and capturing your child's walking patterns on video. Experienced biokineticists and sport science researchers trained in movement analysis will conduct the research. 30 participants will be included in this study.*
- *We plan to compare the walking patterns of black, Setswana children between the ages of 7 to 9 years old, who were back-carried as an infant or child, to the walking patterns of infants or children who were not back-carried.*

Why has your child been invited to participate?

- *Your child has been invited to be part of this research because your child has participated in the knee angle research project and is between the ages of 7 to 9 years, and your child is black and Setswana speaking.*
- *Your child also fit the research because he/she is healthy and he/she was (or wasn't) carried on the primary caregiver's back when he/she was an infant or toddler.*
- *Your child has (or doesn't have) hip joint problems (developmental dysplasia of the hip).*

- *Your child will not be able to take part in this research if he/she is non-Setswana or of any other ethnicity.*
- *If your child is younger than 7 years old, or older than 9 years*
- *If your child has any known bone-, muscle-, nerve- or ligament disorders, except for hip joint problems (developmental dysplasia of the hip).*
- *If your child or direct family members (mother, father, brother/sister, grandfather/grandmother) has a known disorder such as bone joint problems (skeletal dysplasia), brain injury before or at birth (cerebral palsy), foot deformities and or calcium-, iron- or vitamin D deficiency (metabolic diseases such as Rickets)*

What will be expected of your child?

- *Your child will be expected to visit the NWU's biomechanics laboratory. We will provide transport to and from the laboratory if necessary. He/She will have to wear tight fitting shorts and a tight fitting T-shirt and remove their shoes and socks.*
- *He/She will then undergo body composition measurements (body mass and stature) and special markers will be attached with double sided tape to his/her skin. This will not hurt and should take approximately 20 minutes.*
- *Once the markers are attached, will your child walk in a circle, over a plate in the ground which will measure forces and cameras will capture their walking style and -patterns. They will walk in this circle 5 to 10 times and this should not take longer than 15 minutes.*
- *When your child completed their walking, we will remove the markers and he/she can return to school or home.*

Will you or your child gain anything from taking part in this research?

- *The gains for you and your child if you take part in this study will be that your child's walking pattern will be assessed free of charge (these tests normally cost up to R700) and you will receive a report providing you with information on your child's walking style and patterns, also free of charge.*
- *The other gains of the study is toward the Setswana community, in the knowledge that we will gain as to the walking styles of Setswana children and their development. We will be able to provide guidelines about back-carrying practices and the way it might affect the children's knee development and walking development.*

Are there risks involved in you taking part in this research and what will be done to prevent them?

- *There are no conceivable risks in your child's participation in this study, other than the risks associated with activities of daily living and walking. The greatest risk is the safe transportation of your child to the biomechanics laboratory. Should you make use of the transport provided to you, rest assured that the driver has the necessary license to transport children and that all safety measures will be taken to bring the children to the laboratory safely and to return them.*
- *The tests will not cause your child any bodily or emotional harm, however, should he/she perceive any discomfort, we will immediately stop the tests, and allow your child to withdraw from the study, should they wish to do so.*
- *The walking analysis and will be conducted in a safe environment at the NWU. The corresponding language during all the procedures will be in English and Setswana.*
- *The gains of your child participating in this study outweighs the risk.*

How will we protect your child's confidentiality and who will see your child's findings?

- *Anonymity of your child's findings will be protected by assigning a numbered code to each child, which is only known to the researcher, your child's name will not appear on any documentation. Only the researchers will be able to look at your child's findings. Findings will be kept safe by locking hard copies in locked cupboards in the researcher's office and for electronic data it will be password protected. (As soon as data has been transcribed it will be deleted from the recorders.) Data will be stored for 7 years.*

What will happen with the findings?

- *The findings of this study will be used for this study and subsequent or secondary studies necessary to build and support our knowledge on the walking styles of back-carried children. The anonymised data will be analysed in South Africa by the investigators and statisticians, if necessary.*

How will you know about the results of this research?

- *We will give you the results of this research once analysis has been completed by the end of 2018.*
- *You will be informed of any new relevant findings through information leaflets that will be distributed at your child's school or crèche.*

Will you or your child be paid to take part in this study and are there any costs for you?

No, you or your child will not be paid to participate in this study, but refreshments will be available to your child at the laboratory.

There will be no monetary cost to you, but it may inconvenience you in terms of time taken from your day to bring your child to the laboratory. Transport will however be provided should you require it as to limit any further inconvenience to you.

Is there anything else that you should know or do?

- You can contact Mrs Mariaan van Aswegen at +27 18-389 2897 if you have any further questions or have any problems.
- You can also contact the Health Research Ethics Committee via Mrs Carolien van Zyl at 018 299 1206 or carolien.vanzyl@nwu.ac.za if you have any concerns that were not answered about the research or if you have complaints about the research.
- You will receive a copy of this information and consent form for your own purposes.

Declaration by participant

By signing below, I (name & surname of participant) __________________________ agree to allow my child (name & surname of child) __________________________ take part in the research study titled: The development of genu varum and the tibiofemoral joint profile in back-carried Setswana children.

I declare that:

- I have read this information/it was explained to me by a trusted person in a language with which I am fluent and comfortable.
- The research was clearly explained to me.
- I have had a chance to ask questions to both the person getting the consent from me, as well as the researcher and all my questions have been answered.
- I understand that taking part in this study is **voluntary** and my child have not been pressurised to take part.
- My child and I may choose to leave the study at any time and we will not be handled in a negative way if we do so.
- My child or I may be asked to leave the study before it has finished, if the researcher feels it is in the best interest, or if I do not follow the study plan, as agreed to.

Signed at (*place*) ______________________________ on (*date*) ____________. 20__

__________________________________ .... __________________________

Signature of participant **Signature of witness**

Declaration by person obtaining consent

I *(name)* _________________________________ declare that:

- I clearly and in detail explained the information in this document to

  ____
- I did/did not use an interpreter.
- I encouraged him/her to ask questions and took adequate time to answer them.
- I am satisfied that he/she adequately understands all aspects of the research, as discussed above
- I gave him/her time to discuss it with others if he/she wished to do so.

Signed at (*place*) ___________________________ on (*date*) _____________ 20__

___________________________________ _____________________________

Signature of person obtaining consent **Signature of witness**

Declaration by researcher

I *(name)* ________________________________ declare that:

- I explained the information in this document to ______________________
- I used a Setswana interpreter
- I encouraged him/her to ask questions and I was available should he/she want to ask any further questions.
- The informed consent was obtained by an independent person.
- I am satisfied that he/she adequately understands all aspects of the research, as described above.
- I am satisfied that he/she had time to discuss it with others if he/she wished to do so.

Signed at (*place*) _______________________ on (*date*) ________________ 20__

___________________________________ .... _______________________

Signature of researcher **Signature of witness**

Informed Consent into Kinematic Investigation – Setswana Version

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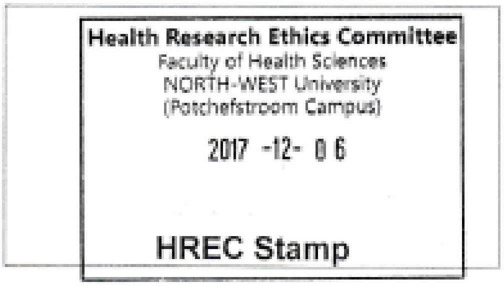

TOKOMANE YA KITSISO YA MAITLAMO YA BOTSAYAKAROLO JWA NGWANA WA GAGO MO THUTONG YA PATLISISO

SETLHOGO SA PATLISISO: Tlhabololo ya porofaele ya digoro le tokololo ya lengole mo go belegeng bana ba Batswana

NOMORO KAELO YA MAITSHOLO: NWU-00094-17-A1

MOTLHOTLHOMISIMOGOLO: Dr. Stanislaw Czyz

MOITHUTI WA THUTO E KGOLWANE: Mrs Mariaan van Aswegen

ATERESE
Romela ka Poso: North-West University, Private Bag X6001, 2520, Potchefstroom, North West Province, South Africa; Internal box #481
Aterese ya mogae: PhASRec, buildng K3, 1st floor, room 111; Fanie du Troit Sports Field; C/o Thabo Mbeki & Meyer Street, Potchefstroom (Die Built); 2531; North West Province; South Africa
Imeile: stanislaw.czyz@nwu.ac.za

NOMORO IKGOLAGANYO: (018) 285 2625

Ngwana wa gago o laleditswe go tsaya karolo mo thutong ya patlisiso e e leng karolo ya dikirii ya me ya Bongaka mo Saeseng ya Motsamao ya Setho. Ka kopo tsaya nako go buisa tshedimosetso e e tlhagisitsweng fa, e e tlaa tlhalosang ka botlalo ka ga thuto e. Ka kopo botsa potso nngwe le nngwe ka ga karolo nngwe le nngwe e o sa e tlhaloganyeng ka botlalo mabapi le thuto e go mmatlisisi kgotsa mongwe yo o e tlhalosang. Go botlhokwa gore o tlhaloganye gore patlisiso e bua ka ga eng le gore ngwana wa gago o ya go amega jang. Gape, itse fa ngwana wa gago a ithaopa mme o letleletswe go ka gana. Fa o gana se ga se ne se go ama, wena le ngwana wa gago ka mokgwa mongwe o o sa siamang. O letleletswe gape go ka ikgogela morago le fa o ne o setse o dumetse go ka tsaya karolo jaanong.

Thuto e e dumeletswe semmuso ke Komiti ya Boitekanelo ya Patlisiso ya Maitsholo ya Legoro la Disaense ya Boitekanelo ya Yunibesithi ya Bokone Bophirima (NWU00094-17-A1) e tlaa dirwa go ya ka ditsamaiso le mekgwa ya Maitsholo mo Patlisisong ya Boitekanelo: Ditheo, Tirego le Dipopego (DoH, 2015) le tsamaiso ya maitsholo a boditšhabatšhaba a a maleba mo thutong e. Go ka nna botlhokwa fa maloko a komiti ya maitsholo kgotsa batho ba ba maleba go tlhatlhoba direkoto tsa patlisiso.

Patlisiso ya thuto e e ka ga eng??

- *Thuto e e tlaa dirwa mo laborateri ya saense mo kagong ya PhASRec lebala la metshameko la K3, Fanie du Toit c/o Thabo Mbeki & Meyer Street, Potchefstroom (Die Bult), 2531 re tla dirisa baya matshwao mo letlalong la ngwana wa gago ka sengaparetsi ka fa le ka fa gabedi re be re gatisa mokgwa wa motsamao wa ngwana wa gago ka bidio. Babatlisisi ba ba itekanetseng ba na le maitemogelo, a ba katisitswe mo thutong ya go dirisa tshekatsheko ya motsamao, ba tlaa dira patlisiso go akaretswa batsayakarolo ba le 30 mo thutong e.*
- *Re rulagantse go bapisa mokgwa wa tiriso ya motsamao wa montsho, bana ba Setswana ba ba magareng a dingwaga di le 7 go ya go 9, bao ba neng ba belegwa fa e le masea kgotsa bana go mokgwa wa tiriso wa masea kgotsa bana ba ba sa belegwang.*

Goreng ngwana wa gago a laleditswe go tsaya karolo?

- *Ngwana wa gago o laleditswe go tsaya karolo mo patlisisong e gonne e ene e le motsayakarolo mo porojekeng ya patlisiso ya tshokamo ya lengole gape o magareng a dingwaga di le 7 go ya 9 e bile ke montsho yo o buang Setswana.*
- *Ngwana wa gago o lekanetse thuto e gonne a itekanetse e bileo ne (kgotsa o ne a sa) belegwe ke motlhokomedimogolo fa a ne a le monnye kgotsa lesea.*
- *Ngwana wa gago o na (kgotsa ga a na) mathata a noka (bogole jwa serope)*
- *Ngwana wa gago a ka se tseye karolo mo patlisisong e fa a sa tsamae a tshegediwa, e se Motswana kgotsa merafe e mengwe*
- *Fa ngwana wa gago a le kwa tlase ga dingwaga di le 7 kgotsa di feta 9.*
- Fa ngwana wa gago a na le bothata bo bo itsegeng ba marapo, tshika kgotsa mosifa tshika kwantle ga mathata a noka (bogole ba letheka)
- *Fa ngwana wa gago kgotsa maloko a losika ka tlhamalalo (mme, rre, nkgonne/kgaitsadi, rremogolo/mmemogolo) ba na le bothata bo bo itsegeng jaaka mathata a tokololo ya lerapo, bogole ba marapo), kgobalo ya tlhaloganyo pele kgotsa ka nako ya pelegi (go swa mfama), leoto le le sa tshwaneng le kgotsa tlhaelo ya khalisiamo, mooko, dikotla tsa D (malwetse a go nyemetlhana jaaka digoro)*

Go solofetswe eng mo ngwaneng wa gago?

- *Ngwana wa gago o tshwanelwa ke go etela laborateri ya Saense ya NWU. Re tla tlamela ka sepalangwa go ya le go bowa mo laborateri fa go tlhokega. O tlaa tshwanelwa ke go apara diaparo tse dikhutshwane tse di mo tsimpang le sekipa se se mo tsimpang a be a rola ditlhako le dikousu.*
- *O tla simolola go dira diteko tsa kagego ya mmele (boima ba mmele le bogolo) matshwao a kgethegileng a tlaa ngaparetswa ka lentle le bopele ba sengaparetsi mo letlalong la gagwe.*
- *Fa matshwao a se tse a ngapareditswe ngwana wa gago o tlaa dikologa mo godimo ga poleiti e e mo fatshe e e tlaa metang maatla le dikhemera di tlaa mo tshwantsha mekgwa wa metsamao ya bona.*
- *Fa ngwana wa gago a feditse ka metsamao, re tla tlosa matshwao mme a ka boela kwa sekolong kgotsa gae.*

A wena kgotsa ngwana wa gago le tlaa boelwa ke sengwe go tswa mo go tseyeng karolo mo thutong e?

Dipoelo tsa gago le ngwana wa gago fa le tsaya karolo mo thutong e ke gore mokgwa wa motsamao wa ngwana wa gago o tlaa tlhatlhojwa ntle le tuelo (diteko tse gantsi di duelelwa R700) o tla amogela pegelo e e go bolelelang ka ga tshedimosetso mo mekgweng le tiriso ya metsamao ya ngwana wa gago ntle le tuelo.

- *Dipoelo tse dingwe gape tsa thuto ke go ya ka baagi ba Setswana mo kitsong e re tlaa e bonang jaaka ya mekgwa ya metsamao ya bana ba Batswana le tlhablololo ya yona. Re tla kgona le go neela ditsamaiso ka ga ditlwaelo tsa pelego le mekgwa e e ka amang kago ya lengole le motsamao wa bana*

A go na le go ka tsena mo diphatseng mo go tseyeng karolo mo patlisisong e le gore go ka dirwa eng go di thibela?

- *Ga gona diphatsa dipe tse di akantsweng mo go tseyeng karolo ga ngwana wa gago mo thutong e, kwa ntle ga diphatsa tse di tsamaelanang le ditirwana tsa letsatsi la go phela le go tsamaya. Diphatsa tse dikgolo ke tshireletsego ya dipalangwa tsa bana go ya laborateri ya saense. Fa o ka dirisa sepalangwa se o se neelwang go netefatswa gore mokgwetsi o na le lekwalo tetla la go kgweetsa bana gape mekgwa yotlhe ya tshireletso e tlaa tsewa go isa bana kwa laborateri ba ba balesegile le go ba busetsa morago.*

- *Diteko ga di ne di utlwisa mmele le mowa wa ngwana wa gago botlhoko, le fa go le jalo fa a ka bona a a sa nnisege, ka bonako re tlaa emisa diteko le go mo letla go ikgogela morago go tswa mo thutong fa a batla go dira jalo.*
- *Tshekatsheko ya motsamao e tlaa direlwa mo tikologong e e babalesegileng kwa NWU. Puo e e tlaa dirisiwang ka nako ya ditsamaiso e tlaa nna Seesimane le Setswana.*
- *Ke badiri fela ba tshekatsheko ya motsamao bao ba tlaaa nna teng mo laborateri go netefatsa tulo e e kgethegileng mme e bolokesegile.*
- *Dipoelo tsa botsayakarolo jwa ngwana wa gago bo fokotsa diphatsa.*

Re tla sireletsa jang ngwana wa gago le sephiri sa gagwe le gore ke mang yo o tlaa bonang ditshwetso?

- *Tlhokaina la ditshwetso tsa ngwana wa gago le tla sireletswa ka go neela khoutu ya nomore go ngwana mongwe le mongwe yo a itseweng ke mmatlisisi, leina la ngwana wa gago ga le kitla le tlhagelela gope mo nngweng ya ditokomane. Ke mmatlisisi fela yo a tla lebelelang ditshwetso tsa ngwana wa gago. Ditshwetso di tla bolokwa ka dipampiri mo kobotlong e e notletsweng mo phaposing ya mmatlisisi le dinewa tsa mafaratlhatlha a thekenoloji di tlaa sireletswa ka pulamolomo. (Fa dinewa di se na go sekwasekwa e tlaa tloswa mo direkotong). Dinewa di tlaa bolokwa mo nakong ya dingwaga di le 7.*

Go tlaa diragalang ka ditshwetso?

- *Ditshwetso tsa thuto e di tla dirisiwa mo thutong e gape morago ga moo kgotsa dithuto tse kgolwane go aga le go tshegetsa kitso ya rona mo tirisong ya go belega bana ka fa morago le tlhabololo ya lengole. Dinewa tse di sa bontshiwang di tlaa sekwasekwa mo Aforikaborwa ke motlhotlhomisi le baitseanape wa dipalo, fa go tlhokega.*

O tla itse jang ka ga dipholo tsa patlisiso e?

- *Re tla go neela dipholo tsa patlisiso e fa fela tshekatsheko e feditswe mo bofelong ba ngwaga wa 2018.*

- *O tla bolelelwa ka ditshwetso dingwe tse dintšwa ka pampitshana ya tshedimosetso e e tlaa phatlhalatswang kwa sekolong kgotsa kheretšhe ya ngwana wa gago.*

A wena kgotsa ngwana wa gago o tlaa duelwa mo go tseyeng karolo mo thutong e le a go na le ditshenyegelo dingwe go wena?

Nnyaya, wena kgotsa ngwana wa gago ga le kitla le duelwa go tsaya karolo mo thutong e, fela go tla nna le dijonyana mo laborateri.
Ga go ne go nna le thulaganyo ya madi a ditshenyegelo go wena mme go tlaa nna le dikoreletsonyana go ya le nako e e tla tsewang ya gago ka letsatsi la fa o tlisa ngwana wa gago kwa laborateri. Go tlaa nna le sepalangwa fa o batla gore o se kgoreletswe ka gope.

Fa go na sengwe se o batlang go se itse kgotsa go dira?

- O ka ikgolanya le Mrs Mariaan van Aswegen mo +2718389 2897 fa e le gore o na le dipotso tse dingwe kgotsa o na le mathata mangwe
- O ka letsetsa gape Komiti ya Boitekanelo ya Patlisiso ya Maitsholo go ya ka Mme Carolien van Zyl mo go 018 299 1206 kgotsa carolien,vanzyl@nwu.ac,za fa o na le sengwe se se sa arabiwang ka ga patlisiso kgotsa fa o ngongorega ka ga patlisiso.
- O tla amogela khopi ya tshedimosetso e le foromo ya maitlamo go ya ka maikaelelo a gago.

Tlhomamiso ka motsayakarolo

Ka go saene fa tlase, Nna (leina la motsadi/motlhokomedi
Sefane_____________________________________ Ke dumelela ngwanake
(leina le sefane) ____________________________________ go tsaya karolo mo setlhogong sa patlisiso ya thuto: Tlhabololo ya porofaele ya digoro le tokololo ya lengole mo go belegeng bana ba Batswana

Ke bolela gore

- Ke buisitse tshedimosetso e kgotsa ke e tlhaloseditswe ke motho yo o tshepegang ka puo e ke itseng e bile ke le phuthulogile ka yona.
- Patlisiso e tlhalositswe sentle mo go nna.
- Ke nnile le tetla ya go botsa dipotso go batho ba babedi bao ba neng ba amogela maitlamo mo go nna gape le mmatlisisi le dipotso tsotlhe di arabilwe.
- Ke tlhalogantse gore go tsaya karolo mo thutong e ke boithaopo mme nna le ngwanake ga ra patelediwa go tsaya karolo.
- Nna le ngwanake re ka tlhopha go tlogela thuto ka nako nngwe le nngwe e bile ga re ne re tshwarwa ka mokgwa o o sa siama fa re dira jalo.
- Ke neetse tetla ya go dira diteko le go tsaya ditshwantsho mo ngwaneng wa *me.*
- Nka kopiwa go tlogela thuto pele e fetswa, fa mmatlisisi a bona go tshwanela kgotsa fa ke sa sale thulaganyo ya thuto morago jaaka go dumelwane.

Saennwe mo *(lefelo)*_________________________ _ka *(letlha)*___________*20*___

______________________________ ________________________
Tshaeno ya motsayakarolo **Tshaeno ya mosupi**

Tlhomamiso ka moamogedi wa tumelano

Nna(*Leina*) _________________________________ bolela gore

- Ke bontshitse sentle le go tlhalosa ka botlalo kitso e e mo pampiring go ____
- Ke dirisitse/ga ka dirisa motšhomolodi.
- Ke mo rotloeditse go botsa dipotso le go tsaya nako ya gagwe mo go di arabeng
- Ke kgotsofetse gore o tlhalogantse dintlha tsotlhe tsa patlisiso sentle jaaka ditlhalositswe fa godimo
- Ke mo neetse nako ya go buisana le ba bangwe fa a batla go dira jalo.
-

Saennwe mo*(Lefelo)*___________________________ka*(letlha)*_________20__

__________________________________ __________________________
Tshaeno ka moamogedi wa tumalano **Tshaeno ka mosupi**

Tlhomamiso ka mmatlisisi

Nna(*Leina)* ___________________________________ bolela ka:

- Ke tlhalositse kitso mo pampiring e go ________________________
- Ke dirisitse/ga ka dirisa motšhomolodi.
- Ke mo rotloeditse go botsa dipotso le go nna teng fa a ne a batla go botsa ka dipotso tse dingwe.
- Tumalano ya maitlamo e amogetswe ke motho yo o ikemetseng
- Ke kgotsofetse gore o tlhalogantse dintlha tsotlhe tsa patlisiso jaaka di tlhalositswe fa godimo
- Ke kgotsofetse gonne o nnile nako ya go buisana le ba bangwe fa a ne a batla go dira jalo.

Saenilwe kwa (*lefelo*)______________________ka (*letlha*)____________20___

____________________________ ______________________

Tshaeno ya mmatlisisi **Tshaeno ya mosupi**

APPENDIX D: CHILD ASSENT DOCUMENTS

Child Assent into Clinical Investigation – English Version

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS

Health Research Ethics Committee
Faculty of Health Sciences
NORTH-WEST University
(Potchefstroom Campus)
2017 -12- 06

HREC Stamp

CHILD ASSENT FORM – TO PARTICIPATE IN A RESEARCH STUDY

TITLE OF THE RESEARCH STUDY: The development of genu varum and the tibiofemoral joint profile in back-carried Setswana children.

ETHICS REFERENCE NUMBERS: NWU-00094-17-A1

PRINCIPAL INVESTIGATOR: Dr. Stanislaw Czyz

POST GRADUATE STUDENT: Mrs Mariaan van Aswegen

ADDRESS:
Mail: North-West University, Private Bag X6001, 2520, Potchefstroom, North West Province, South Africa; Internal box #481
Physical address: PhASRec, building K3, 1st floor, room 111; Fanie du Troit Sports Field; C/o Thabo Mbeki & Meyer Street, Potchefstroom (Die Built); 2531; North West Province; South Africa
Email: stanislaw.czyz@nwu.ac.za

CONTACT NUMBER: (018) 285 2625

Dear ___________________________________(child's name)

You are invited to be part of a research study along with 499 other kids from Ikageng and Potchefstroom! You received this letter because your parents feel it is ok for you to participate and they have given their blessing, but you must decide if YOU feel like taking part. Let us explain…

You are going to be asked to do a couple of things, like stand on the scale, have your height measured and another test where we measure your legs lengths.
We also want to measure your knees with a ruler with two arms, but before we measure, we will use a body pen to make some marks on your legs. The fancy pen will wipe off easily from your skin, so don't worry. Then we'll place the ruler's circle part will be over your kneecap, and the one arm will go over your thigh and the other over your shin. This funny ruler will be used for 3 tests, and it will not hurt you. For two of the tests you will lie on a bed on your stomach, while we do the measurements. We will take a picture of your legs, with all the marks drawn on them, but your face will not be in the photo.

We promise we will not hurt you or harm you in any way. None of these tests will hurt your body, but if you feel uncomfortable at any point in time, you may tell the researcher, your teacher or anyone. If you want to stop the tests, you must tell us, we will stop everything, and you can go back to your classroom. Your teacher or a friend will be allowed to watch how we do all these tests, if you want him/her there.

There will be a small snack for you after you have completed the tests, to say thank you for helping us. Unfortunately, we cannot give you any money after you helped us, but these tests normally cost a lot of money (more than R400! Which is the same as 40 Oreo McFlurry ice creams!), and we offer them to you for FREE! We will give you a leaflet on knee angles that you can show to your parents. This will help them to know when to take you to a doctor if your knees don't look right to them.

The person who looked after you the most when you were small, will also answer some questions on when you were small.

Do you agree to participate?
Please mark in the block – YES if you want to or mark NO if you don't want to. Ps. If you don't want to – it is perfectly ok, we understand.

YES	NO
	

Thank you, you are a champion!

____
Please sign your name here

____
Write today's date here

Child Assent into Clinical Investigation – Setswana Version

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Health Research Ethics Committee
Faculty of Health Sciences
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(Potchefstroom Campus)
2017 -12- 06
HREC Stamp

FOROMO YA TUMELELO YA NGWANA – GO TSAYA KAROLO MO THUTONG YA PATLISISO

SETLHOGO SA PATLISISO: Tlhabololo ya porofaele ya digoro le tokololo ya lengole mo go belegeng bana ba Batswana
NOMORO KAELO YA THEBOLO MAITSEO: NWU-00094-17-A1

MOTLHOTLHOMISIMOGOLO: Dr. Stanislaw Czyz
MOITHUTI WA THUTO E KGOLWANE: Mrs Mariaan van Aswegen

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Imeile: stanislaw.czyz@nwu.ac.za

NOMORO KGOLAGANO: (018) 285 2625

Yo o rategang_______________________________________(leina la ngwana

O lalediwa go nna mongwe wa bana ba le 499 ba e leng batsayakarolo mo thutong ya patlisiso go tswa mo Ikageng le Potchefstroom! O amogetse lekwalo le gonne batsadi ba gago ba bona go siame go ka tsayakarolo e bile ba go eleletsa matlhogonolo, mme go tswa mo go wena gore a o batla go tsaya karolo. Nte re tlhalose...

O tlaa kopiwa go dira dilo di le mmalwanyana, jaaka go ema mo sekaleng, go metiwa boleele jwa gago le diteko tse dingwe di tshwana le go meta boleele jwa maoto a gago.
Re tlaa batla gape go meta mangole a gago ka rula ka matsogo a mabedi, mme pele re meta, re tlaa dira matshwao a mmele wa pene ka go tshwaya maoto a gago. Pene e mabonobono e phimoga bonolo mo letlalo, ka jalo se tshwenyege. Gape re tlaa baya rula go sekeletsa theledi, seatla se sengwe se tlaya mo seropeng mme se sengwe se tlaaa ya mo seledung. Rula e e sa tlwaelegang e, e tlaa dirisiwa mo ditekong tse tharo, mme e ka se go utlwise botlhoko. Go ya ka diteko tse pedi o tlaa patlama mo bolang ka mpa, fa re ntse re go meta. Re tlaa tsaya setshwantsho sa leoto la gago le matshwao otlhe a a mo go lona mme sefatlhego sa gago ga se ne se tlhagelela mo setshwantshong.

Re tshepisa gore ga re ne re go utlwisa botlhoko kgotsa re go gobatsa. Mo ditekong tse ga go epe e e tlile go go utlwisa botlhoko, mme fa e le gore ga o nnisege, o ka bolelela mmatlisisi, morutabana wa gago kgotsa mongwe fela. Fa o batla go emisa diteko, o re bolelele re tlaa emisa sengwe le sengwe mme o ka boela kwa phaposing ya gago. Morutabana kgotsa tsala ya gago a ka dumelelwa go lebelela fa go dirwa diteko tse, fa o ba letla. E tlaa nna rona basaense re le bararo, morutabana wa gago kgotsa motsadi wa gago le wena mo phaposing. Phaposi e teng mo lebaleng la sekolo sa gago mme e bile e bolokesegile.

Go tlaa nna le sejonyana sa tebogo morago ga go fetsa diteko. Ka maswabi ga gona madi a re ka go fang ona fa o fetsa go re thusa, mme gantsi diteko tse di re batla madi a a kwa godimo (a ka feta R400 e e tshwanang fela le dibebetsedidi di le 40 tsa Oreo McFlurry) mme rona re go fa tsona MAHALA! Re tlaa go fa setlankananyana sa dikhutlo tsa lengole tse o ka bontshang batsadi ba gago. Se se tlaa ba thusa gore ba itse gore re go isa leng ngakeng fa mangole a gago a sa siama.

Motho yo a go godisitseng fa o ne o le monnye le ena o tlaa tshwanelwa ke go araba dipotso.

A o dumela go tsaya karolo?
Tswetswee bontsha mo bolokong ka – EE fa o batla kgotsa tshwaya NNYAYA fa o sa batle.
Ka kopo fa o sa batle – go siame ra tlhaloganya.

EE	NNYAYA
	

Re a leboga o mogaka!

____
Ka kopo saena leina la gago fa

____
Kwala letlha la gompieno fa

Child Assent into Kinematic Investigation – English Version

NORTH-WEST UNIVERSITY
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Email: stanislaw.czyz@nwu.ac.za

CONTACT NUMBER: (018) 285 2625

Dear ___________________________________ (child's name)

You are invited to be part of a research study along with 29 other kids from Ikageng and Potchefstroom! You received this letter because you helped us last time to measure your knees and your parents feel it is ok for you to participate and they have given their blessing, but you must decide if YOU feel like taking part, again... Let us explain what is going to happen this time…

This time you are coming to our laboratory at the university (the school for old people).
You are going to be asked to do a couple things (again), like stand on the scale, have your height measured and another test where we measure your legs lengths.
We are going to paste markers on your legs, and then all you do is walk over a plate 5 times whilst cameras are taking a video of your walking patterns.

We need you to wear a tight short and a tight sleeveless shirt and to be barefoot.

Again we promise that we will not hurt you or harm you in any way. None of these tests will hurt your body, but if you feel uncomfortable at any point in time, you may tell the researcher, your parent or anyone. If you want to stop the tests, you must tell us, we will stop everything, and you can go back to your home or school. Your parent or a friend will be allowed to watch how we do all these tests, if you want him/her there.

This should not take too long and you will be on your way home or back to school soon.

Just like last time, there will be a small snack for you after you have completed the tests, to say thank you for helping us. Unfortunately, we still cannot give you any money after you helped us, but these tests cost even more money (more than R700! Which is the same as 70 Oreo McFlurry ice creams!), and we offer them to you for FREE! We will give you a leaflet on walking patters that you can show to your parents. This will help them to know when to take you to a doctor if your walking patterns don't look right to them.

Do you agree to participate?
Please mark in the block – YES if you want to or mark NO if you don't want to. Ps. If you don't want to – it is perfectly ok, we understand.

YES	NO
	

Thank you, you are a champion!

____
Please sign your name here

____
Write today's date here

Child Assent into Kinematic Investigation – Setswana Version

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS

Health Research Ethics Committee
Faculty of Health Sciences
NORTH-WEST University
(Potchefstroom Campus)
2017 -12- 06
HREC Stamp

FOROMO YA TUMELELO YA NGWANA – GO TSAYAKAROLO MO THUTONG YA PATLISISO

SETLHOGO SA PATLISISO: Tlhabololo ya porofaele ya digoro le tokololo ya lengole mo go belegeng bana ba Batswana

NOMORO KAELO YA THEBOLO MAITSHOLO: NWU-00094-17-A1

MOTLHOTLHOMISIMOGOLO: Dr. Stanislaw Czyz
MOITHUTI WA THUTO E KGOLWANE: Mrs Mariaan van Aswegen

ATERESE
Romela ka Poso: North-West University, Private Bag X6001, 2520, Potchefstroom, North West Province, South Africa; Internal box #481
Aterese ya mogae: PhASRec, building K3, 1st floor, room 111; Fanie du Troit Sports Field; C/o Thabo Mbeki & Meyer Street, Potchefstroom (Die Built); 2531; North West Province; South Africa
Imeile: stanislaw.czyz@nwu.ac.za

NOMORO IKGOLAGANYO: (018) 285 2625

Yo o rategang ________________________________ leina la ngwana

O laledìwa go nna motsayakarolo mo thutong ya patlisiso le bana ba ka nna 29 go tswa mo Ikageng le Potchefstroom! O amogetse lekwalo le gonne o re thusitse ka go meta mangole a gago, gape batsadi ba gago ba bona go siame go ka tsayakarolo e bile ba go eleletsa matlhogonolo, mme go tswa mo go wena gore a o batla go tsaya karolo gape, Nte re tlhalose tlhalose se se tlaa diragalang ka nako e...

Ka nako e o tlaa tla mo laborateri mo Yunibesithing (Sekolo sa batho ba bagolo). O tlaa kopiwa go dira dilo dile mmalwa(gape), jaaka o ema mo sekaleng, go metiwa boleele jwa gago le diteko tse dingwe tseo re tla mmetang boleele jwa maoto a gago. Re tlo ngaparetsa matshwao mo maoto a gago mme se o tshwanetseng go se dira ke go tsamaya ga tlhano mo godimo ga poleiti fa khemera e ntse e gatisa bidio ya dikaelo tsa motsamao wa gago. Laborateri ke lefelo le le babalesegileng, gape go tla be go se na batho ba bantsi, e tla be e le fela bao ba go dirang diteko.

Re tlhoka gore o apare seaparo se sekhutshwane se se go tsimpampang le hempe e e se nang matsogo e e go tsimpang gape o se ke wa rwala ditlhako.

Gape re tshepisa gore ga re ne re go utlwisa botlhoko kgotsa re go gobatsa ka mokgwa mongwe.Ga go na teko epe e e tlileng go utlwisa mmele wa gago botlhoko, mme fela fa o bona o sa nnisege ka nako nngwe, o ka bolelela mmatlisisi, motsadi wa gago kgotsa mongwe fela. Fa o batla go emisa diteko, o ka re bolelela, re tla dira jalo mme o ka boela gae kgotsa kwa sekolong sa gago. Motsadi wa gago kgotsa tsala ba ka letwa go lebelela fa go dirwa diteko tsotlhe, fa wena o dumela.

Se se ka se tseye lobaka mme o tla boela gae kgotsa kwa sekolong ka bonako.
Jaaka mo nakong e e fetileng, go tlaa nna le dijonyana morago ga go fetsa diteko, e le go go leboga fa o re thusitse. Ka maswabi ga re ne re kgona go go fa madi morago ga go re thusa, fela diteko tse di duela madi a mantsi (a feta R700! E e lekanang le dibebebtsi tsa Oreo McFlurry di le 70!), mme re go fa tsona MAHALA! Re tlaa go fa pampitshana ya mekgwa ya metsamao wa gago go e bontsha batsadi. Se se tlaa ba thusa go itse gore re ka go isa leng ngakeng fa dikaelo tsa go tsamaya ga gago go sa siama

A o dumela go tsaya karolo?
Tswetswee bontsha mo bolokong ka – EE fa o batla kgotsa tshwaya NNYAYA fa o sa batle.
Ka kopo fa o sa batle – go siame ra tlhaloganya

EE	NNYAYA
	

Re a leboga o mogaka!

______________________________ Ka kopo saena leina la gago fa

______________________________ Kwala letlha la gompieno fa

APPENDIX E: AUTHOR GUIDELINES FOR JOURNALS

Frontiers in Pediatrics – Article One

Author Guidelines

1. Summary Table

Please view the table below for a summary on currently accepted article types and general manuscript style guidelines. Article types may vary depending on journal.

	Abstract (max. length)	**Running title (5 words)**	**Figures and/or tables (combined)**	**Manuscript (max. length)**	**Peer review**	**Author fees**	**Submitted to PubMed Central or other indexing databases**
Original Research	350 words	✔	15	12'000 words	✔	✔	✔
Review	350 words	✔	15	12'000 words	✔	✔	✔
Book Review	✘	✘	1	1'000 words	✔	✘	✔
Brief Research Report	250 words	✔	4	4'000 words	✔	✔	✔
Classification	250 words	✔	10	2'000 words	✔	✔	✔
Case Report	350 words	✔	4	3'000 words	✔	✔	✔
Clinical Trial	350 words	✔	15	12'000 words	✔	✔	✔
Community Case Study	350 words	✔	5	5'000 words	✔	✔	✔
Conceptual Analysis	350 words	✔	10	8'000 words	✔	✔	✔
Curriculum, Instruction, and Pedagogy	350 words	✔	5	5'000 words	✔	✔	✔
Data Report	✘	✔	2	3'000 words	✔	✔	✔
Editorial	✘	✘	0	1'000 words*	✔	✘	✔
Field Grand Challenge	✘	✔	1	2'000 words	✔	✘	✔
Focused Review (1)	350 words	✔	5	5'000 words	✔	✘	✔

Frontiers Commentary (1)	✘	✘	1	1'000 words	✔	✘	✔
General Commentary	✘	✘	1	1'000 words	✔	✔	✔
Hypothesis and Theory	350 words	✔	15	12'000 words	✔	✔	✔
Methods	350 words	✔	15	12'000 words	✔	✔	✔
Mini Review	250 words	✔	2	3'000 words	✔	✔	✔
Opinion	✘	✔	1	2'000 words	✔	✔	✔
Policy & Practice Reviews	350 words	✔	15	12'000 words	✔	✔	✔
Policy Briefs	125 words	✔	5	3'000 words	✔	✔	✔
Perspective	250 words	✔	2	3'000 words	✔	✔	✔
Registered Report	350 words	✔	15	12,000 words	✔	✔	✔
Specialty Grand Challenge	✘	✔	1	2'000 words	✔	✘	✔
Systematic Reviews	350 words	✔	15	12'000 words	✔	✔	✔
Technology and Code	350 words	✔	15	12'000 words	✔	✔	✔

(1) Tier 2 article - field level article reserved to authors of selected Tier 1 articles.
* Editorials for Research Topics with 5 to 10 published articles have a maximum of 1'000 words, for Research Topics with more than 10 published articles the following applies: 1'100 words for 11 articles, 1'200 for 12 articles, 1'300 for 13 articles etc. up to maximum 5'000 words, for 50 or more papers.
Appendices and footnotes will be considered in the total length and word count of the article.

2. Manuscript Guidelines

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If the article is published, authors are then strongly encouraged to link from the preprint server to the Frontiers publication to enable readers to find, access and cite the final peer-reviewed version. Please note that we cannot consider for publication content that has been previously published, or is already under review, within a scientific journal, book or similar entity.

2.2. Registration with Frontiers

Please note that the corresponding and all submitting authors MUST register with Frontiers before submitting an article. You must be logged in to your personal Frontiers Account to submit an article. For any co-author who would like his/her name on the article abstract page and PDF to be linked to a Frontiers profile on the Loop network, please ensure to register before the final publication of the paper.

2.3. Manuscript Requirements and Style Guide

2.3.1. General standards

Word Files

If working with Word please use Frontiers Word templates.

LaTeX Files

If you wish to submit your article as LaTeX, we recommend our Frontiers LaTeX templates. These templates are meant as a guide, you are of course welcome to use any style or formatting and Frontiers journal style will be applied during typesetting.

Experiments

Authors are required to specifically state in their legends how many times experiments were performed (in general we require n=3 as a minimum) and what specific statistical analysis was performed.

2.3.1.1. Article Type

Frontiers requires authors to carefully select the appropriate article type for their manuscript, and to comply with the article-type descriptions defined in the journal's "Article Types", which can be seen from the "For Authors" menu on any Frontiers journal page. Please note that not all articles types are available for all journals/specialties. Please contact us if you have any questions. **Please pay close attention to the word count limits.**

Focused Reviews, Frontiers Commentaries and Grand Challenge articles are invited by the chief editor and cannot be part of any Frontiers Research Topic. Unless you were contacted by the chief editor or the editorial office regarding the submission of a paper selected for tier 2 promotion, do not submit a Focused Review or a Frontiers Commentary - instead, submit a Review or a General Commentary.

Please see Additional Requirements for specific article types including Focused Reviews, General Commentaries, Protocols and Data Reports.

2.3.1.2. Manuscript Length

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

2.3.1.3. Language Editing

Frontiers requires manuscripts submitted to meet international standards for English language to be considered for publication.
For authors who would like their manuscript to receive language editing or proofing to improve the clarity of the manuscript and help highlight their research, Frontiers recommends the language-editing services provided by the following external partners:

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

The Charlesworth Group

Frontiers recommends the Charlesworth Group Author Services, who has a long standing track record in language editing and proofing. This is a third-party service for which Frontiers authors will receive a discount by visiting the following link: http://www.charlesworthauthorservices.com/~Frontiers.

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

2.3.1.4. Language Style

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

2.3.1.5. Search Engine Optimization (SEO)

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

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

2.3.1.6. Title

The title is written in title case, centred, and in 16 point bold Times New Roman font at the top of page.

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

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

- Titles that are a mere question without giving the answer.
- Unambitious titles, for example starting with "Towards", "A description of", "A characterization of", "Preliminary study on".
- Vague titles, for example starting with "Role of...", "Link between...", "Effect of..." that do not specify the role, link, or effect.
- Include terms that are out of place, for example the taxonomic affiliation apart from species name.

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

- "Corrigendum: Title of original article"
- "Book Review: Title of book"
- General Commentaries
  - "Commentary: Title of original article" (This does not apply to Frontiers Commentaries)
  - "Response: Commentary: Title of original article"
- "Editorial: Title of Research Topic"

For article types requiring it, the running title should be a maximum of 5 words in length. (see Summary Table)

2.3.1.7. Authors and Affiliations

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

Example: Max Maximus, Department of Excellence, International University of Science, New York, NY, USA.

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

Correspondence:

Dr. Max Maximus
maximus@gmail.com

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

2.3.1.8. Consortium/Group and Collaborative Authors

Consortium/group authorship should be listed in the manuscript with the other author(s). In cases where authorship is retained by the consortium/group, the consortium/group should be listed as an author separated by "," or "and". Consortium/group members can be listed in a separate section at the end of the manuscript.

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

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

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

2.3.1.9. Headings and Sub-headings

Except for special names (e.g. GABAergic), capitalize only the first letter of headings and subheadings. Headings and subheadings need to be defined in Times New Roman, 12, bold. You may insert up to 5 heading levels into your manuscript (not more than for example: 3.2.2.1.2 **Heading title**).

2.3.1.10. Abstract

As a primary goal, the abstract should render the general significance and conceptual advance of the work clearly accessible to a broad readership. In the abstract, minimize the use of abbreviations and do not cite references. The text of the abstract section should be in 12 point normal Times New Roman. See Summary Table for abstract requirement and length according to article type.

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

2.3.1.11. Keywords

All article types: you may provide up to 8 keywords; at least 5 are mandatory.

2.3.1.12. Text

The entire document should be single-spaced and must contain page and line numbers in order to facilitate the review process. Your manuscript should be written using either LaTeX or MS-Word. Templates are available (see above)

2.3.1.13. Nomenclature

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

2.3.1.14. Sections

Your manuscript is organized by headings and subheadings. For Original Research Articles, Clinical Trial Articles, and Technology Reports the section headings should be those appropriate for your field and the research itself.

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

Introduction

Succinct, with no subheadings.

Materials and Methods

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

Results

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

Discussion

This section may be divided by subheadings. Discussions should cover the key findings of the study: discuss any prior art related to the subject so to place the novelty of the discovery in the appropriate context; discuss the potential short-comings and limitations on their interpretations; discuss their integration into the current understanding of the problem and how this advances the current views; speculate on the future direction of the research and freely postulate theories that could be tested in the future.
For further information, please see Additional Requirements for specific article types including Focused Reviews, General Commentaries, Case Reports and Data Reports amongst others or you can check the descriptions defined in the journal's "Article Types", which can be seen from the "For Authors" menu on any Frontiers journal page.

2.3.1.15. Acknowledgments

This is a short text to acknowledge the contributions of specific colleagues, institutions, or agencies that aided the efforts of the authors.

2.3.1.16. Author Contributions Statement

The Author Contributions Statement is mandatory and should represent all the authors. It can be up to several sentences long and should briefly describe the tasks of individual authors. Please list only 2 initials for each author, without full stops, but separated by commas (e.g. JC, JS). In the case of two authors with the same initials, please use their middle initial to differentiate between them (e.g.

REW, RSW). The Author Contributions Statement should be included at the end of the manuscript before the References.

2.3.1.17. Conflict of Interest Statement

A Conflict of Interest Statement needs to be included at the end of the manuscript before the references. Here, the authors need to declare whether or not the submitted work was carried out in the presence of any personal, professional or financial relationships that could potentially be construed as a conflict of interest. For more information on conflicts of interest, see our Editorial Policies.

2.3.1.18. Contribution to the Field Statement

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

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

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

2.3.2. References

All citations in the text, figures or tables must be in the reference list and vice-versa. The references should only include articles that are published or accepted. Data sets that have been deposited to an online repository should be included in the reference list, include the version and unique identifier when available. For accepted but unpublished works use "in press" instead of page numbers. Unpublished data, submitted manuscripts, or personal communications should be cited within the text only, for the article types that allow such inclusions. Personal communications should be documented by a letter of permission. Website urls should be included as footnotes. Any inclusion of verbatim text must be contained in quotation marks and clearly reference the original source. Preprints can be cited as long as a DOI or archive URL is available, and the citation clearly mentions that the contribution is a preprint. If a peer-reviewed journal publication for the same preprint exists, the official journal publication is the preferred source.

The following formatting styles are meant as a guide, as long as the full citation is complete and clear, Frontiers referencing style will be applied during typesetting.

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Reference list: provide the names of the first six authors followed by et al. and doi when available.
In-text citations should be called according to the surname of the first author, followed by the year.

For works by 2 authors include both surnames, followed by the year. For works by more than 2 authors include only the surname of the first author, followed by et al., followed by the year. For Humanities and Social Sciences articles please include page numbers in the in-text citations.

Article in a print journal:

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

Article in an online journal:

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

Article or chapter in a book:

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

Book:

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

Abstract:

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

Patent:

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

Data:

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

Theses and Dissertations:

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

Preprint:

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

For examples of citing other documents and general questions regarding reference style, please refer to the [Chicago Manual of Style.]

[Frontiers Science Endnote Style]
[Frontiers Science, Engineering and Humanities Bibstyle]

- **HEALTH, PHYSICS AND MATHEMATICS: For articles submitted in the domain of HEALTH or the journal Frontiers in Physics and Frontiers in Applied Mathematics and Statistics please apply the Vancouver system for in-text citations.**

Reference list: provide the names of the first six authors followed by et al. and doi when available. In-text citations should be numbered consecutively in order of appearance in the text – identified by Arabic numerals in the parenthesis for Health articles, and in square brackets for Physics and Mathematics articles.

Reference examples

Article in a print journal:

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

Article in an online journal:

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

Article or chapter in a book:

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

Book:

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

Abstract:

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

Patent:

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

Data:

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

Theses and Dissertations:

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

Preprint:

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

For examples of citing other documents and general questions regarding reference style, please refer to Citing Medicine.

Frontiers Health Endnote Style
Frontiers Health and Physics Bibstyle

2.3.3. Disclaimer

Any necessary disclaimers which must be included in the published article should be clearly indicated in the manuscript.

2.3.4. Supplementary Material

Frontiers journals do not support pushing important results and information into supplementary sections. However, data that are not of primary importance to the text, or which cannot be included in the article because it is too large or the current format does not permit it (such as movies, raw data traces, power point presentations, etc.) can be uploaded during the submission procedure and will be displayed along with the published article. All supplementary files are deposited to FigShare for permanent storage, during the publication stage of the article, and receive a DOI.
The Supplementary Material can be uploaded as Data Sheet (word, excel, csv, cdx, fasta, pdf or zip files), Presentation (power point, pdf or zip files), Supplementary Image (cdx, eps, jpeg, pdf, png or tif), Supplementary Table (word, excel, csv or pdf), Audio (mp3, wav or wma) or Video (avi, divx, flv, mov, mp4, mpeg, mpg or wmv).
Supplementary material is not typeset so please ensure that all information is clearly presented, the appropriate caption is included in the file and not in the manuscript, and that the style conforms to the rest of the article. To avoid discrepancies between the published article and the supplementary material, please do not add the title, author list, affiliations or correspondence in the supplementary files. For Supplementary Material templates (LaTex and Word) see Supplementary Material for Frontiers.

Suggested Fonts

The title is written in title case, centred, and in 16 point bold Times New Roman font at the top of page.

Headings and subheadings need to be defined in Times New Roman, 12, bold.
The text of the abstract section should be in 12 point normal Times New Roman.
The body text is in 12 point normal Times New Roman.

2.3.5. File Requirements

For Latex Files, when submitting your article please ensure to upload all relevant manuscript files including:

- tex file
- PDF
- .bib file (if the bibliography is not already included in the .tex file)

Figures should be included in the provided pdf. In case of acceptance, our Production Office might require high resolution files of the figures included in the manuscript in eps, jpg or tif format. In order to be able to upload more than one figure at a time, save the figures (labeled in order of appearance in the manuscript) in a zip file, and upload them as 'Supplementary Material Presentation'.

To facilitate the review process, please include a Word Count at the beginning of your manuscript, one option is teXcount which also has an online interface.

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

2.3.6. Additional Requirements per article types

2.3.6.1. CrossMark Policy

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

2.3.6.2. Commentaries on Articles

For General Commentaries, the title of your manuscript must have the following format: "Commentary: Title of the original article". At the beginning of your Commentary, please provide the complete citation of the article commented on. Authors commenting on a Frontiers article must submit their commentary for consideration to the same Journal and Specialty as the original article.

Rebuttals may be submitted in response to Commentaries; our limit in place is one commentary and one response. Rebuttals should be submitted as General Commentary articles and the title should have the following format: "Response: Commentary: Title of original article".

2.3.6.3. Book Reviews

The title of a book review needs to follow the format "Book Review: Title of book". For book Reviews, you must also provide the full book details at the beginning of the article in this format: "Book Review: Full book reference"

2.3.6.4. Focused Reviews

For Tier 2 invited **Focused Reviews**, to shape the paper on the importance of the research to the field, we recommend structuring the Review to discuss the paper's Introduction, Materials and

Methods, Results and Discussion. In addition the authors must submit a short biography of the corresponding author(s). This short biography has a maximum of 600 characters, including spaces

A picture (5 x 5 cm, in *.tif or *.jpg, min 300 dpi) must be submitted along with the biography in the manuscript and separately during figure upload.

Focused Reviews highlight and explain key concepts of your work. Please highlight a minimum of four and a maximum of ten key concepts in bold in your manuscript and provide the definitions/explanations at the end of your manuscript under "Key Concepts". Each definition has a maximum of 400 characters, including spaces.

2.3.6.5 Systematic Reviews

For Systematic Reviews, the following article structure applies.

- Title: include systematic review/meta-synthesis/meta-analysis as appropriate in the title

Each of the sections should include specific sub-sections as follows

- Abstract
    - Background
    - Methods
    - Results
    - Conclusions
- Introduction
    - Rationale
    - Objectives
    - Research question
- Methods
    - Study design
    - Participants, interventions, comparators
    - Systematic review protocol
    - Search strategy
    - Data sources, studies sections and data extraction
    - Data analysis
- Results
    - Provide a flow diagram of the studies retrieved for the review
    - Study selection and characteristics
    - Synthesized findings
    - Risk of bias
- Discussion
    - Summary of main findings
    - Limitations
    - Conclusions

2.3.6.6. Data Reports

For Data Reports, please make sure to follow these additional specific guidelines.

1. The data sets (defined as a collection of data that contains individual data units organized in a standardized reusable format, including pre-processed or raw data) must be deposited in a public repository for long-term data preservation prior to submission of the Data Report. The data set(s) is to be fixed and made publicly available upon publication of the Data Report.

2. Our data sharing policy also requires that the dataset be made available to the Frontiers editors and reviewers during the review process of the manuscript. Prior to submission of your Data Report manuscript, please ensure that the repository you have selected supports confidential peer-review. If it does not, we recommend that the authors deposit the datasets to figshare or Dryad Digital Repository for the peer-review process. The data set(s) can then be transferred to another relevant repository before final publication, should the article be accepted for publication at Frontiers.

Note that it is the authors' responsibility to maintain the data sets after publication of the Data Report. Any published Frontiers Data Report article will be considered for retraction should the data be removed from the final selected repository after publication or the access become restricted.

3. The submitted manuscript must include the following details:
- Detailed statement of contribution of the data report to the field
- Name of the data set
- Name of the database/repository where the data set has been submitted
- Link to the data set for confidential peer-review (which can be updated after acceptance, prior to publication once the data is made public)
- Description of how the data was acquired, data collection period
- Filters applied to the data
- Overview of the data files and their formats
- Reference to and/or description of the protocols or methods used to collect the data
- Information on how readers may interpret the data set and reuse the data

All these elements will be peer-reviewed and are required for the publication of the Data Report. Any future updates to the data set(s) should be deposited as independent versions in a repository and the relevant information may be published as General Commentaries linked on the Frontiers website to the initial Data Report.

Any detailed analyses or new scientific insights relating to the Data Report can be submitted as independent research articles which can also be linked on the Frontiers website to the Data Report article. The protocols and methodology used to collect the data can also be submitted as Methods articles.

2.3.6.7. Case Reports

Case Reports should include the following:
- Background
- Case Presentation
  For human patients: age, sex and occupation of the patient, presenting symptoms, the patient's history and any relevant family or social history, and relevant clinical findings
- For animal patients: age, sex, and breed of the animal, presenting problems, the animal's history, and relevant clinical findings.
  Description of laboratory investigations and diagnostic tests.
- Discussion of the underlying pathophysiology and the novelty or significance of the case. Authors are required to obtain written informed consent from the patients (or their legal representatives) for the publication.

2.3.6.8. Policy & Practice Reviews

For Policy and Practice Reviews, the following article structure applies:

- Abstract
- Introduction
- Sections on assessment of policy/guidelines options and implications
- Actionable Recommendations and Conclusions

2.3.6.9. Policy Briefs

For Policy Briefs, the following article structure applies:

- Abstract (bullet point format)
- Introduction
- Sections on Policy Options and Implications
- Section on Actionable Recommendations
- Conclusions

2.3.6.10. Registered Report

Registered Reports are empirical research articles outlining a proposed methodology and analyses which are peer-reviewed and pre-registered before data collection. Registered Reports should include an Introduction, Methods and preliminary results from any pilot experiments (if applicable). If the Registered Report is endorsed following peer-review and the research is conducted according to the approved methodology, the manuscript will be given In Principle Acceptance. Following data collection, the authors should submit a complete manuscript containing the peer-reviewed sections included in the Registered Report, as well as the Results and Discussion sections. If the Results include unregistered analysis, these should be indicated separately as 'Exploratory Analysis'. Authors have 1 year after their registered report is accepted to submit a full manuscript. The format is appropriate for any hypothesis-driven research, including both original studies and replications.
Registered Reports have a maximum word count of 3,000 and may include 2 Figures/Tables. Following data collection, the completed version of the manuscript should follow the guidelines for an Original Research article with a maximum word count of 12,000. Registered Reports incur a A-type article fee, charged after the acceptance of the completed manuscript.

2.4. Figure and Table Guidelines

2.4.1. CC-BY Licence

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

2.4.2. General Style Guidelines for Figures

The maximum number of figures and tables for all article types are shown in the Summary Table. Frontiers requires figures to be submitted individually, in the same order as they are referred to in the manuscript, the figures will then be automatically embedded at the end of the submitted manuscript. Kindly ensure that each table and figure is mentioned in the text and in numerical order.

For graphs, there must be a self-explanatory label (including units) along each axis. For figures with more than one panel, panels should be clearly indicated using labels (A), (B), (C), (D), etc. However, do not embed the part labels over any part of the image, these labels will be added during typesetting according to Frontiers journal style. Please note that figures which are not according to the guidelines will cause substantial delay during the production process.

Permissions may be necessary in the following scenarios:

- Republishing
- Modifying/adapting
- Partial Figures

It is the responsibility of the authors to acquire the licenses, to follow any citation instructions requested by third-party rights holders, and cover any supplementary charges.

2.4.3. General Style Guidelines for Tables

Tables should be inserted at the end of the manuscript. If you use a word processor, build your table in word. If you use a LaTeX processor, build your table in LaTeX. An empty line should be left before and after the table.

Please note that large tables covering several pages cannot be included in the final PDF for formatting reasons. These tables will be published as supplementary material on the online article abstract page at the time of acceptance. The author will notified during the typesetting of the final article if this is the case. A link in the final PDF will direct to the online material.

For additional information, please see our Editorial Policies: 3.5 Image Manipulation.

2.4.4. Figure and Table Requirements

Legends

Legends should be preceded by the appropriate label, for example "Figure 1" or "Table 4". Figure legends should be placed at the end of the manuscript (for supplementary images you must include the caption with the figure, uploaded as a separate file). Table legends must be placed immediately before the table. Please use only a single paragraph for the legend. Figure panels are referred to by bold capital letters in brackets: (A), (B), (C), (D), etc.

Image Size

Figure images should be prepared with the PDF layout in mind, individual figures should not be longer than one page and with a width that corresponds to 1 column or 2 columns.

- **All articles are prepared using the 2 column layout:** 2 column articles can contain images 85 mm or 180 mm wide.

2.4.5. Format

The following formats are accepted:

TIFF (.tif) TIFF files should be saved using LZW compression or any other non-lossy compression method.

JPEG (.jpg)

EPS (.eps) EPS files can be uploaded upon acceptance

Color Image Mode

Images must be submitted in the color mode RGB.

Resolution Requirements

All images must be uploaded separately in the submission procedure and have a resolution of **300 dpi at final size**. Check the resolution of your figure by enlarging it to 150%. If the resolution is too low, the image will appear blurry, jagged or have a stair-stepped effect.

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

Chemical Structures

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

Drawing settings: chain angle, 120° bond spacing, 18% of width; fixed length, 14.4 pt; bold width, 2.0 pt; line width, 0.6 pt; margin width 1.6 pt; hash spacing 2.5 pt. Scale 100% Atom Label settings: font, Arial; size, 8 pt.

Assign all chemical compounds a bold, Arabic numeral in the order in which the compounds are presented in the manuscript text. Figures containing chemical structures should be submitted in a size appropriate for incorporation into the manuscript.

Legibility

Figures must be legible. Check the following:

- The smallest visible text is no less than 8 points in height, when viewed at actual size.
- Solid lines are not broken up.
- Image areas are not pixilated or stair stepped.
- Text is legible and of high quality.
- Any lines in the graphic are no smaller than 2 points width.

2.5. Funding disclosure

Details of all funding sources must be provided in the funding section of the manuscript including grant numbers, if applicable. All Frontiers articles are published with open access under the CC-BY Creative Commons attribution license. Articles published with Frontiers automatically fulfil or exceed the requirements for open access mandated by many institutions and funding bodies, including the National Institutes of Health, the Medical Research Council, Research Councils UK, and the Wellcome Trust. Frontiers submits funding data to the Open Funder Registry which is a funder identification service from CrossRef resulting from collaboration between scholarly publishers and funding agencies.

2.6. Materials and Data Policies

Frontiers is committed to open science and open data, and we strongly encourage authors to maximize the availability of data included in their articles by making generated data publicly available where possible, and ensuring that published data sets are cited in accordance with our data citation guidelines. We aim to achieve the best community standards regarding data availability, ensuring increased levels of transparency and reproducibility in our published articles.

Our policies on data availability are informed by community-driven standards, which Frontiers endorses, such as the Transparency and Openness (TOP) guidelines, and the joint declaration of data citation principles produced by FORCE 11.

2.6.1. Availability of Materials

Authors are strongly encouraged to make all materials used to conduct their research available to other researchers. Research materials necessary to enable the reproduction of an experiment should be clearly indicated in the Materials and Methods section. Relevant materials such as protocols, analytic methods, and study material should preferably be uploaded to an online repository providing a global persistent link/identifier. If this is not possible, authors are strongly encouraged to make this material available upon request to interested researchers, and this should be stated in the manuscript.

Resource Identification Initiative

Authors wishing to participate in the Resource Identification Initiative should cite antibodies, genetically modified organisms, software tools, data, databases, and services using the corresponding catalog number and RRID in your current manuscript. For more information about the project and for steps on how to search for an RRID, please click here.

2.6.2. Availability of Data

Frontiers requires that authors make all data relevant to the conclusions of the manuscript available to editors and reviewers during peer-review to enable complete and objective evaluation of the work described.

We strongly encourage authors to make the raw data supporting the conclusions of the manuscript available in publicly accessible repositories. To comply with best practice in their field of research, authors are required to make certain types of data available to readers at time of publication in specific stable, community-supported repositories such as those listed below. Authors are encouraged to contact our data availability office at datapolicy@frontiersin.org prior to submission with any queries concerning data reporting.

2.6.3. Data Citation Guidelines

Authors are encouraged to cite all datasets generated or analyzed in the study. Where datasets are cited, they should be included in the references list to maximize future usability. The following format should be used:
[Dataset] Author names. (year) Data Title. Repository name. Version. Persistant identifier

2.6.4. Data Availability Statements

Data availability statements are required for all manuscripts published with Frontiers. During the submission process, authors will be asked to detail the location of the raw data underlying the conclusions made in the manuscript, and whether it will be made available to other researchers following publication. Authors will also be asked for the details of any existing datasets that have been analysed in the manuscript. These datasets should be cited in accordance with our data citation guidelines.

A statement will be automatically generated using the information provided in the submission form; however, manuscripts containing incomplete or incorrect statements will be prevented from entering the review process.

Examples of acceptable statements

57. **Datasets are in a publicly accessible repository:**
The datasets [GENERATED/ANALYZED] for this study can be found in the [NAME OF REPOSITORY] [LINK]

58. **Datasets are available on request:**
The raw data supporting the conclusions of this manuscript will be made available by the authors, without undue reservation, to any qualified researcher.

59. **All relevant data is contained within the manuscript:**
All datasets [GENERATED/ANALYZED] for this study are included in the manuscript and the supplementary files.

60. **Restrictions apply to the datasets:**
The datasets for this manuscript are not publicly available because: [VALID REASON]. Requests to access the datasets should be directed to [NAME, EMAIL].

61. **Data has been obtained from a third party:**

The data analyzed in this study was obtained from [SOURCE], the following licenses/restrictions apply [RESTRICTIONS]. Requests to access these datasets should be directed to [NAME, EMAIL].

62. **No datasets were generated for this study**

2.6.5. Recommended and Required Repositories

Authors are required to deposit the following data-types in public, community-supported repositories, such as those listed below, prior to publication of an associated Frontiers manuscript:

Data-type	Recommended Repositories	Metadata Standard
Genetic and genomic sequence (DNA/ RNA)^	GenBank DNA Data Bank of Japan (DDBJ) European Nucleotide Archive (ENA)	MiXS
Metagenomic sequence	EBI Metagenomics	MiXS
DNA and RNA trace or short-read sequencing data	NCBI Trace Archive NCBI Sequence Read Archive	MiXS
Genetic polymorphism data, including SNP and CNV data	dbSNP dbVar European Variation Archive DGVa	MiXS
Gene expression data; chromatin immunoprecipitation data (deep-sequencing or microarray)	ArrayExpress Gene Expression Omnibus (GEO)	MIAME / MINSEQE
Data linking genotype to phenotype	dbGaP	
Protein sequence data	UniProt	
Proteome profiling data	PRIDE PeptideAtlas ProteomeXchange	MIAPE
Small molecule, protein, protein complex data structural data	Crystallography Open Database Cambridge Structural Database wwPDB (Protein DataBank) Electron Microscopy Databank	CIF
Taxonomy data	Zoobank	

^ Genetic sequence variants should be annotated according to the guidelines established by the Human Variome Project.

Authors are encouraged to consider deposition in public, community-supported repositories of the data-types listed below:

Data-type	Recommended Repositories	Metadata Standard

Protein-protein interaction data	Database of Interacting Proteins (DIP)	MIMIx
Metabolite and metabolome profiling data	MetaboLights Human Metabolome Database	MSI
Small-molecule screening data, chemical compound data	PubChem	CIF
Flow cytometry data	Flow Repository	
Brain Imaging data / Neuroimaging data	OpenNeuro INDI NITRC NeuroVault [Statistical maps]	BIDS
Trait data	TRY database	
Phenology data	National Phenology Network	
Any data	FigShare Dryad Digital Repository	None

2.6.6. Inclusion of Zoological Nomenclature

The International Code of Zoological Nomenclature, in a recent 2012 amendment to the 1999 Zoological Code, allows all electronic-only papers, such as those published by the Frontiers journals, to have valid new taxon names and nomenclatural acts. However, these new names or nomenclatural acts must be registered in ZOOBANK and have associated Life Science Identifiers (LSIDs). Registration must be done by the authors before publication. Should your manuscript include any zoological new taxon names and/or nomenclatural acts, please ensure that they are registered prior to final publication.

2.6.7. Inclusion of RNAseq Data

Studies employing RNASeq for comparative transcriptomic analyses must contain at least 3 biological replicates (unless otherwise justified). Each biological replicate should be represented in an independent library, each with a unique barcode if libraries are multiplexed for sequencing. Validation on a number of key transcripts highlighted in the study is also highly recommended.
Full data accompanying these experiments must be made available to reviewers at the time of submission in a freely accessible resource e.g the sequence read archive (SRA) or European Nucleotide Archive (ENA). Depending on the question addressed in a manuscript, de novo assemblies of transcriptomes may also require multiple replicates and assembled sequences together with sequence annotation must be made freely available e.g figshare or dryad.

2.6.8 Inclusion of Proteomics Data

Authors should provide relevant information relating to how peptide/protein matches were undertaken, including methods used to process and analyse data, false discovery rates (FDR) for large-scale studies and threshold or cut-off rates for peptide and protein matches. Further information should include software used, mass spectrometer type, sequence database and version, number of sequences in database, processing methods, mass tolerances used for matching, variable/fixed modifications, allowable missed cleavages, etc.

Authors should provide as supplementary material information used to identify proteins and/or peptides. This should include information such as accession numbers, observed mass (m/z), charge, delta mass, matched mass, peptide/protein scores, peptide modification, miscleavages, peptide sequence, match rank, matched species (for cross-species matching), number of peptide matches, etc. Ambiguous protein/peptide matches should be indicated.

For quantitative proteomics analyses, authors should provide information to justify the statistical significance, including biological replicates, statistical methods, estimates of uncertainty, and the methods used for calculating error.

For peptide matches with biologically relevant post-translational modifications (PTMs) and for any protein match that has occurred using a single mass spectrum, authors should include this information as raw data or annotated spectra, or submit data to an online repository (recommended option; see table below).
Raw or matched data and 2-DE images should be submitted to public proteomics repositories such as those participating in ProteomeXchange. Submission codes and/or links to data should be provided within the manuscript.

2.7. Statistics

Frontiers requires that all statements concerning quantitative differences should be based on quantitative data and statistical testing. For example, if a quantitative statement is made regarding the abundance of a certain protein based on a western blot, we request that the blot be scanned and the abundance assessed quantitatively using the correct analytic software (e.g. ImageJ) and statistics in order to support that statement.

Statistics should/must be applied for independent experiments. The number of independent samples and the deviation parameters (e.g. Standard Error of the Mean, Standard Deviation, Confidence Intervals) should be clearly stated in the Methods or the Figure legends. In general, technical replicates within a single experiment are not considered to be independent samples. Where multiple comparisons are employed (e.g. microarray data or Genome-wide association studies), any analysis should correct for false positive results. Descriptions of statistical procedures should include the software and analysis used, and must be sufficiently detailed to be reproduced.

3. Editorial Policies and Publication Ethics

Frontiers' ethical policies are a fundamental element of our commitment to the scholarly community. These policies apply to all the Frontiers in journal series. Frontiers has been a member of the Committee of Publication Ethics since January 2015 and follows COPE guidelines where applicable.

3.1. Authorship and Author Responsibilities

Frontiers follows the International Committee of Medical Journal Editors guidelines which state that, in order to qualify for authorship of a manuscript, the following criteria should be observed:

- Substantial contributions to the conception or design of the work; or the acquisition, analysis or interpretation of data for the work;
- Drafting the work or revising it critically for important intellectual content;
- Provide approval for publication of the content;

- Agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Contributors, who do not meet these criteria, but nonetheless provided important contributions to the final manuscript should be included in the acknowledgements section. It is the authors responsibility to get written approval by persons named in the acknowledgement section. In order to provide appropriate credit to all authors, as well as assigning responsibility and accountability for published work, individual contributions should be specified as an Author Contributions statement.

This should be included at the end of the manuscript, before the References. The statement should specify the contributions of all authors. You may consult the Frontiers manuscript guidelines for formatting instructions. Please see an example here:

AB, CDE and FG contributed conception and design of the study; AB organized the database; CDE performed the statistical analysis; FG wrote the first draft of the manuscript; HIJ, KL, AB, CDE and FG wrote sections of the manuscript. All authors contributed to manuscript revision, read and approved the submitted version.

The corresponding author takes primary responsibility for communication with the journal and editorial office during the submission process, throughout peer review and during publication. The corresponding author is also responsible for ensuring that the submission adheres to all journal requirements including, but not exclusive to, details of authorship, study ethics and ethics approval, clinical trial registration documents and conflict of interest declaration. The corresponding author should also be available post-publication to respond to any queries or critiques.

Requests to modify the authors list after submission should be made to the editorial office using the authorship changes form.

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Material submitted to Frontiers must comply with the following policies to ensure ethical publication of academic work:

lxvii. *Original content and duplicate publication:* Frontiers only publishes original content. Authors confirm the submission of original content in the Terms & Conditions upon submission. Manuscripts submitted to Frontiers must not have been previously published or be under consideration for publication elsewhere, either in whole or in part. If an article has been previously submitted for publication elsewhere, Frontiers will only consider publication if the article has been definitively rejected by the other publisher(s) at the point of submission to Frontiers.

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lxix. *Fabrication and falsification:* Frontiers opposes both the fabrication of data or images (i.e. fake or made up data) and the falsification of data or images (i.e. the intentional misrepresentation or deceptive manipulation of data).

lxx. *Plagiarism:* Plagiarism occurs when an author attempts to present previously published work as original content. Every manuscript submitted to Frontiers is screened for textual overlap by the software CrossCheck, powered by iThenticate. Manuscripts found to contain textual overlap are not considered for publication by Frontiers. For more details on what constitutes plagiarism, please see here.

We reserve the right to contact the affiliated institutions of authors, who have not acted according to good research and publication practices.

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Frontiers accepts manuscript submissions that are exact translations of previously published work. This should be clearly stated in the manuscript upon submission. Permission from the original publisher and authors needs to be sought and also stated in the manuscript, and the relevant documents should be provided as supplementary data for verification by the Editor and the editorial office. The original work from which the manuscript has been translated should be clearly referenced.

- *"This is a ('language') language translation/reprint of ('insert title here') originally published in ('insert name here'). ('Insert name here') prepared this translation with support from (insert name of funding source, if any). Permission was granted by ('Insert name here')."*

Please note that Frontiers may request copies of related publications if there are any concerns about overlap or possible redundancy.

3.4. Plagiarism and Duplication

Frontiers checks all submitted manuscripts for plagiarism and duplication, and publishes only original content. Those manuscripts where plagiarism or duplication is shown to have occurred will not be considered for publication in a Frontiers journal. It is required that all submissions must consist as far as possible of content that has not been published previously. In accordance with COPE guidelines, we expect that "original wording taken directly from publications by other researchers should appear in quotation marks with the appropriate citations." This condition also applies to an author's own work.

For submissions adapted from theses, dissertations, conference abstracts or proceedings papers, please see the following sections for more information.

Theses and Dissertations

Frontiers allows the inclusion of content which first appeared in an author's thesis so long as this is the only form in which it has appeared, is in line with the author's university policy, and can be accessed online. If the thesis is not archived online, it is considered as original unpublished data and thus is subject to the unpublished data restrictions of some of our article types. This inclusion should be noted in the Acknowledgements section of the manuscript and the thesis should be cited and referenced accordingly in the Reference list. For some examples, please check our in Manuscript Requirements and Style Guide at 2.3.1

Conferences, Proceedings and Abstracts

Manuscripts that first appeared as conference papers must be expanded upon if they are to be considered as original work. You are required to add a substantial amount of original content in the form of new raw material (experiments, data) or new treatment of old data sets which lead to original discussion and/or conclusions, providing value that significantly exceeds the original conference version. As a rule of thumb, at least 30% of content must be original. Authors submitting such work are required to:

- Seek permission for reuse of the published conference paper if the author does not hold the copyright (proof of permission should be submitted as supplementary material or sent to editorial.office@frontiersin.org with the manuscript ID upon submission).
- Cite the conference in the Acknowledgements section, or the references section if applicable.

Blogs

Although permissible, extended manuscript content which previously appeared online in non-academic media, e.g. blogs, should be declared at the time of submission in the acknowledgements section of the manuscript.

3.5. Image Manipulation

Frontiers takes concerns regarding image manipulation seriously. We request that no individual features within an image are modified (eg. enhanced, obscured, moved, recycled, removed or added). Image processing methods (e.g. changes to the brightness, contrast or color balance) must be applied to every pixel in the image and the changes should not alter the information illustrated in the figure. Where cropped images of blots are shown in figures, a full scan of the entire original gel(s) must be submitted as part of the supplementary material. Where control images are re-used for illustrative purposes, this must be clearly declared in the figure legend. If any form of image processing is legitimately required for the interpretation of the data, the software and the enhancement technique must be declared in the methods section of the manuscript. Image grouping and splicing must be clearly stated in the manuscript and the figure text. Any concerns raised over undeclared image modifications will be investigated and the authors will be asked to provide the original images.

3.6. Conflicts of Interest

A conflict of interest can be anything potentially interfering with, or that could reasonably be perceived as interfering with, full and objective peer review, decision-making or publication of articles submitted to Frontiers. Personal, financial and professional affiliations or relationships can be perceived as conflicts of interest.

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The Frontiers review system is designed to guarantee the most transparent and objective editorial and review process, and because handling editor and reviewers' names are made public upon the publication of articles, conflicts of interest will be widely apparent.
Failure to declare competing interests can result in the rejection of a manuscript. If an undisclosed competing interest comes to light after publication, Frontiers will take action in accordance with internal policies and Committee on Publication Ethics guidelines.

What Should I Disclose?

As an author, disclosure of any potential conflicts of interest should be done during the submission process. Consider the following questions and make sure you disclose any positive answers:

72. Did you or your institution at any time receive payment or services from a third party for any aspect of the submitted work?

73. Do you have financial relationships with entities that could be perceived to influence, or that give the appearance of potentially influencing, what you wrote in the submitted work?
74. Do you have any patents and copyrights, whether pending, issued, licensed and/or receiving royalties related to the research?
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If you failed to disclose any of the potential conflicts of interest above during submission, or in case of doubt, please contact as soon as possible the Frontiers Editorial Office at editorial.office@frontiersin.org with the details of the potential conflicts.

Example statement: “Author xxx was employed by company xxxx. All other authors declare no competing interests.”

The handling editors and reviewers will be asked to consider the following potential conflicts of interest before accepting any editing or review assignment:

FAMILY	1. Are any of the authors a spouse or significant other, a member of the same family or a very close personal friend? Review Editors should also not be a member of the same family as the handling editor.
	2. Are you currently hosting or have hosted a Frontiers Research Topic with any of the authors within the past 2 years? Are you currently hosting a Frontiers Research Topic with the Editor? 3. Are you currently collaborating or have you collaborated on a research project or a publication with any of the authors within the past 2 years?
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3.7. Bioethics

All research submitted to Frontiers for consideration must have been conducted in accordance with Frontiers guidelines on study ethics. In accordance with COPE guidelines, Frontiers reserves the right to reject any manuscript that editors believe does not uphold high ethical standards, even if authors have obtained ethical approval or if ethical approval is not required.

3.7.1. Studies involving animal subjects

All research involving regulated animals (i.e. all live vertebrates and higher invertebrates) must be performed in accordance with relevant institutional and national guidelines and regulations.
Frontiers follows International Association of Veterinary Editors guidelines for publication of studies including animal research. Approval of research involving regulated animals must be obtained from the relevant institutional review board or ethics committee prior to commencing the study.
Confirmation of this approval is required upon submission of a manuscript to Frontiers; authors must provide a statement identifying the full name of the ethics committee that approved the study.
For most article types, this statement should appear in the Materials and Methods section. An example ethics statement:

This study was carried out in accordance with the principles of the Basel Declaration and recommendations of [name of guidelines], [name of committee]. The protocol was approved by the [name of committee].

Should the study be exempt from ethics approval, authors need to clearly state the reasons in the declaration statement and in the manuscript. Studies involving privately owned animals should demonstrate the best practice veterinary care and confirm that informed consent has been granted by the owner/s, or the legal representative of the owner/s. Frontiers supports and encourages authors to follow the ARRIVE guidelines for the design, analysis and reporting of scientific research.

Humane Endpoints

All manuscripts describing studies where death is an endpoint will be subject to additional ethical considerations. Frontiers reserves the right to reject any manuscripts lacking in appropriate justification.

3.7.2. Studies involving human subjects

Research involving human subjects is expected to have been conducted in accordance with the World Medical Association’s Declaration of Helsinki. Studies involving human participants must be performed in accordance with relevant institutional and national guidelines, with the appropriate institutional ethics committee's prior approval and informed written consent from all human subjects involved in the study including for publication of the results. Conformation of this approval is required upon submission of a manuscript to Frontiers; authors must provide a statement identifying the full name of the ethics committee that approved the work and confirm that study subjects (or when appropriate, parent or guardian) have given written informed consent. For most article types, this statement should appear in the Materials and Methods section. An example ethics statement:

This study was carried out in accordance with the recommendations of [name of guidelines], [name of committee]. The protocol was approved by the [name of committee]. All subjects gave ***written informed consent*** *in accordance with the Declaration of Helsinki.*

Should the study be exempt from ethics approval, authors need to clearly state the reasons in the declaration statement and in the manuscript. In order to protect subject anonymity, identifying information should not be included in the manuscript unless such information is absolutely necessary for scientific purposes AND explicit approval has been granted by the subjects.

3.7.3. Inclusion of identifiable human data

Frontiers follows the ICMJE recommendations on the protection of research participants, which state that patients have a right to privacy that should not be violated without informed consent. We require non-essential identifiable details to be omitted from all manuscripts, and written informed consent will be required if there is any doubt that anonymity can be maintained.
It is the responsibility of the researchers and authors to ensure that these principles are complied with, including the obtaining of written, informed consent.

Written informed consent can be documented on a form provided by an institution or ethics committee, and it must clearly state how the identifiable data will be used. Frontiers also makes available its own form , which may be used for this purpose, but use of the Frontiers form is not required if a suitable alternative form of consent, meeting the ICMJE recommendations, is used. We consider it to be the author' duty to encourage participants or patients whose consent for publication is required to read and understand the ICMJE guidelines, for their information prior to completing the consent form. Participants should also be encouraged to ask any questions and to ensure they are comfortable before they sign the consent form.

The completed consent forms should be stored by authors or their respective institutions, in accordance with institutional policies. Frontiers does not need to view the completed form, and this should not be included with the submission. The completed form should be made available on request from the editor or editorial office, both during the review process and post-publication.
The determination of what constitutes identifiable data lies with our editors and editorial office staff, and manuscripts may be rejected if the required consent documents cannot be provided. Please note that written informed consent for publication is required for all case report articles where the patient or subject is identified or identifiable.

3.7.4. Clinical Trials

The World Health Organization defines a clinical trial as "any research study that prospectively assigns human participants or groups of humans to one or more health-related interventions to evaluate the effects on health outcomes." In accordance with the Clinical Trial Registration Statement from the International Committee of Medical Journal Editors (ICMEJ), all clinical trials must be registered in a public trials registry at or before the onset of participant enrolment. This requirement applies to all clinical trials that begin enrolment after July 1, 2005. To meet the requirements of the ICMJE, and Frontiers', clinical trials can be registered with any Primary Registry in the WHO Registry Network or an ICMJE approved registry.

Clinical trial reports should be compliant with the [Consolidated Standards of Reporting Trials (CONSORT)] both in terms of including a flow diagram presenting the enrolment, intervention allocation, follow-up, and data analysis with number of subjects for each and taking into account the CONSORT Checklist of items to include when reporting a randomized clinical trial.
The information on the clinical trial registration (Unique Identifier and URL) must be included in the abstract.

3.8. Corrections

Frontiers recognizes our responsibility to correct errors in previously published articles. If it is necessary to communicate important, scientifically relevant errors or missing information, and compelling evidence can be shown that a major claim of the original article was incorrect, a Correction should be submitted detailing the reason(s) for and location(s) of the change(s) needed using the below template. Corrections can be submitted if a small portion of an otherwise reliable publication proves to be misleading, e.g. an error in a figure that does not alter conclusions OR an error in statistical data not altering conclusions OR mislabeled figures OR wrong slide of microscopy provided, or if the author / contributor list is incorrect when a deserving author has been omitted or somebody who does not meet authorship criteria has been included. The contribution to the field statement should be used to clearly state the reason for the Correction. Please note, a correction is not intended to replace the original manuscript.

The title of the submission should have the following format: "Corrigendum: Title of original article".
It is advised to use the corrigendum Word and LaTeX templates.
If the error was introduced during the publishing process, the Frontiers Production Office should be contacted.

3.9. Retractions

As a member of the Committee on Publication Ethics (COPE), Frontiers abides by their guidelines and recommendations in cases of potential retraction.

Frontiers also abides by two other key principles, as recommended by COPE:

- Retractions are not about punishing authors.
- Retraction statements should be public and linked to the original, retracted article.

While all potential retractions are subject to an internal investigation and will be judged on their own merits, Frontiers considers the following reasons as giving cause for concern and potential retraction:

- Clear evidence that findings are unreliable, either as a result of misconduct (e.g. data fabrication) or honest error (e.g. miscalculation or experimental error)
- Findings have previously been published elsewhere without proper attribution, permission or justification (i.e. cases of redundant publication)
- Major plagiarism
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- Politically-motivated articles where objectivity is a serious concern
- The singling out of individuals or organizations for attack
- Faith issues (e.g. intelligent design)

- Papers that have made extraordinary claims without concomitant scientific or statistical evidence (e.g. pseudoscience)

Readers who would like to draw the editors' attention to published work that might require retraction should contact the authors of the article and write to the journal, making sure to include copies of all correspondence with authors.

Please find more details on our comments and complaints policy here

3.10. Support and Ethical concerns

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For any ethical concerns, please contact us at editorial.office@frontiersin.org.

Journal of Gait and Posture – Article Two and Four

Guide for Authors

Aims and scope

JOURNAL DESCRIPTION

Gait and Posture publishes new and innovative basic and clinical research on all aspects of human movement, locomotion and balance.

The topics covered include: Techniques for the measurement of **gait** and **posture,** and the standardization of results presentation; Studies of normal and **pathological gait**; Treatment of gait and **postural abnormalities**; Biomechanical and theoretical approaches to gait and posture; Mathematical models of **joint** and **muscle mechanics**; **Neurological** and **musculoskeletal** function in gait and posture; The evolution of **upright posture** and **bipedal locomotion**; Adaptations of carrying loads, walking on uneven surfaces, climbing stairs, running and performing other movements. Spinal biomechanics only if they are directly related to gait and/or posture and are of general interest to our readers; The effect of aging and development on gait and posture; Psychological and cultural aspects of gait; Patient education.

Submission checklist

You can use this list to carry out a final check of your submission before you send it to the journal for review. Please check the relevant section in this Guide for Authors for more details.

Ensure that the following items are present:

One author has been designated as the corresponding author with contact details:

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All necessary files have been uploaded:

Manuscript:

- Include 3-5 keywords
- Include a structured abstract (see below for format)
- All figures (include relevant captions)
- All tables (including titles, description, footnotes)
- Ensure all figure and table citations in the text match the files provided
- Indicate clearly if color should be used for any figures in print
- Graphical Abstracts / Highlights files (where applicable)
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Further considerations

- Manuscript has been 'spell checked' and 'grammar checked'
- All references mentioned in the Reference List are cited in the text, and vice versa

- Permission has been obtained for use of copyrighted material from other sources (including the Internet)
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- Journal policies detailed in this guide have been reviewed
- Referee suggestions and contact details provided, Based on journal requirements

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Author contributions

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Authorship

All authors should have made substantial contributions to all of the following: (1) the conception and design of the study, or acquisition of data, or analysis and interpretation of data, (2) drafting the article or revising it critically for important intellectual content, (3) final approval of the version to be submitted.

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In line with the position of the International Committee of Medical Journal Editors, the journal will not consider results posted in the same clinical trials registry in which primary registration resides to be prior publication if the results posted are presented in the form of a brief structured (less than 500 words) abstract or table. However, divulging results in other circumstances (e.g., investors' meetings) is discouraged and may jeopardise consideration of the manuscript. Authors should fully disclose all posting in registries of results of the same or closely related work.

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Introduction

State the objectives of the work and provide an adequate background, avoiding a detailed literature survey or a summary of the results.

1. Article types accepted are: Original Article (Full Paper or Short Communication), Review Article,

Book Review. Word limits are as follows: Full Paper 3,000 words plus no more than 6 figures/tables in total; Short Communication 1,200 words plus no more than 3 figures/tables in total.The recommended word limit for Review Papers is 6,000 words. The word limits are non-inclusive of figures, tables, references, and abstracts. If the Editor feels that a paper submitted as a Full Paper would be more appropriate for the Short Communications section, then a shortened version will be requested. References should be limited to 30 for Full Papers; and 15 for Short Papers; there is no limit for review articles. A structured abstract of no more than 300 words should appear at the beginning of each Article. Authors must state the number of words when submitting.

Short Communications are intended to introduce new techniques that improve the analysis and evaluation of human movement. This article type is not for preliminary or case studies, and such submissions will be rejected without review. Authors submitting a Short Communication should justify why it is a Short Communication rather than a Full Paper in their cover letter. Gait and Posture does not accept case reports.

All papers should contribute to improved understanding of human movement, particularly in clinical populations, and must therefore include a statement of significance in both the structured abstract and the main text. The contribution may be methodological; however Articles that simply validate existing methods or technologies are discouraged. Validation of methodology should instead be included within a larger study in which the methodology is used to answer a clinically relevant question.

2. All publications will be in English. Authors whose 'first' language is not English should arrange for their manuscripts to be written in idiomatic English **before** submission. A concise style avoiding jargon is preferred.

3. Authors should supply up to five keywords that may be modified by the Editors.

4. Authors should include a structured abstract of no more than 300 words including the following headings: Background, Research question, Methods, Results and Significance. The scientific and clinical background should be explained in 1-2 sentences. One clear scientifically relevant question should be derived from the background which represents the principle research question of the paper. This should be framed specifically as a question not simply as a description. The Methods section should summarise the core study methodology including the type of study (prospective/retrospective, intervention etc), procedures, number of participants and statistical methods. The Results section should summarise the study's main findings. The Significance section should place the results into context. Furthermore this section should highlight the clinical and/or scientific importance of the work, answering the question "so what?" This section should not simply repeat the study results or conclusions.

5. Acknowledgements should be included in the title page. Include external sources of support.

6. The text should be ready for setting in type and should be carefully checked for errors. Scripts should be typed double-spaced on one side of the paper only. Please do not underline anything, leave wide margins and number every sheet.

7. All illustrations should accompany the typescript, but not be inserted in the text. Refer to photographs, charts, and diagrams as 'figures' and number consecutively in order of appearance in the text. Substantive captions for each figure explaining the major point or points should be typed on a separate sheet.

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9. Authors should also note that files containing text, figures, tables or multimedia data can be placed in a supplementary data file which will be accessible via ScienceDirect (see later section for further details).

What information to include with the manuscript

Having read the criteria for submissions, authors should specify in their letter of transmittal whether they are submitting their work as an Original Article (Full Paper or Short Communication), Review Article, or Book Review. Emphasis will be placed upon originality of concept and execution. Only papers not previously published will be accepted. Comments regarding articles published in the Journal are solicited and should be sent as "Letter to the Editor". Such Letters are subject to editorial review. They should be brief and succinct. When a published article is subjected to comment or criticism, the authors of that article will be invited to write a letter or reply.

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All contributors who do not meet the criteria for authorship as defined above should be listed in an acknowledgements section. Examples of those who might be acknowledged include a person who provided purely technical help, writing assistance, or a department chair who provided only general support. Authors should disclose whether they had any writing assistance and identify the entity that paid for this assistance.

Work on human beings that is submitted to *Gait & Posture* should comply with the principles laid down in the Declaration of Helsinki; Recommendations guiding physicians in biomedical research involving human subjects. Adopted by the 18th World Medical Assembly, Helsinki, Finland, June 1964, amended by the 29th World Medical Assembly, Tokyo, Japan, October 1975, the 35th World Medical Assembly, Venice, Italy, October 1983, and the 41st World Medical Assembly, Hong Kong, September 1989. The manuscript should contain a statement that the work has been approved by the appropriate ethical committees related to the institution(s) in which it was performed and that subjects gave informed consent to the work. Studies involving experiments with animals must state that their care was in accordance with institution guidelines. Patients' and volunteers' names, initials, and hospital numbers should not be used.

All Articles should include a justification of their sample size. While there is no set requirement for minimum sample size, studies considered to have too small a sample size to answer the research question will be rejected.

At the end of the text, under a subheading "Conflict of interest statement" all authors must disclose any financial and personal relationships with other people or organisations that could inappropriately influence (bias) their work. Examples of potential conflicts of interest include employment, consultancies, stock ownership, honoraria, paid expert testimony, patent applications/registrations, and grants or other funding.

All sources of funding should be declared as an acknowledgement. Authors should declare the role of study sponsors, if any, in the study design, in the collection, analysis and interpretation of data; in the writing of the manuscript; and in the decision to submit the manuscript for publication. If the study sponsors had no such involvement, the authors should so state.

Authors are encouraged to suggest referees although the choice is left to the Editors. If you do, please supply their postal address and email address, if known to you.

Please note that papers are subject to single-blind review whereby authors are blinded to reviewers.

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All randomised controlled trials submitted for publication in *Gait & Posture* should include a completed Consolidated Standards of Reporting Trials (CONSORT) flow chart. Please refer to the CONSORT statement website at http://www.consort-statement.org for more information. The Journal has adopted the proposal from the International Committee of Medical Journal Editors (ICMJE) which require, as a condition of consideration for publication of clinical trials, registration in a public trials registry. Trials must register at or before the onset of patient enrolment. The clinical trial registration number should be included at the end of the abstract of the article. For this purpose, a clinical trial is defined as any research project that prospectively assigns human subjects to intervention or comparison groups to study the cause-and-effect relationship between a medical intervention and a health outcome. Studies designed for other purposes, such as to study pharmacokinetics or major toxicity (e.g. phase I trials) would be exempt. Further information can be found at http://www.icmje.org.

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Following assessment one of the following will happen:

A: The paper will be accepted directly. The corresponding author will be notified of acceptance by e-mail or letter. The Editor will send the accepted paper to Elsevier for publication.

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Journal of Early Human Development – Article Three

Early Human Development

Guide for Authors

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Provide sufficient details to allow the work to be reproduced by an independent researcher. Methods that are already published should be summarized, and indicated by a reference. If quoting directly from a previously published method, use quotation marks and also cite the source. Any modifications to existing methods should also be described.

Results

Results should be clear and concise.

Appendices

If there is more than one appendix, they should be identified as A, B, etc. Formulae and equations in appendices should be given separate numbering: Eq. (A.1), Eq. (A.2), etc.; in a subsequent appendix, Eq. (B.1) and so on. Similarly for tables and figures: Table A.1; Fig. A.1, etc.

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Structured Abstract not exceeding 250 words should be given at the beginning of the paper. The Abstract should include: background, aims, study design, subjects, outcome measures, results and conclusions.

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Acknowledgements

Collate acknowledgements in a separate section at the end of the article before the references and do not, therefore, include them on the title page, as a footnote to the title or otherwise. List here those individuals who provided help during the research (e.g., providing language help, writing assistance or proof reading the article, etc.).

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List funding sources in this standard way to facilitate compliance to funder's requirements:

Funding: This work was supported by the National Institutes of Health [grant numbers xxxx, yyyy]; the Bill & Melinda Gates Foundation, Seattle, WA [grant number zzzz]; and the United States Institutes of Peace [grant number aaaa].

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Tables should be typed, with double spacing, each on a separate sheet, numbered consecutively with arabic numerals, and should only contain horizontal lines. A short descriptive heading should be given above each table, and any footnotes and explanations underneath.

References

References should be in the Vancouver style. For more details refer Reference Style

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Examples:

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[1] J. van der Geer, J.A.J. Hanraads, R.A. Lupton, The art of writing a scientific article, J. Sci. Commun. 163 (2010) 51–59. https://doi.org/10.1016/j.Sc.2010.00372.

Reference to a journal publication with an article number:

[2] J. van der Geer, J.A.J. Hanraads, R.A. Lupton, 2018. The art of writing a scientific article. Heliyon. 19, e00205. https://doi.org/10.1016/j.heliyon.2018.e00205.

Reference to a book:

[3] W. Strunk Jr., E.B. White, The Elements of Style, fourth ed., Longman, New York, 2000.

Reference to a chapter in an edited book:

[4] G.R. Mettam, L.B. Adams, How to prepare an electronic version of your article, in: B.S. Jones, R.Z. Smith (Eds.), Introduction to the Electronic Age, E-Publishing Inc., New York, 2009, pp. 281–304.

Reference to a website:

[5] Cancer Research UK, Cancer statistics reports for the UK. http://www.cancerresearchuk.org/aboutcancer/statistics/cancerstatsreport/, 2003 (accessed 13 March 2003).

Reference to a dataset:

[dataset] [6] M. Oguro, S. Imahiro, S. Saito, T. Nakashizuka, Mortality data for Japanese oak wilt disease and surrounding forest compositions, Mendeley Data, v1, 2015. https://doi.org/10.17632/xwj98nb39r.1.

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You can access the review forum and track the progress of your manuscript using the following link:
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Manuscript title: The profile and development of the lower limb in setswana-speaking children between the ages of 2-to 9 years
Manuscript ID: 497581
Submitted By: Stanislaw H. Czyz
Authors: Mariaan Van Aswegen, Stanislaw H. Czyz, Sarah Johanna Moss
Journal: Frontiers in Pediatrics, section Children and Health

Article type: Original Research
Submitted on: 12 Sep 2019

-----------ADDITIONAL INFORMATION-----------

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Submission notice – Gait and Posture

Dear Mrs. van Aswegen,

You have been listed as a Co-Author of the following submission:
Journal: Gait & Posture
Title: Back-carrying in Setswana-speaking children related to lower limb development
Corresponding Author: Stanislaw Czyz
Co-Authors: Mariaan van Aswegen, Sarah Moss, Francois Steffens

Stanislaw Czyz submitted this manuscript via Elsevier's online submission system, EVISE®. If you are not already registered in EVISE®, please take a moment to set up an author account by navigating to http://www.evise.com/evise/faces/pages/navigation/NavController.jspx?JRNL_ACR=GAIPOS

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Thank you,
Gait & Posture
This message was sent automatically. Please do not reply

APPENDIX G: QUESTIONNAIRE

KNEE DEVELOPMENT OF TODDLERS & CHILDREN IN NORTH WEST PROVINCE QUESTIONNAIRE

DIPOTSOLOTSO KA GA NONOFO YA LENGOELE LA NGWANA YO O SIMOLOLANG GO TSAMAYA & BANA KA KAKARETSO MO POROFENSENG YA BOKONEBOPHIRIMA.

The following survey is supplementary to the biomechanical investigation that your child will undergo. It is an anonymous and voluntary survey and you may withdraw at any time. Please ensure that your name does not appear on the questionnaire to guarantee confidentiality. Please write your contact details on the separate sheet, to allow us to confirm certain answers if necessary.

Patlisiso e e latelang ke ya tlaleletso go tlhotlhomisi ya biomechanical e ngwana wa gago a tlaa e tsenelang. Ke patlisiso ya sephiri le ya boithaopo mme o ka ikgogela morago nako nngwe le nngwe. Tswee tswee, netefatsa fa leina la gago le sa tlhagelele ka gope mo dipotsolotsong tse go netefatsa fa e le ya sephiri tota. Ka kopo kwala dintlha tse re ka ikgolaganyang le wena ka tsona mo letlhareng le le kwa thoko, go re neela tetla ya go netefatsa dintlha dingwe fa go tlhokega.

Please read the following questions carefully. Mark the correct blocks, or when asked please write your answer.
The main investigator will contact you if there are any blank areas.
Tswee tswee, buisa dipotso tse di latelang ka kelotlhoko.
Tshwaya diboloko tse di nepagetseng kgotsa fa o bodiwa potso, tswee tswe kwala karabo ya gago.
Mmatlisismogolo o tlaa ikgolaganya le wena fa go na le dintlha dingwe tse o sa di tlatsang.

Your participation in this important study is greatly appreciated.
Re lebogela go tsaya karolo ga gago go go botlhokwa mo patlisisong e.

Section 1: Personal Background Information
Karolo 1: Lemorago la Tshedimosetso ya Mmotsolotswa

This section is to gather background information about the <u>parent or guardian</u>, who <u>spends the most time</u> taking care of the child being investigated.
Karolo e, ke go kokoanya lemorago la tshedimosetso ka ga <u>motsadi kgotsa motlhokomedi</u> yo o tlholang a tlhokometse ngwana ka dinako tse tsotlhe.

1.1	Date of Birth (parent) *Letlha la matsalo*	d d m m y y y y	
1.2	Age *Dingwaga*	☐☐	
1.3	Sex *Bong*	☐ Male *Monna*	☐ Female *Mosadi*
1.4	Occupation *Tiro*	☐ Stay at home caregiver *Motlhokomedi Yo o nnang kwa gae*	
		☐ Half day position *A o dira halofo ya letsatsi*	____________ (eg. Secretary / *sk. Mokwaledi*)
		☐ Full day position *Tiro ya letsatsi lotlhle / ya nako e e tletseng*	____________

1.5 Highest education (Mark only one)
O feletse kae ka dithuto? (*Tshawaya e le nngwe fela*)

☐	Primary school *Sekolo se se potlana*	Grade *Mophato* ________
☐	High school *Sekolo se segolo*	Grade *Mophato* ________
☐	Matric certificate *Setifikeite sa Marematlou / Materiki*	
☐	Diploma in.. *Dipoloma*	____________
☐	Degree in.. *Digerata*	____________
☐	Honours in.. *Onase*	____________

☐ PhD
Dithuto tsa BoNgaka ______________________

1.6 Place of residency
Lefelo la bonno

☐ Potchefstroom
☐ Ikageng
☐ Mohadin
☐ Promosa
☐ Other
A mangwe: ______________________

☐ Shanti / Shack
Mokhukhu
☐ Flat / Townhouse
Folete/Ntlo ya setoropo
☐ House
Ntlo
☐ Other:
E nngwe: ______________________

1.7 If the child is <u>currently still</u> being back-carried: Please measure the following circumferences of the primary care provider, who mostly carries the child:
Fa ngwana a sa ntse a pepiwa: Tsweetswe meta bokgolokwe jwa motlhokomedi yo a tlholang a pepa ngwana.

Measure the waist circumference around the narrowest part of the waist, and the hip around the widest part, over the hips:
Meta bokgolokwe jwa letheka kwa bo tlaseng jwa letheka le bophara jwa noka.

Waist circumference:
Bokgolokwe jwe letheka: ☐☐☐ cm

Hip circumference:
Bokgolokwe jwa noka: ☐☐☐ cm

1.8 Stature:
Popego: ☐☐☐ m

1.9 Does any member of the child's direct family members (Parents, Grandparents, siblings) suffer from any of the following conditions:
A go na le mongwe wa lelapa la ngwana (Batsadi, Bonkgolo, Boabuti/Boausi) ba ba nang le nngwe ya seemo se se latelang?)

☐ Bone related problems
Mathata a tsamaelang le marapo
(Orthopaedic disorders)
E.g. Arthritis, Hip dysplasia, clubfoot

please specify:
Tsweetswe kaya: ______________________

☐ Nerve problems
Mathata a tshika ya kutlo
(Neuromuscular disorders / disease)
E.g. Parkinson's, Multiple sclerosis etc.

please specify:
Tsweetswe kaya: ______________________

☐ Muscle problems
Mathata a mosifa
(Muscular disorders)
E.g. Muscular Dystrophy, Polymyositis

please specify:
Tsweetswe kaya: ______________________

☐ Food intake problems
Mathata a go tlhaela dikotla
(Nutritional deficiencies):
E.g. Rickets / *Digoro*, Scurvey, Kwashiorkor / *Kwashioko*

please specify:
Tsweetswe kaya: ______________________

☐ Other: please specify:
Tse dingwe: Tsweetswe kaya: ______________________

____

Section 2: Child demographics and developmental questions
Karolo 2: Dintlha tsa ngwana tsa botso le dipotso tsa kgodiso

This section asks questions on the child's demographics and questions on when the child started walking and whether or not he/she has any leg deformities such as bow-legs ("brackets" or "bullet hole"), or knock-knees ("kiss-kiss").
Karolo e, e botsa dipotso tsa botso jwa ngwana le dipotso tsa go re ngwana o simolotse leng go go tsamaya le gore a mme o na le go sa iketlang mo lengwe la leoto jaaka bow-legs (Digoro or bullet hole) kgotsa mangole a a thulanang (Kiss-Kiss).

2.1 Date of Birth (child) / *Letlha la matsalo (ngwana)*

d	d	m	m	y	y	y	y

2.2 Age (child) / *Dingwaga* ☐☐

2.3 Sex (child) / *Bong (ngwana)*
- ☐ Male / *Monna*
- ☐ Female / *Mosadi*

2.4 Place of birth (child) / *Letlha la matsalo (ngwana)*
- ☐ Potchefstroom
- ☐ Ikageng
- ☐ Mohadin
- ☐ Promosa
- ☐ Other / *A mangwe*

2.5 When did the child start walking on his own?
Ngwana o simolotse leng go tsamaya ka boene?

- ☐ Very early, around 7 to 8 months
  Ka bonakonako, mo kgweding ya bosupa go ya borobedi
- ☐ Early, around 9 to 10 months
  Ka bonako, mo kgweding ya borobongwe go ya bo lesome
- ☐ Normal, around 11 to 12 months
  Ka tlwaelo, ka bo kgwedi ya bolesomelebongwe go ya go ya somelebobedi
- ☐ Little later, around 13 to 14 months
  Kwa pelenyana, ka bo kgwedi ya bolesomeleboraro go ya go ya bolesomenne
- ☐ Later around 15 to 16 months
  Kwa pele, ka bo kgwedi ya bolesomelebotlhano go ya go ya bolesomeleborataro
- ☐ Much later, around 17 to 18 months
  Kwa pele thata, ka bo kgwedi ya bolesomelebosupa go ya go ya bolesomeleborobedi)
- ☐ Other: please state the age:
  E nngwe, tsweetswe kaya dingwaga: ____________________

2.6 Have you noticed any leg deformity on the child?
A o bone go sa iketlang mo leotong la ngwana?
- ☐ No / *Nnyaa*
- ☐ Yes / *Ee*

If yes, please specify:
Fa go le jalo, tsweetswe kaya jalo:

- ☐ Bow legs ("brackets" or "bullet hole")
  Digoro/Digobo kgotsa "bullet hole"
- ☐ Knock-knees ("kiss-kiss")
  Mangole a a Gotlhanang "kiss-kiss"
- ☐ Clubfoot
- ☐ Other, please specify:
  E nngwe, tsweetswe kaya jalo: ____________________

If yes, when did you notice it the first time?
Fa go le jalo, o le bone leng la ntlha?

- ☐ At birth
  Ka pelego
- ☐ When he/she started walking
  Fa a simololola go tsamaya
- ☐ Other, please state when:
  E nngwe, Tsweetswe kaya go re leng: ____________________

If yes, is the deformity…
Fa go le jalo, a go sa iketlang go a …

- ☐ Improving / *Tokafala*
- ☐ Staying the same / *Go nna go ntse go tshwana*
- ☐ Getting worse / *Go ketefalela/kwa pele*
- ☐ Changing - e.g. from bow-leg to knock-knee
  Go a fetoga, sk. Go tswa go bow-leg go ya go knock-knee

Section 3: Influencing factors
Karolo ya 3: Mabaka a a tlhotlheletsang maemo

This section asks questions on the child's sport participation and other activities and how the child was primarily carried.
Karolo e, e botsa dipotso ka ga botsayakarolo jwa ngwana mo metshamekong le ditiro tse dingwe le ka ga gore ngwana o ne a tshotswe jang bogolo jwa nako.

Rate the following questions on a scale of 0 to 5. Circle the appropriate number
Seelo sa dipotso tse di latelang mo sekaleng sa 0 go ya go 5. Sekeletsa palo e e maleba.

0 = not at all, 1 = very little, 2 = little, 3 = average, 4 = often, 5 = always / very often
0 = Le e seng, 1 = go le gonnye thata, 2 = go le gonnye, 3 = ka selekano, 4 = ka dinako dingwe, 5 = ka dinako tsotlhe /ka sewelo

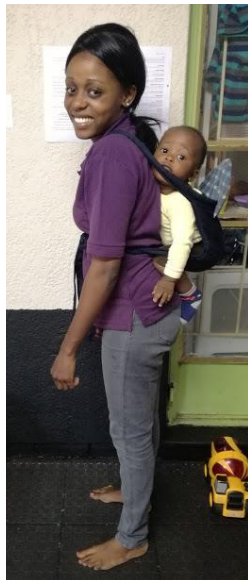
3.1	The child enjoys playing outside and to be active *Ngwana o itumelela go tshamekela kwa ntle le go nna a le matlhagatlhaga*	0	1	2	3	4	5
3.2	The child likes to sit and play quietly *Ngwana o rata go nna a tshameka ka setu*	0	1	2	3	4	5
3.3	The child likes to run, hop, jump and climb *Ngwana o rata go tabogakaka, a kotamakotama, a tlolatlola le go palama dilo*	0	1	2	3	4	5
3.4	The child plays street soccer and or other team sports *Ngwana o tshameka kgwele ya dinao ya kwa mmileng le metshameko e mengwe ya ditlhopha*	0	1	2	3	4	5
3.5	The child attends regular sport practice sessions *Ngwana o tsenela diikatiso tsa metshameko ka tlhomamo*	0	1	2	3	4	5

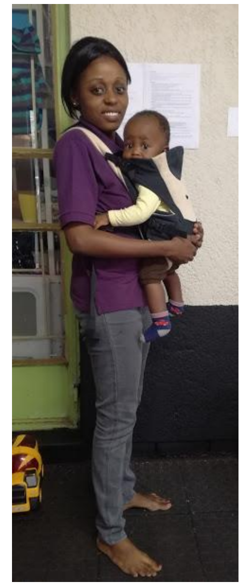
3.6 Was/Is the child carried on the back? ("Pepa")
A ngwana o ne a/o a pepiwa?
☐ No / *Nnyaa* ☐ Yes / *Ee*

How was/is the child mostly carried on the back? Rate how often below for each relevant carrying position. Circle the appropriate number:
Ngwana a ne a/o pepiwa jang go le gantsi? Neela seelo sa sebaka se o neng/a pepiwa ka sona fa tlase fa go maemo mangwe le mangwe a a maleba. Sekeletsa palo e e nepagetseng.

0 = never, 1 = very little, 2 = sometimes, 3 = average, 4 = often, 5 = always / very often
0 = Le e seng, 1 = go le gonnye thata, 2 = go le gonnye, 3 = ka selekano, 4 = ka dinako dingwe, 5 = ka dinako tsotlhe /ka sewelo.

3.7	☐ On the back Legs spread *Mo mokwatleng* *Maoto a paraletse*	☐ On the back Legs down *Mo mokwatleng* *Maoto a lepeletse*	☐ On the side *Mo letlhakoreng*	☐ At the front Legs down *Maoto lepelepetse kwa tlase*
	0-1-2-3-4-5	0-1-2-3-4-5	0-1-2-3-4-5	0-1-2-3-4-5



If yes, to which age was/is the child carried?
Fa o re ee, o ne a pepiwa go fitlha a nna kana kang?

☐ 1 year
Ngwaga o le 1

☐ 2 years
Dingwaga di le 2

☐ Other: please state the age:
Tse dingwe: Tsweetswe neela dingwaga tsa ngwana: ___________

☐ 3 years
Dingwaga di le 3

☐ 4 years
Dingwaga di le 4

If yes, for which purpose(s) is/was the child carried on the back? (Mark all relevant ones)
Fa o re ee, o ne o mo pepela eng? Neela lebaka. (Tshwaya dikarabo tsotlhe tse di leng maleba fa)

☐ To soothe him/her when he/she started crying
Go mo tuntuletsa fa a simolola go lela

☐ To keep him/her safe and happy while I work
Go mo tshola a babalesegile le go mo itumedisa fa nna ke tsweletse ke dira (bereka)

☐ For transport when I walked to town
Go mo pepela go tsamaya le ena jaaka go ya kwa toropong

☐ For transport while I went shopping
Go mo pepela go tsamaya le ena jaaka go ya kwa mebenkeleng

☐ It is my belief / culture that babies must be carried on the back
Ke tumelo ya me / setso sa me gore bana ba pepiwe mo mokwatleng

☐ For medical reasons - the Doctor told me to
Ke mo pepela mabaka a kalafi – Ngaka ya me o ntaetse jaalo

☐ Other reasons:
Mabaka a mangwe: ____________________

If yes, how many hours did the child spend on your back per day?
Fa o re ee, ngwana o nnile sebaka sa diura di le kae mo mokwatleng wa gago ka letsatsi?

☐ 30 minutes to 1 hour per day
Metsotso e le 30 go ya go ura e le 1 ka letsatsi

☐ 2-3 hours per day
Diura di le 2-3 ka letsatsi

☐ 4-5 hours per day
Diura di le 4-5 ka letsatsi

☐ 6-7 hours per day
Diura di le 6-7 ka letsatsi

☐ other: please specify:
Tse dingwe: Tsweetse totobatsa: ____________________

3.2 Was/Is the child swaddled in blankets? ☐ No ☐ Yes
A ngwana o ne a potokiwa ka dikobo? ☐ *Nnyaa* ☐ *Ee*

(Tightly wrapped in blankets with the arms across their chest, feet together)
(A o ne a potokiwa a tiisitswe ka mabogo mo sehubeng, le maoto a kopane)

If yes, to which age was/is the child swaddled?
Fa o re ee, ngwana o ne a potokiwa jaalo a le dikgwedi di le kae?

☐ 0-3 months
Dikgwedi di le 0-3

☐ 4-6 months
Dikgwedi di le 4-6

☐ 7-9 months
Dikgwedi di le 7-9

☐ Other: please state the age:
Tse dingwe: twee tswe bolela dikgwedi tsa ngwana: ____________________

If yes, for which purpose(s) is/was the child swaddled? (Mark all relevant ones)
Fa o re ee, ngwana o ne a potokelwa eng jaalo? (Tshwaya dikarabo tsotlhe tse di leng maleba fa)

☐ To soothe him/her when he/she started crying
Go mo tuntuletsa fa a simolola go lela

☐ To keep him/her warm while he/she sleeps at night
Go mo thuthafatsa fa a robetse bosigo

☐ To keep him/her warm while he/she sleeps at day
Go mo thuthafatsa a a robetse motshegare.

☐ For transport while I went shopping
Go mo potokela gore ke tsamaye le ena jaaka go ya kwa mebenkeleng

☐ It is my belief / culture that babies must be swaddled
Ke tumelo ya me

☐ For medical reasons - the Doctor / Nurse told me to
Ke mo potokela mabaka a kalafi – Ngaka / Mooki wa me o ntaetse jaalo

☐ Other reason:
Mabaka a mangwe: ____________________

If yes, how many hours was the child swaddled per day?
Fa o re ee, ngwana o ne a potokilwe diura di ka nna kae ka letsatsi?

- [ ] Less than 2 hours per day
  Kwa tlase ga diura di le 2 ka letsatsi
- [ ] 2-3 hours per day
  Diura di le 2-3 ka letsatsi
- [ ] 4-5 hours per day
  Diura di le 4-5 ka letsatsi
- [ ] 6-7 hours per day
  Diura di le 6-7 ka letsatsi
- [ ] other: please specify:
  Tse dingwe: tsweetswe totobatsa: ____________________

3.3 Is/was the child ever pushed in a stroller / pram?
A ngwana o kile a kgoromediwa ka phorema?

- [ ] No *Nnyaa*
- [ ] Yes *Ee*

If yes, to which age was/is the child pushed in a stroller/pram?
Fa o re ee, ngwana o kgoromediwa ka phorema go fitlha a nna dikgwedi di le kae?

- [ ] 9-10 months
  Dikgwedi di le 9-10
- [ ] 11-12 months
  Dikgwedi di le 11-12
- [ ] 1-2 years old
  Dingwaga di ka nna 1-2
- [ ] 3-4 years old
  Dingwaga di le 3-4
- [ ] Other: please state the age:
  Tse dingwe: tswee tswee bolela bogolo jwa ngwana: ____________

If yes, for which purpose(s) is/was the child pushed in the stroller / pram? (Mark all the relevant ones)
Fa o re ee, ngwana o ne a kgoromeletswa eng ka phorema? (Tshwaya dikarabo tsotlhe tse di leng maleba fa)

- [ ] To soothe him/her when he/she started crying
  Go mo tuntuletsa fa a simolola go lela
- [ ] For transport when I walked to town
  Go mo kgoromeletsa gore ke tsamaye le ena jaaka go ya kwa toropong
- [ ] For transport while I went shopping
  Go mo kgoromeletsa gore ke tsamaye le ena jaaka go ya kwa mebenkeleng
- [ ] It is my belief / culture that babies must be pushed in a stroller / pram
  Ke tumelo ya me / setso sa me gore bana ba tshwanetse go kgoromediwa ka phorema
- [ ] For medical reasons - the Doctor / Nurse told me to
  Ke mo kgorometsa ka phorema ka mabaka a kalafi – Ngaka / Mooki wa me o ntaetse jaalo
- [ ] Other reasons:
  Mabaka a mangwe: ____________________

If yes, how many hours was the baby pushed in the stroller / pram per day?
Fa o re ee, o ne o mo kgorometsa ka phorema sebaka se se kana kang ka letsatsi?

- [ ] less than 2 hours per day
  Kwa tlase ga diura di le 2 ka letsatsi
- [ ] 2-3 hours per day
  Diura di le 2-3 ka letsatsi
- [ ] 4-5 hours per day
  Diura di le 4-5 ka letsatsi

☐ 6-7 hours per day
Diura di le 6-7 ka letsatsi 6-7

☐ other: please specify:
Tse dingwe: tswee tswee bolela bogolo jwa ngwana : ___ __________

The information below will be destroyed once data capture is complete:

Primary care giver's contact details
Dintlha tsa go ikgolaganya le motlhokomedimogolo wa ngwana

Name of child:
Leina la ngwana: ______________________________

Name of primary caregiver:
Leina la motlhokomedimogolo: ______________________________

Contact number of primary caregiver:
Nomore ya go ikgolaganya le motlhokomedimogolo: ______________________________

Thank you!
Ke a leboga!

APPENDIX H: RECORDING DOCUMENTS

Clinical Investigation – Data Sheet

CHILD KNEE DEVELOPMENT STUDY DATA SHEET: PARTICIPANT NUMBER: ______________

GUARDIAN/PARENT NAME: _________________________ CONTACT NR: ___________________________________

E-MAIL: ____

PHYSICAL ADDRESS: ____

CHILD NAME: __________________________ DATE OF BIRTH: ____________________

WEIGHT: ___________kg HEIGHT: _________cm

PARENTAL CONSENT: RECEIVED YES / NO AGREE / DISAGREE

CHILD ASSENT: RECEIVED YES / NO AGREE / DISAGREE VERBAL / SIGNED

ROAD TO HEALTH CHART: RECEIVED & PHOTOGRAPHED YES / NO

QUESTIONNAIRE: RECEIVED YES / NO

PARENT PHONED YES / NO

BACK CARRIED YES / NO

OBSERVED: ANTEVERSION / RETROVERSION GENU VARUM / GENU VALGUM / NEUTRAL

MEASURMENT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT
TFA	°	°	°	°	°	°
Q-ANGLE	°	°	°	°	°	°
ICD	cm	cm	cm	cm	cm	cm
IMD	cm	cm	cm	cm	cm	cm
MEDIAL TIBIAL TORSION	°	°	°	°	°	°
LATERAL TIBIAL TORSION	°	°	°	°	°	°
ANTEVERSION	°	°	°	°	°	°
RETROVERSION	°	°	°	°	°	°
STRUCTURAL LEG LENGTH	cm	cm	cm	cm	cm	cm
FUNCTIONAL LEG LENGTH	cm	cm	cm	cm	cm	cm

INCLUSION CRITERIA:

CRITERION	YES/NO
Self-declared healthy black, Setswana toddlers and children, residing in Ikageng / Potchefstroom	
Between 2 – 9 years of age & can walk	
Back-carried / not back-carried	
Healthy / Known DDH o Toddlers and children with known DDH included & specially categorised according to those back-carried vs not-back-carried. o Keep separate from apparently healthy, “normal” data.	
Known orthopaedic-, skeletal-, or muscular- or neuromuscular- or connective tissue disorders (except DDH)	
Disorders such as, but not limited to: skeletal dysplasia, cerebral palsy, foot deformities &/ metabolic diseases (which might affect bone development) such as Rickets.	
NO parent with, or family history of known musculoskeletal disorders	

COMMENTS:

CHILD FITS INCLUSION CRITERIA YES / NO: REASON:

____

CHILD EXCLUDED YES / NO: REASON:

____

COMPLETED WHOLE TEST BATTERY YES / NO: REASON:

____

VIDEO CLIP TAKEN YES / NO: REASON: ___________________________________

DATE: ____________________ SCHOOL / CRECHE: ____________________________

ASSISTANTS: ____

CHILD RECEIVED FEEDBACK

SIGNATURE: ________________________YES / NO: REASON: ____________________________________

CHILD RECEIVED FOOD PARCEL

SIGNATURE: ________________________YES / NO: REASON: ____________________________________

Clinical Investigation – English Feedback sheet to Parent

Dear Parent of _______________________________,

Thank you so much for allowing your child to participate in this research study. Your son / daughter's knee alignment was tested today.

This is what normal knee development typically looks like from infancy to 7 years of age and older:

________________________ is ______ years old, and his/her knees looks like this (arrow above).

We found a measurement of _______ degrees, in the bowed leg / knock-knee direction.

For his/her age it should be between ______ to ______ degrees.

- ☐ Therefore, his/her measurement is completely **normal**.
- ☐ His/her knee measurement is **slightly** below / above the recommended range. This can still normalise within the next _____ years.
- ☐ His / her knee measurement is **considerably** below / above the recommended range.
    - IF the measurement is considerably lower / higher, it doesn't necessarily mean they have a problem. It may still normalise.
    - However, if your son/daughter has hip or knee pain that is really bothering them, **and** their knee measurement was abnormal, you can take him/her to the clinic with this feedback form.

Feel free to contact me if you have any further enquiries.

Thank you

Mariaan van Aswegen

018-389 2897

Clinical Investigation – Setswana Feedback sheet to Parent

Go motsadi wa ga _______________________________,

Re lebogela go neya tetla ga gago gore ngwana wa gago a tseye karolo mo dipatlisisong tsena. Re dirile diteko tsa go tlhola go ema ga lengole la ngwana wa gago ka jeko.

Sentshwantsho se se kafa tlase se bontsa go ema ga lengole go tloya boseyeng go fitlha go dingwaga dile 7 le go feta:

_________________________ O dingwaga dile ________, lengole la gagwe le eme jaana (Jaaka go tshwailwe kwa godimo).

Re bone mmeto wa digrata dile _____ka fa ntlheng ya digoro/difapha.

Mo dingwageng tsa gagwe, mmeto o tshwanetse go nna magareng ga digrata dile _____ Go fitlha ka _____.

- ☐ Ka jalo, mmeto wa gagwe o **siame**
- ☐ Mmeto wa gagwe o kwa tlase / go dimo **go se nene** ga selekanyo se se beilweng. Se se santse se ka siama/ rarabologa mo dingwageng dile ….. tse ditlang
- ☐ Mmeto wa gagwe o kwa tlase / go dimo **thata** go feta tekanyo e e beilweng.
    - Fa mmeto o le kwa tlase/ go dimo thata, seo ga se kae fa go na le bothata, go santse go ka siama
    - Fa ele gore ngwana wag ago ona le ditlhabi tse di mo tshwenyang mo lengoleng kgotsa mo lethekeng mme fo godimo ga foo, ana le mmeto wa go ema ga lengole o oleng kwa tlase / go dimo ga selekanyo mo ise kwa tliliniking ka di pholo tsena.

Fa o na le dipotso tse dingwe, o ka i kgolaganya lenna.

Ke a leboga

Mariaan van Aswegen 018-389 2897

APPENDIX I: IMAGE PERMISSIONS

Chapter 2: Figure 2-1a – Baby Slings & Carriers

Dear Mariaan,

You may use the image and credit to "Baby Slings & Carriers" or our website - babyslingsandcarriers.com

Thank you.

Kind Regards,
Pearline
BabySlingsAndCarriers.com
Your Partner in Ergonomic Babywearing
****
Help rate our service at https://www.facebook.com/pg/babyslingsandcarriers/reviews/
Fun stuff and sneak peeks at https://www.instagram.com/babyslingsandcarriers/
****

On Wed, Aug 14, 2019 at 3:40 PM Mariaan Van Aswegen <20383800@nwu.ac.za> wrote:
Dear Pearline,

Thank you for getting back to me.

I'm referring to this picture

It will be published like above.

You may indicate if you want me to reference a specific brand, photographer, model or company, should you give permission for me to use the image.

Kind regards
Mariaan

Mariaan van Aswegen
MSc (Med) in Biokinetics - Wits
Sport Science Lecturer - Sportwetenskap Lektor
Programme Leader (Mafikeng) - Program Leier (Mafikeng)
Faculty of Health Sciences - Fakulteit Gesondheidswetenskappe
Tel: 018 389 2897
www.nwu.ac.za

>>> "Baby Slings & Carriers" <contact@babyslingsandcarriers.com> 8/14/2019 9:23 AM >>>
Hi Mariaan,

Can you please let me know which image you are referring to?

Thank you.

Kind regards,
Pearline

On Tue, 13 Aug 2019, 17:22 , <noreply@storesonlinepro.com> wrote:
Notification for Baby Slings & Carriers
Log on to your account (1995686) for the details of the order.
Date: Tue 13 Aug 2019 5:22:17 PM SGT
Name
Mariaan
Email Address
20383800@nwu.ac.za
Message / Comments / Questions
Good morning,

I am a lecturer and PhD candidate from the North-West University in South Africa.

I'm completing my PhD entitled "The development of genu varum and the tibiofemoral joint profile in back-carried Setswana children" and seek your permission to print and publish the photo below (from https://www.babyslingsandcarriers.com) in the second chapter of my thesis? I will be published in black and white, along with various other photos of carrier devices. I will be asking permission to publish these photos from all the sites.

(I can't paste the picture here - please return an email)

I look forward to your reply.
Kind regards
Mariaan van Aswegen

Chapter 2: Figure 2-1c – Ubutu Baba

Good Day Mariaan,

I have spoke to the business owner and she has given her permission, as long as you credit the image to Ubuntu Baba.

Thank you

Nadia Khan
(standing in for Megan)

Megan Eadie
Certified Babywearing Educator & UB Boutique Manager
www.ubuntubaba.com

UB UBUNTU BABA®

On Tue, Aug 13, 2019 at 11:30 AM Mariaan Van Aswegen <20383800@nwu.ac.za> wrote:
Good morning,

I am a lecturer and PhD candidate from the North-West University in South Africa.

I'm completing my PhD entitled "The develpment of genuvarum and the tibiofemoral joint profile in back-carried Setswana children" and seek your permission to print and publish the photo below (from https://ubuntubaba.com/product/the-stage-2/) in the second chapter of my thesis? It will be published in black and white, as presented here, along with various other photos of carrier devices. I will be asking permission to publish these photos from all the sites.

I look forward to your reply.

Mariaan van Aswegen
MSc (Med) in Biokinetics - Wits
Sport Science Lecturer - Sportwetenskap Lektor
Programme Leader (Mafikeng) - Program Leier (Mafikeng)
Faculty of Health Sciences - Fakulteit Gesondheidswetenskappe
Tel: 018 389 2897
www.nwu.ac.za

Chapter 2: Figure 2-1d – Osha slings

Hi Mariaan,

¶
Thank you so much for getting in touch with us.

¶
You are welcome to use our images as long as each of them is clearly credited as the property of Oscha Slings with in the citation.

¶
Good luck with your project!

¶
Best wishes,

¶
Marta

¶
Customer Care Manager
Oscha Slings

On Tue, Aug 13, 2019 at 12:32 PM Oscha Slings <info@oschaslings.com> wrote:
New Enquiry From: Mariaan van Aswegen <20383800@nwu.ac.za>
Phone Number: +27794071006

Message Body:
Good morning,
I am a lecturer and PhD candidate from the North-West University in South Africa.

I'm completing my PhD entitled "The development of genu varum and the tibiofemoral joint profile in back-carried Setswana children" and seek your permission to print and publish the photo below (from https://www.oschaslings.com/shop/category/babywearing/baby-wrap/) in the second chapter of my thesis? It will be published in black and white, along with various other photos of carrier devices. I will be asking permission to publish these photos from all the sites.

¶(I cannot paste the picture here - please email)

I look forward to your reply.

--
This e-mail was sent from a contact form on Oscha Slings (https://www.oschaslings.com)

¶
--
Customer Care

tel 0131 440 9767 | www.oschaslings.com

24/4 Dryden Road, Loanhead, Midlothian,
Scotland GB EH20 9HX

Chapter 2: Creative commons Wikimedia

The following pertains to images:

Figure 2-b
Figure 2-
Figure 2-

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- **Adapt** — remix, transform, and build upon the material
- for any purpose, even commercially.
-

- The licensor cannot revoke these freedoms as long as you follow the license terms.

Under the following terms:

APPENDIX J: AWARDS

European College of Sport Science – Young Investigator Award Finalist notice

Dear YIA finalist,

I hereby thank you very much for your submission of an abstract to enter the 2019 ECSS Young Investigators Award competition. Your abstract has undergone a thorough review by two independent experts in the field, and it was judged to be among the finalists. Congratulations!

Notification of acceptance of your abstract as well as the exact schedule of your presentation is available in your ECSS account**.**

Please note that that the YIA winners will be announced on Thursday (July 4) at 14:00h at the ECSS booth. If you are one of the winners, you will be invited to a cocktail reception Thursday evening. This event is invitation only and you will need to collect your invitation from the ECSS booth and confirm your attendance.

I look forward to your presentations in Prague!

Yours sincerely

Flemming Dela

Flemming Dela
Chair Scientific Board
European College of Sport Science
University of Copenhagen
phone +45 3532 7425
e-mail fdela@sund.ku.dk

sport-science.org
ecss-congress.eu

share your knowledge

European College of Sport Science – Young Investigator Award Travel Grant Winner notice

Dear YIA Travel Grant Winner,

Congratulations!

Your YIA abstract has been awarded with the ECSS 2019 YIA travel grant.

To now receive your ECSS 2019 YIA travel grant, please follow the steps listed below:

1. Finalize your registration for the 24th annual ECSS Congress in Prague, by ***paying your congress registration fee online via your ECSS account*** (Please note that the registration fee must have been paid before receiving the travel grant)

2. ***Please fill in all details in the YIA travel grant form attached*** (name, country, bank account details, etc.) and ***send it to*** office@sport-science.org

Following this, the ECSS 2019 YIA travel grant amount of 500 Euro will be transferred to your bank account.

Congratulations once again. We very much look forward to welcome you to Prague this summer.

Yours in sport science

The ECSS

European College of Sport Science

Feldblumenweg 26

50858 Cologne

Germany

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FIEP 2019 New Leaders

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Dear FIEP New Leaders,

As FIEP Catalunya New Leaders program coordinator, I would like to congratulate you for being selected as FIEP New Leaders and warmly welcome you to the 30th FIEP International Congress that will be held in Barcelona from 27th to 29th, June, 2019.
With this letter/email, we are inviting you to participate to the congress and following the link attached, be able to register free of charge and without the need of paying a fee.

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Just follow the registration instructions to proceed and do not hesitate to contact me if you have any query.

Looking forward to seein you in Barcelona!

Best Regards,

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The Relationship between Lower Limb Angle Measures and Back-Carrying of Setswana Children

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Based on Original Research

Introduction
Treatment of knee malalignments, such as excessive genu varum, poses high burdens health systems (Omololu et al., 2003), however, social or cultural causes of knee malalignments has never been studied before. For example, the consequences of children having been back-carried (BC) in their infancy and childhood, in relation to their knee development has never been assessed. Previous studies on the low incidence of developmental hip dysplasia (DDH) in BC children, didn't directly investigate developmental consequences of BC practices (Graham, Manara, Chokotho, & Harrison, 2015; Roper, 1976). This study divulges important lacking information about the relationship of lower limb (LL) (ankles, knees, and hips) angle measures and back-carrying of black Setswana children. Consequently, two objectives of this study are to determine relationships between LL angle measures and back-carrying in Setswana children. Firstly, the relationship between FP tibiofemoral (TF) measures, in BC and non-back-carried (non-BC) children is determined. Secondly, the relationship between TP torsion measures, in BC and non-BC children is determined.

Methods
Hip, knee and ankle measurements were obtained through clinical measurements from 691, healthy 2- to 9-year-old, black Setswana-speaking children. FP clinical measurements included the TFA, Q-angle and intercondylar distance (ICD) for genu varum or intermalleolar distance (IMD) for genu valgum, all obtained with the participant in standing. TP measurements were the Craig's test, measuring the hip anteversion angle (AVA) and tibial torsion angle (TTA), of which both were measured with the participant in prone, and knee flexed to 90°. Participant demographic information such as sex, age and body mass index (BMI) was also collected. A questionnaire was used to determine the BC-, swaddling- and pram use practices, employed by mothers. Carrying practices

were classified into BC in general (BC-gen), BC with the legs spread (BC-LS) around the mother, and BC with the legs down (BC-LD). Along with BC practices, frequencies how often mothers would employ BC practices, were included (very little, sometimes, average, often, always). Side carrying (SC) and front carrying (FC) in a carrier device with the baby's legs hanging down, were the other two carrying practices employed. A type of regression analysis, the Classification and Regression Tree Analysis (CART), was performed. CART does not assume linear relationships, or any type of underlying distribution, but aims to classify the sample into subgroups with the means of the subgroups as diverse as possible. CART analysis is exploratory in nature and does not provide quantitative (e.g. p=value, test values, etc.) measures. Cohen's d was used to assess effect sizes (between nodes). Interaction between BC and the TFA, Q-angle, AVA and TT were first analysed, followed by an analysis of TFA, Q-angle, AV and TT in terms of age, sex and BMI.

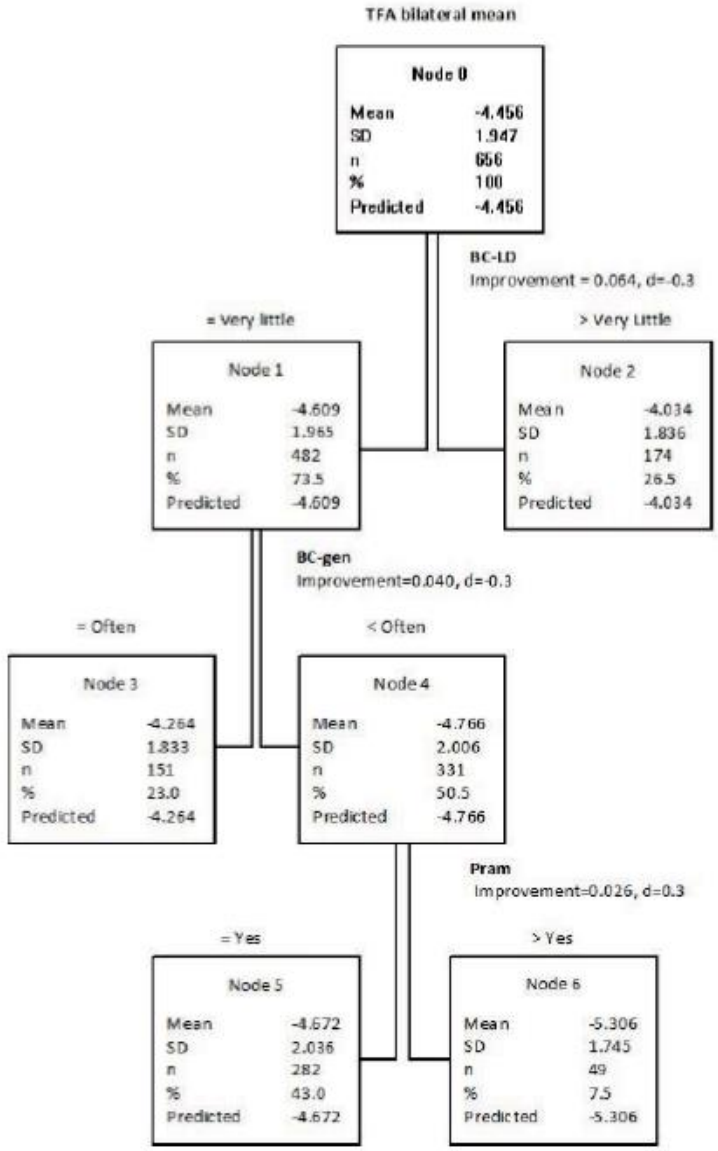
Results

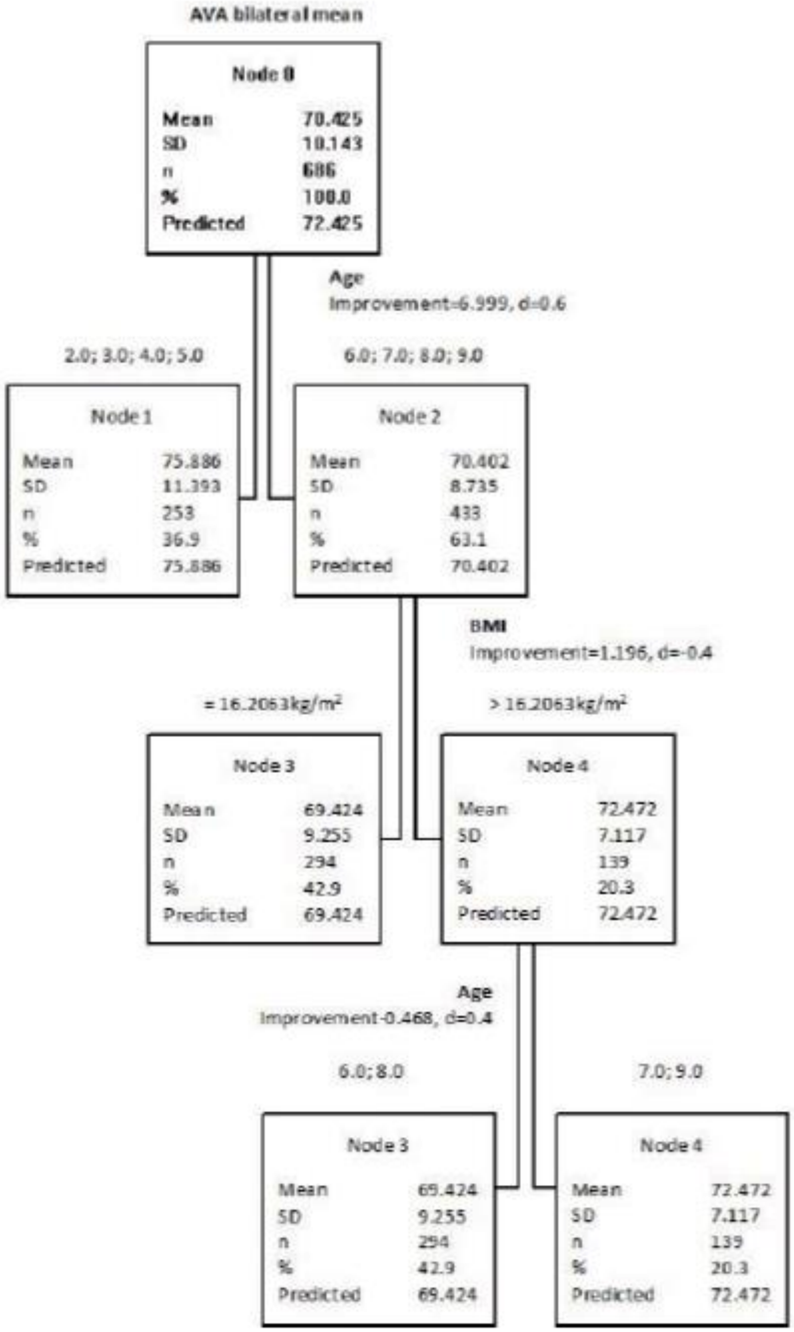
Figure 1 shows the CART tree for TFA, BC-LD, BC-gen and pram use. Node 2, shows the smallest valgus mean (n=174, TFAmean=-4.0°, d=-0.3) and represents children BC-LD more often than very little. Node 3, (n=151, TFAmean=-4.3°, d=-0.3) represents BC-LD less than or equal to very little, and BC-gen equal to, or less than often.

The CART for IMD the smallest valgus mean (n=138, IMDmean=-1.0cm, d=-0.3) was reported for BC-LD more often than average, whilst the largest valgus mean (n=70, IMDmean=-1.9cm, d=0.3) was reported in those BC-LD less or equal than average and who were in a pram. The smallest TTA mean was found in those not FC nor swaddled (n=64, TTAmean=8.8°, d=0.3), whilst the largest TTA mean was found in those who FC (n=194, TTAmean=11.7°, d=-0.3). The smallest valgus mean (n=282, TFAmean=-4.0°, d=0.5) was observed in 2- and 5 to 9-year-old females. In the same age category, males, BC-LD more often than little had the second smallest valgus mean (n=89, TFAmean=-4.3°, d=-0.3). From a mean IMD of -1.48 cm in 689 participants, the subgroup with a BMI lower than 16.6kg/m2, had an IMD of -1.07 cm (n=499, d=1.0) vs a mean of -2.55 cm (n=190, d=1.0) in those with a BMI greater than 16.6kg/m2. In younger children (2- to 5-year-olds) with a BMI smaller than 16.6kg/m2, greater genu valgum (n=177, IMDmean=-1.65kg/m2, d=-0.8) was observed than in older children (n=322, IMDmean=0.76kg/m2, d=-0.8). Younger children (3-to 5-year-olds), with a BMI greater than16.6kg/m2, had greater genu valgum (n=53, IMDmean=-3.5cm, d=-0.8) than 2- and 6- to 9-year-olds (n=137, IMD mean=-2.174cm, d=-0.8). Figure 2 shows lower mean AVA (n=433, AVAmean=70.4°, d=0.6) in older (6-to 9-year-olds) participants than in younger (2-to 5-year-olds) participants (n=253, AVAmean=75.9°, d=0.6). A greater AVA mean was found in the older group, with a BMI greater than 16.2kg/ m^2 (n=139, AVAmean=72.5°, d=-0.4).

Discussion and Conclusion

Results from our analysis classified relationships between BC frequency and specific dependent variables (knee angles), depending on the correlations between variables grouped per node. The relationship between TFA and BC-LD, showed that the closest to genu varum angles were observed in children who were BC-LD more frequently than those BC-LD less frequently. This relationship was characterized with low effect size (d=-0.3). Importantly, the grouping between BMI and the clinical variable subgroups. Greater IMD distances, thus genu valgum, were observed in children with larger BMI's. Smaller AVA means were consistently observed in older children, whilst an increase in BMI lead to greater AVA means. Further analysis with the factor BC-LS is necessary to investigate the true effect of BC practices on knee development, as it appears that a relationship between BC-LD and knee development does exist. (Image.1) Figure 1: CART for TFA vs BC-LD, BC-gen and Pram. (Image.2) Figure 2: CART for AVA vs age and BMI


TFA bilateral mean
Node 0
Mean -4.456
SD 1.947
n 656
% 100
Predicted -4.456
BC-LD
Improvement = 0.064, d=-0.3
= Very little
> Very Little
Node 1
Mean -4.609
SD 1.965
n 482
% 73.5
Predicted -4.609
Node 2
Mean -4.034
SD 1.836
n 174
% 26.5
Predicted -4.034
BC-gen
Improvement=0.040, d=-0.3
= Often
< Often
Node 3
Mean -4.264
SD 1.833
n 151
% 23.0
Predicted -4.264
Node 4
Mean -4.766
SD 2.006
n 331
% 50.5
Predicted -4.766
Pram
Improvement=0.026, d=0.3
= Yes
> Yes
Node 5
Mean -4.672
SD 2.036
n 282
% 43.0
Predicted -4.672
Node 6
Mean -5.306
SD 1.745
n 49
% 7.5
Predicted -5.306



Graham, S. M., Manara, J., Chokotho, L., & Harrison, W. J. (2015). Back-carrying infants to prevent developmental hip dysplasia and its sequelae: is a new public health initiative needed? Journal of Pediatric Orthopaedics, 35(1), 57-61.

Omololu, B., Tella, A., Ogunlade, S., Adeyemo, A., Adebisi, A., Alonge, T., . . . Akinpelu, A. (2003). Normal values of knee angle, intercondylar and intermalleolar distances in Nigerian children. West African journal of medicine, 22(4), 301-304.

Roper, A. (1976). Hip dysplasia in the African Bantu. Bone & Joint Journal, 58(2), 155-158.

Kinematic gait comparisons of the tibiofemoral joint between back-carried and non-back-carried Setswana-speaking children

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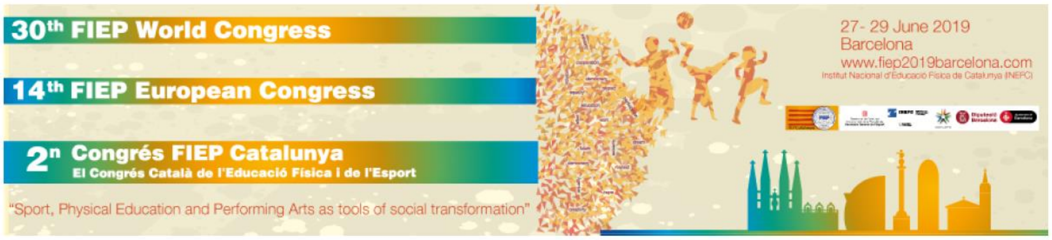
Purpose: In South Africa, there is a strong cultural tradition of mothers back-carrying their children, sometimes for extensive durations. Research report differences in static lower limb measures, such as at the tibiofemoral angle, femoral anteversion angle and in the tibial torsion angle between back-carried and nonback-carried, Setswana-speaking children. The discrepancies found in static measures, lead to an interest to determine whether the static differences would translate into dynamic differences during gait. The objective of this study was to compare the tibiofemoral angles in the gait of back-carried and non-back-carried children.
Methods: Twelve non-back-carried (mean age=8.00±0.95 years) and 14 back-carried (mean age=8.01±0.73years) participants participated in the study, however, data from only 12 participants in each group were analysed. Lower body kinematic gait analysis was performed at self-selected walking speeds, using the Qualisys Track Manager (QTM, Qualisys AB, Sweden) software and six wall-mounted cameras (OQUS 3+). Reflective markers were placed on each lower extremity at anatomical landmarks, using the CAST (6DOF) protocol. Analysis of knee kinematics was performed in the sagittal-, transverse- and frontal planes, for the left limb only, at left heel-strike (LHS), left mid-stance (LMS) and left toe-off (LTO) gait phases.
Results: Data was analyzed using the Bayesian independent t-test to compare back-carried with non-back-carried data. In three comparisons of LHS in all three planes , the observed data supported H0. However, the Bayesian factor reached values above 1 and below 3 providing inconclusive evidence. It means that the observed data was only one to three times more likely under the null-hypothesis that postulated the absence of the effect of back-carry on knee angles. The alternative-hypothesis proposed the presence of the effect. The observed data supported the alternative-hypothesis while analyzing LMS in sagittal and frontal planes. The Bayes factor was above 0.33. In the transverse plane, the observed data supported the null-hypothesis; however, the BF was below 3. These values also yielded inconclusive evidence. Analysis of LTO in the sagittal and transverse planes, the Bayes factor was below 3 and the data supported the null-hypothesis, whereas in the frontal plane observed data supported the alternative-hypothesis, although the BF was above 0.33.
Conclusions: The observed data yielded inconclusive evidence for either the null or alternative-hypothesis. Therefore, there is not strong enough evidence to claim an influence of back-carrying on knee angles (LHS, LMS or LTO). The most significant contribution of our study is that the results of the Bayesian analysis may be used as prior in subsequent studies investigating relationships between knee angles and back-carrying.

Keywords: back-carrying, kinematic gait analysis, knee angles, tibiofemoral joint.

APPENDIX L: ORAL PRESENTATION CERTIFICATE

FIEP Oral Certificate:



ORAL PRESENTATION CERTIFICATE

We hereby certificate that the work Accepted as oral presentation

THE RELATIONSHIP BETWEEN LOWER LIMB ANGLE MEASURES AND BACK-CARRYING OF SETSWANA CHILDREN

has been presented by:

Mrs Mariaan Van Aswegen

during the 30th FIEP World, 14th FIEP European and 2nd FIEP Catalan Congress, FIEP 2019, held from 27 to 29 June, 2019 in Barcelona

Prof. Enric Maria Sebastiani

President of the 30th FIEP World, 14th FIEP European and 2nd FIEP Catalan Congress, FIEP 2019