The effect of wearing shoes on the outcome of selected balance measures in children with typical development and with mild motor dysfunction

By

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Declaration

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Abstract

Balance is a critical motor skill essential for the development of functional performance. It is complex in nature as it involves many systems, namely the motor system, sensory system and central nervous system. As the human is bipedal, meaning we walk on two legs, the feet are an important factor as they form the base of support from which we balance. Wearing shoes affect development of feet and may affect balance. Current outcome measures for balance in children are indifferent as to wearing shoes or not.

The primary aim of this study was to determine whether wearing shoes affects the scores of selected paediatric balance and motor function measures, namely the Paediatric Balance Scale (PBS) and the Bruininks-Oseretsky Test of Motor Proficiency (BOT-MP), and to determine whether this effect is greater in children with balance impairments compared to their age matched peers with typical development (TD).

A descriptive, cross-sectional study design was used to determine the effect of wearing shoes on balance. Children four to ten years were recruited from five purposively selected schools in Johannesburg, South Africa. Children were included if they had been referred to physiotherapy or occupational therapy for balance, postural or gross motor concerns. These children were allocated to the mild motor dysfunction group. They were then matched for age and gender with their peers who had never been referred for physiotherapy or occupational therapy. All children were tested with shoes on and barefoot, using the BOT-MP and the PBS. The test scores were compared between groups and between outcome measures.

Children had significantly better balance when wearing shoes compared to being barefoot when tested with the BOT-MP. This was found for both the typically developing group ($p < 0.0001$) and the group with mild motor dysfunction ($p < 0.001$). No significant difference was found when testing with the PBS within or between the groups. There was also a weak relationship between age and gender with older children having better balance and girls having better balance than boys of the same age.

Based on this study, the effect of shoes was detectable in the BOT-MP however, not when using the PBS. This study concluded that wearing shoes may improve balance and practitioners should control for this when assessing balance in the clinical setting. This study also found that girls scored slightly better when matched to their male peers of the same age. This study also suggests that recommendations on which shoes should be worn to assist children who have poor balance should be developed as there are currently no clear guidelines for this.

Abstrak

Balans is ‘n kritiese motoriese vaardigheid noodsaaklik vir die ontwikkeling van funksionele beweging. Dit is kompleks van aard en afhanklik van menige sisteme, naamlik die motoriese sisteem, sensoriese sisteem en die sentrale senuweestelsel. Die mens staan en loop op twee bene (bipedaal) en die voete speel ‘n kritiese rol met betrekking tot ondersteuning en balans. Skoene affekteer die ontwikkeling van die voete en dus dan ook die balans. Die huidige uitkomsmetings om balans te toets in kinders is onverskillig met betrekking tot die dra van skoene, aldan nie.

Die primêre doel van die studie was om vas te stel of skoene dra die uitkoms van geselekteerde pediatriese balans- en motoriese vaardighede metings, naamlik die “Paediatric Balance Scale” (PBS) en die “Bruininks-Oseretsky Test of Motor Proficiency” (BOT-MP), sal beinvloed en om te bepaal of the effek groter is in kinders met balans probleme invergelyking met hulle ouderdom portuurgroep met tipiese/ normale ontwikkeling.

`n Beskrywende deursnitstudie ontwerp is gebruik om die effek van skoene op kinders se balans te bepaal. Kinders tussen die ouderdom van vier tot tien jaar is gewerf van vyf doelgerig geselekteerde skole in Johannesburg, Suid-Afrika. Kinders was ingesluit as hul vir fisioterapie of arbeidsterapie verwys is, spesifiek vir balans, postuur of grof motoriese vaardigheidsproblem. Hierdie kinders het die minimaal motoriese disfunksie groep gevorm. Daarna is hulle gepaar met kinders van dieselfde ouderdom en geslag. Laasgenoemde is kinders wat nie voorheen verwys is vir fisioterapie of arbeidsterapie nie. Alle kinders is getoets op die BOT-MP en die PBS, met en sonder skoene. Die twee uitkomsmetings se balanstoetstellings is met mekaar vergelyk asook tussen die twee groepe kinders.

Kinders het beduidend beter balans getoon op die BOT-MP met skoene aan invergelyking met toe hulle kaalvoet was. Die beduidende resultate is in beide groepe, naamlik die kinders met tipiese ontwikkeling ($p< 0.0001$) en kinders met minimale motoriese disfunksie ($p< 0.001$) gevind. Met die PBS is daar geen noemenswaardige verskil binne of tussen die groepe nie. Daar was `n swak

korrelasie tussen ouderdom en geslag. Ouer kinders het beter balans as jonger kinders en dogters het beter balans as seuns in dieselfde ouderdomsgroep.

Op grond van hierdie studie was die effek van skoene dra waarneembaar met die BOT-MP uitkomsmeting maar nie met die PBS nie. Hierdie studie het tot die gevolgtrekking gekom dat, skoene dra balans kan verbeter en dat terapeute dit in ag moet neem en daarvoor kontroleer wanneer hulle balans in kinders toets. Hierdie studie het ook gevind dat dogters beter balans het as seuns van dieselfde ouderdom. Hierdie studie stel ook voor dat riglyne ontwikkel word vir die voorskryf van skoen vir kinders met swak balans aangesien daar huidiglik geen duidelike riglyne is nie.

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Glossary

Definitions and Terminology

Adolescence - the period in human growth and development that occurs after childhood and before adulthood, from ages 10 to19 (WHO 2016).

Base of support (BOS) - The area of the single contact between the body and support surface or, if there is more than one contact with the support surface, the area enclosing all the contacts with the support surface (Pollock, Durward, Rowe & Paul, 2000).

Centre of gravity (COG) - point at which the mass of a body or object is centred; when weight on all sides is equal (Pollock et al., 2000).

Centre of mass (COM) - a point representing the mean position of the matter in a body or system (Pollock et al., 2000).

Dynamic balance - the ability to maintain stability during weight shifting, often while changing the base of support (Karimi & Solomonidis, 2011).

Postural Control- the act of maintaining, achieving or restoring a state of balance during any posture or activity (Pollock et al., 2000).

Postural Equilibrium- involves the coordination of movement strategies to stabilise the COM during both self-initiated and externally triggered disturbances of stability (Horak, 2006).

Postural stability - the ability to maintain or control the centre of mass (COM) in relation to the base of support (BOS) to prevent falls and complete desired movements (Westcott, Lowes & Richardson, 1997).

Static balance - the ability to maintain an upright posture and to keep the line of gravity within the limits of the base of support. It is also known as Quiet Standing (Geuze, 2003).

Acronyms and Abbreviations

BBS- Berg Balance Scale
BOS- Base of Support
BOT-MP- Bruininks-Oseretsky Test of Motor Proficiency
BOT 2- Bruininks-Oseretsky Test of Motor Proficiency second edition
CNS- Central Nervous System
COG- Centre of gravity
COM- Centre of Mass
COP- Centre of pressure
CP- Cerebral Palsy
FRT- Functional Reach Test
MABC- Movement ABC
MMD- Mild Motor Dysfunction
OM- Outcome measure
PBS- Pediatric Balance Scale
P-CTSIB- Pediatric Clinical Test of Sensory Interaction and Balance
PDMS- Peabody Developmental Motor Scales
PI- Primary Investigator
PRT- Pediatric Reach Test
ROM- Range of motion
SATCo- Segmental Assessment of Trunk Control
SMO- Supramalleolar orthoses
SPD- Sensory Processing Disorder
SR- Systematic reviews
TCMS- Trunk Control Measurement Scale
TD- Typically Developing
TMW- 10-Metre Walk Test
TOLS- Timed One Leg Stance
TUDS- Timed Up and Down Stairs

TUG- Timed Up and Go

WHO- World Health Organisation

WMA- World Medical Association

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Chapter 1: Introduction

1.1 Background

Balance is a critical motor skill and one that is most often assessed to deduce level of functional performance (Geldhof, Cardon, De Bourdeaudhuij, Danneels, Coorevits, Vanderstraeten & De Clercq, 2006). The ability to control balance is complex as it involves a variety of systems. Integration of sensory information from the somatosensory, vestibular, and visual systems. These systems work together with the nervous and muscular system and are vital to control body alignment with respect to the environment. They help to stabilise the body's centre of mass (COM) during perturbations, resulting in subsequent motor output or movement (Dunsky, Zeev & Netz, 2017). Measurement of balance is complex and challenging due to the many factors involved as well as the internal and external influences that affect balance (Rudd, Barnett, Butson, Farrow, Berry & Polman, 2015). One of the factors that significantly influences balance is the foot. This is due to the foot being the base of support when the body is standing. The foot can either be bare or shod and this has been of great interest to the research community. One contentious and long debated issue in the literature, especially in the paediatric population is whether children should be allowed to wear their shoes when testing their balance. It has been shown that in children, shoes can affect performance of basic motor skills such as balancing, jumping or sprinting (Hertel, Gay, & Denegar, 2002; Tsai, Yu, Mercer & Gross, 2006).

The human is unique in that we are bipedal; meaning we walk on two legs, and need to walk upright against gravity. As such, the feet are vital to consider when looking at locomotion and other gross motor milestones including balance, as they form the base of the legs and are the base of support in all activities that require standing and walking. The development of balance begins from birth, as children transition through milestones like rolling, crawling and sitting. Eventually this culminates with typically developing infants mastering standing independently and then walking between ten and 18 months of age (Condon & Cremin, 2014). In children, the foot provides stability and locomotion during the sitting to crawling phase and then finally independent walking milestones (Karasik, Tamis-lemonda & Adolph, 2011), allowing the child to learn about and engage with their social and physical environments (Shumway-Cook and Woollacott, 2012; Price, Morrison, Hashmi, Phethean & Nester, 2018). Pre-schoolers continue to develop fundamentals of locomotion and motor skills, relying heavily on the development of balance, stability and postural control. In the author's opinion, this makes the foot essential for balance. Between the ages seven to ten years, children begin to develop adult-like balance (Shumway- Cook and Woollacott, 1985) and researchers agree that by seven years of age, children have completed the development of the structures responsible for motor control (de Sá, Boffino, Ramos & Tanaka, 2018). When testing balance, there are many components to look out for including balance strategies like a 'fixed- support' strategy which can include either the ankle or hip or 'change-in-support' strategy for example, a stepping response (Pollock et al., 2000).

Some tests or outcome measures require the wearing of shoes, including the Timed Up and Down Stairs (TUDS) (Zaino, Marchese & Westcott, 2004), others specify barefoot, including the Paediatric Clinical Test of Sensory Interaction and Balance (P-CTSIB) (Deitz, Richardson, Atwater, Crowe & Odiorne, 1991) and the Timed One Leg Stance (TOLS) (Zaino et al., 2004). Some do not mention whether shoes should be worn at all, such as the Paediatric Balance Scale (PBS) (Franjoine, Darr & Held, 2010). It is the opinion of some therapists and researchers that shoes are simply part of a child's clothing and don't influence gait kinetics and kinematics (Oeffinger, Brauch, Cranfil, Hisle, Wynn, Hicks and Augsburger, 1999) and most children, especially in high income countries, have grown up wearing shoes, and as such should be worn during testing as this is closest to every day function. Others believe that shoes are important therapeutic tools capable of correcting deformity thereby preventing significant disability later in life (Staheli, 1991) and because it affects gross motor function such as balance (Zech, Venter, Villers, Sehner, Wegscheider, Hollander, 2018), should not be worn during testing as it can affect the score of the test. What is evident from the literature is that a majority of children in high income countries wear shoes, already from a very early age (Sachitenandam & Joseph, 1995; Staheli, 1991; Zech et al., 2018) but what is not evident is whether wearing shoes is something that therapists or testers should consider when implementing measures of balance in clinical practice.

Some published research tends to focus more on quality of movement and assess how the child moves during specific balance activities. This is assessed/measured using equipment such as posturography, force plate measurement and platform studies (Condon & Cremin, 2014; Westcott et al., 1997; Shumway-Cook & Horak, 1986). One critique, in the author’s opinion, of these lab-based assessments of balance is that they all typically measure postural sway and velocity but do little to describe the impact that poor balance has on childhood activities. In the paediatric population however, several standardised outcome measures (OMs) have been developed for interpreting or inferring balance (Condon & Cremin, 2014). The most commonly used include PBS, Movement ABC (MABC), Peabody Developmental Motor Scales (PDMS) and Timed Up and Go (TUG). As stated above not all these OMs specify wearing shoes may or should be worn during testing. It is of clinical importance to be able to observe the foot and its reaction forces when balancing to see what the child is/is not using when balancing/attempting to balance, for example, is the child using ankle strategy or are the intrinsic muscles of the foot able to stabilise the child. This can assist the therapist in a treatment protocol for rehabilitation.

Changes in structure/ position of the foot could influence functionality (Franklin, Grey, Heneghan, Bowen & Li, 2015). There are 104 cutaneous mechanoreceptors in the foot that are responsible for sensing changes in pressure, vibration and skin stretch. These receptors are responsible for balance and movement control and adjust according to input they receive. This, in turn affects how the foot reacts and changes position accordingly to re-stabilise the body if needed. Skin receptors may therefore be able to detect not only the movement of the centre of pressure (COP) as it moves, but may also be able to initiate postural reflexes that promote a more stable standing position (Kennedy & Inglis, 2002). The typically developing child is born with flat feet but this generally reduces with age i.e. as a child gets older, their flat foot posture should reduce and an arch develops that needs to be maintained (Martínez-nova, Gijón-noguerón, Alfageme-garcía, Montes-alguacil, & Margaret, 2018). Martínez-Nova et al (2018) found that most children have pronated feet until the age of ten. In their study of 1032 children, only 4% had a supinated foot posture.

Children begin to wear shoes in many western populations as early as nine-ten months when they begin to take their first steps. Although the primary reason is to protect the foot, wearing shoes may in fact impair further foot development. Emslie (1939), showed that children wearing shoes had many more deformities than those not wearing shoes and as such it was proposed that the design of children's shoes should be based on the barefoot model and take into account shock absorption and load distribution. This demonstrates that footwear and its effects have been explored for a long period of time. Rao et al (1992), observed 2 300 children aged between four and 13 years and found the incidence of a flat foot among those who used footwear (8.6%) was significantly higher compared to those who did not (2.8%). This was across all age groups. They noticed that children wearing closed shoes showed a higher incidence for flat feet than those wearing sandals or slippers (Rao & Joseph, 1992).

Footwear is the primary interface between the individual and the ground and as such will contribute to how ground reaction forces generated in gait are applied to the foot and ankle (Wegener, Hunt, Vanwanseele, Burns & Smith, 2011). Footwear has been designed to offer a role as a mobility aid for children with locomotor impairment since the eighteenth Century (Hill, Healy, & Chockalingam, 2019; Ivanyi, Schoenmakers, Van Veen, Maathuis, Nollet & Nederhand , 2015). Several more studies (Waseda, Suda, Inokuchi, Nishiwaki & Toyama, 2014; (Rao & Joseph, 1992; Sim-Fook & Hodgson, 1958) since then have continued to show shown that inadequate footwear, and even footwear in general, may affect the physiological and biomechanical development of the foot (Wolf, Simon, Patikas,Schuster, Armbrust, Derlein , 2008). These studies have influenced the shoe industry to develop more appropriate footwear for children (Franklin, Li, & Grey, 2018). In 2009, the Canadian Paediatric Society released the following recommendations concerning footwear in children:

1. Infants do not need shoes until they are walking.
2. Shoes are necessary for protection. They should be well fitting, soft, light weight, and have cushioned soles.

3. Orthotics are not beneficial in the management of physiological flexible flatfoot, developmental in-toeing, and mild torsional deformities.
4. Orthopaedic referral is necessary when a child experiences functional disability or pain in association with foot or lower leg abnormalities" (Grueger, 2009).

Two systematic reviews (SRs), one by Bruggemann & Potthast (2005) and another by Wegener et al (2011) both found that shoes also affect gait in children. Shoes provide a perception of protection but could also decrease proprioceptive feedback and therefore adjustments in gait are made to improve stability. The sole of shoes are wider than barefoot and the child could also widen their base of support so that they avoid their feet having contact with each other. Shoes also decrease the intrinsic motion of the foot during walking. The review by Wegener et al., (2011) and Bruggemann & Potthast (2005) concluded that various kinematics are affected when children are walking with and without shoes. Forty five of the 62 (73%) biomechanical comparisons between barefoot and shoe gait were statistically significant ($p<0.05$). From these SRs it is evident that consideration should be given to the impact footwear may have when assessing paediatric gait or planning gait (including shoe and in-shoe prescription) intervention.

Aibast, Okutoyi, Sigei, Adero, Chemjor, Ongaro, Fuku, Konstabel, Clark, Lieberman & Pitsiladis (2017) observed that barefoot children were also more active (spent more time engaged in moderate and vigorous physical activity) than their peers wearing shoes. Zech et al., (2018) looked at a group of 810 children from Northern Germany who all wore shoes and compared them to children growing up barefoot from the Western Cape, South Africa. The findings were that children who grew up barefoot had significant better dynamic balance scores and standing long jump whereas the children who grew up wearing shoes sprinted faster (Zech et al., 2018). This could be because the foot kinematics change when wearing shoes and being barefoot.

If gait is influenced by wearing shoes, then it is possible that *balance* too may be affected. From the above it is evident that shoes, although decreasing foot mobility, do add stability – a core component of good balance (Staheli, 1991). The wearing of shoes is controversial and there is contradicting evidence regarding the effect of shoes on gross motor skills, especially, within the paediatric population (Aibast et al., 2017; Zech et al., 2018). Similarly, whether testing balance should be done with shoes on or off is unclear or perhaps tests should be done in both conditions (with and without wearing shoes) to better understand the effect/impact shoes have on children when testing balance and possibly what strategies they are recruiting in order to balance.

1.2 Statement of the problem

From the literature, it is evident that wearing shoes may affect the natural development or biomechanics of the foot, which can influence balance. While some authors argue wearing shoes is irrelevant when testing motor function and balance (Staheli, 1991; Oeffinger et al, , 1999), others argue barefoot analysis is a more accurate measure of balance and motor function and should be considered when assessment is being done (Emslie, 1939; Sim-Fook & Hodgson, 1958; Zech et al., 2018). Outcome measures for testing balance however are not always prescriptive on the wearing of shoes and as such interpretation of scores may be affected. It is currently unknown whether wearing of shoes affects scoring in selected balance, gait and or functional ability measures in the paediatric population.

Chapter 2: Literature Review

2.1 Introduction

This chapter focusses on the development and biomechanics of the foot in children and how that influences balance and/or the development of motor control. How balance is measured in children is explored and finally, the role of shoes, including the history of the development of shoes and what the current literature says about the effect of shoes on balance in children is also described. The following databases were accessed via Stellenbosch University library: Google Scholar, SCOPUS, PubMed, Science Direct and EBSCO host, from February 2016 until September 2019. The following main keywords were used: ‘balance’, ‘outcome measures’, ‘children’, ‘shoes’ and ‘postural control’ to identify literature pertaining to the topic.

2.2 What is balance?

Balance is the ability to keep the base of support (BOS) of an object within the centre of gravity (COG) (Pollock et al., 2000). If the centre of gravity is displaced, the object will fall unless the object can offset the displacement. Humans fortunately have the ability to counteract the force of gravity using muscular activity and an intact nervous system, allowing for recovery of balance if and when their centre of mass (COM) falls outside of the BOS.

There are two types of balance namely static and dynamic balance (Hatzitaki, Zisi, Kollias & Kioumourtzoglou, 2002). Static balance refers to the ability to maintain the body’s centre of gravity over the base of support during ‘quiet’ standing or sitting. The person remains stationary during this type of balance. Dynamic balance, on the other hand, involves maintaining balance while both the centre of gravity and base of support are moving. Both static and dynamic balance are important factors in the development of postural control (Geldhof et al., 2006).

2.2.1 Postural control

Postural control is defined as the study of how humans are able to maintain/restore balance. The ability to maintain or control the (COM) in relation to the (BOS) prevents falls and allows the body to complete desired movements, for example, walking (Westcott et al., 1997). Postural control is complex as it involves many systems, including the sensory, motor and central nervous systems. Postural control uses the ability to correctly perceive the environment through peripheral sensory systems, as well as to centrally process and integrate proprioceptive, visual, and vestibular inputs at the level of the central nervous system (CNS). This ability then enables the CNS to form appropriate muscle synergies, located in the motor system, needed so that equilibrium can be maintained (Hatzitaki et al., 2002).

2.2.2 Postural equilibrium

Postural equilibrium control is often considered part of postural control. However, these two operate at different levels in the postural control system. Postural control sets a distribution of tonic muscle activity while equilibrium is allocated to compensate for internal or external perturbations (Ivanenko & Gurfinke, 2000).

Postural equilibrium involves the coordination of sensorimotor strategies to stabilise the body's (COM) during both self-initiated (internal) and external influences in postural stability. These strategies can be defined as plan of action to achieve a task i.e. maintaining postural control to perform walking (Horak, 2006). Postural strategies can either be compensatory (reactive) or anticipatory or a combination of both strategies (Pollock et al., 2000). A compensatory postural control strategy might involve a voluntary movement, or an increase in muscle activity in response to a predicted disturbance. A reactive postural control strategy would involve a movement or muscular response following an unpredicted disturbance. Whereas an anticipatory strategy involves a voluntary movement in anticipation of a predicted disturbance. These responses may be 'fixed-support' or 'change-in- support'. 'Fixed-support' occurs where the line of gravity is moved but the BOS remains unaltered, for example ankle or hip strategies. 'Change-in-support' strategies occur were the BOS is moved so that the line of gravity intersects it, for example, the stepping strategy (Horak, 1987). The 'ankle strategy' is used when the postural sway is small and balance can be maintain with minimal movement at the ankle. The ‘stepping strategy’ includes the active stepping forward of the person to maintain or regain balance (Gatev, Thomas, Kepple & Hallett, 1999).

The control of balance is associated with the maintenance of a specified posture, such as sitting or standing (maintenance); voluntary movement, such as the movement between postures (achieving); and the reaction to an external disturbance, such as a trip, a slip or a push (restoring). Both static and dynamic balance are therefore important motor abilities. Improving postural stability leads to better motor performance. From the literature it seems that improving postural control has an integral role to play in motor performance / capacity (Westcott et al., 1997).

2.2.3 Postural Strategies

Postural strategies, with training and practice, can become more effective and efficient (Pollock et al., 2000). These postural strategies, along with developing balance relies heavily on the relationship between feedforward and feedback responses in the body. Static standing balance (quiet standing) is said to be controlled by a closed-loop sensory feedback system. This maintains that the centre of foot pressure moves in phase with the centre of mass (Winter, Patla & Prince, 1997). Integration of both visual and proprioceptive input is needed for this control (Massion & Woollacott, 1996). The importance of visual cues in maintenance of static posture has been well demonstrated, particularly in children, who use them to visually monitor their body during posture (Gallahue & Ozmun, 1998; Riach & Hayes, 1987). In addition to this input, proprioceptive information is processed and integrated at a central level so that it can contribute to a stable posture (Rogers, Wardman, Lord & Fitzpatrick, 2001).

Dynamic balance requires feedforward control (Horak & Nashner, 1986). Stability during dynamic balance is maintained with feedforward control. Postural disturbances are predicted, and those predictions result in anticipatory postural adjustments (APAs) that enable the mover to adjust as necessary and maintain stability (Massion, 1992). Dynamic stability is then more reflexive in nature and depends on the ability for the child to rapidly transform changes of proprioceptive or vestibular origin into proper motor responses/outcomes (Rogers, Wardman, Lord & Fitzpatrick , 2001). In both static and dynamic balance, shoes can have an impact on how the body perceives proprioceptive input as the foot which has no shoe on will have different sensory input than the foot that is covered. Both static and dynamic balance can be viewed as a skill, acquired through training or play and development (Condon & Cremin, 2014). Some authors have suggested that children develop a set of balance strategies i.e. static standing balance first, and then learn how to apply and adapt these strategies in a task dependent manner i.e. dynamic standing balance (Assaiante & Amblard, 1993).

The environment as well as the selection of the appropriate balance strategy is important in each task, but function of neural maturation and experience also plays a role (Hatzitaki et al., 2002). The environment may offer new surfaces in new designs challenge the body and this in turn aids to develop postural control (Adolph, 2008) For example, the ground may be multileveled or flat; sloping or slippery; and it may be obstructed by people or furniture. This all requires adaptation in posture.

Static control has been proven to appear as early on as 15-31 months of age. This is shown through a feedback-based system (Shumway-Cook & Woollacott, 1985). However, to perform a task successfully while standing, upright stance and the completion of the goal-directed task require both upright body position and movement (Haddad, Rietdyk, Claxton & Huber, 2013). Dynamic balance requires the child to apply feedforward control and initiate an APA to upcoming changes and greatly depends on their ability to control gravity and inertial forces (Assaiante & Amblard, 1992). According to Gage (1996), stability in stance is the first prerequisite for normal gait. There is a repeated and rhythmic alternation of double and single leg support during walking with periods of single support necessary to allow swing phase mechanics of the opposite limb. Therefore the ability to control the centre of mass (COM) during single leg stance is important for independent walking (Zumbrunn, MacWilliams & Johnson, 2011).

Children with disabilities, ranging from mild motor impairments to cerebral palsy (CP), have postural control deficits (Shumway-Cook & Woollacott, 1985; Kowalski &

Di Fabio, 1995). This contributes different motor impairments including clumsiness, frequent falls during typical activities of daily living (ADLs) and difficulty in maintaining a sitting or standing position independently (Westcott et al., 1997). As stated above, balance is a complex skill that requires various systems to work together and function well.

When a child has a disability, part of a system or multiple systems may be affected and therefore is unable to function well. For example, a child born with CP may have their muscle system affected by tone and therefore it is difficult for them to maintain standing balance. Or a child with sensory processing disorder (SPD) may battle with somatosensory input and struggle to interpret where their body is in space. In a study, 23 children with spastic diplegia, a form of CP, who were ambulatory were compared to 92 children who had no disability. The results were that the children with CP had decreased balance ability when compared to the control group. The authors' reasons for the differences between groups were mostly due to mechanical changes in posture as well as CNS changes. The mechanical changes noted were due to crouch gait where children had also had surgical intervention, namely a hamstring release. This may then change the COG as well as the BOS and challenge static balance in children with spastic diplegia. Children in both groups, both control and experimental group, had decreased balance when they were asked to close their eyes. However, as seen with children who are typically developing, balance did not improve with age in the group of children with cerebral palsy. This meant that the maturation attributed to improvements in posture did not have as much impact when compared to location and severity of cerebral damage (Rose, Wolff, Jones, Bloch, Oehlert & Gamble , 2007). In other words, even though a natural maturation pathway of postural balance improved, the location and severity restricted the ceiling of balance potential.

In children with DCD, they demonstrate problems in fine and /or gross motor skills/function (Geuze, Jongmans, Schoemaker, & Smits-Engelsman, 2001; Larkin & Rose, 2005). The majority of these children also show issues with both static and dynamic balance (Cherng, Hsu, Chen, & Chen, 2007; Geuze, 2003; Jelsma, Geuze, Mombarg, & Smits-Engelsman, 2014; Macnab, Miller, & Polatajko, 2001).TD children have been shown to use movement strategies in dynamic balance, however, only a few children with DCD demonstrated these techniques, even after practice (Jelsma, Geuze, & Smits-Engelsman, 2019)

2.3 Neuro physiology of Balance

The motor and sensory systems interact to form a perfect relationship to allow the human body to remain in a stable position and if needed to provide a stable position to move from, and back to perform everyday tasks such a walking (Pollock et al., 2000).

2.3.1 Nervous system

The nervous system is responsible for sending and receiving input. This information is used to attain and maintain balance through a series of nervous connections and systems. The sensory system is an important part of this system.

Constant interaction between the central and peripheral components of the body are needed in order to maintain balance (Alexander & Lapier, 1998). Simply stated, peripheral components (the somatosensory, visual, and vestibular systems) are processed by the central nervous system and the most appropriate muscular responses is chosen to control the body position and posture over the base of support (Cote, Ii, Gansneder & Shultz, 2005). Sensory neurons receive impulses and carry them from the sense organs (skin, eyes, ears etc.) to the spinal cord or brain. Interneurons connect sensory and motor neurons and interpret the impulse. This interpretation is sent to the cerebellum which is responsible for balance, movement and coordination. Motor neurons carry impulses from the brain and spinal cord to muscles or glands. For example, if a child is walking on an uneven surface, they will receive sensory input from their skin, eyes and vestibular system (inner ear) that they need to change their gait in order to balance better. This information will go to the Cerebellum via the sensory neuron. Once interpreted, a message of how to adjust the body will be sent via a motor neuron to the relevant muscle/muscle groups. The muscles will then adjust accordingly (Gaerlan, 2010; Shaffer & Harrison, 2007; Shumway-Cook & Woollacott, 1995).

There are two responses to perturbations that have been researched. One type evaluates balance with respect to external conditions, such as different standing surfaces like grass vs brick. Centrally programmed stereotypical postural responses are revealed when an unexpected external disturbances occurs, for example, tripping over some lifted pavement on a brick road. The second type involves an anticipated internal disturbances of balance and reveals feedforward postural adjustments. Feedforward adjustments mean that the controller predicts an external input or behaves using higher- order processing and adapts accordingly, rather than implementing a simple feedback response, for example, if a child sees an object in front of them and steps over it to avoid tripping (Gatev et al., 1999). This requires an intact central nervous system, muscle system and nervous systems.

The nervous system consists of three subsystems that are involved in balance. They are the somatosensory, visual and the vestibular system which all have an important role to play in receiving and processing of sensory information:

The somatosensory system is involved in maintaining postural balance by making the body's musculoskeletal framework aware of the spatial and mechanical status (Gaerlan, 2010). This includes sense of position, movement and balance. The somatosensory system of the lower limb includes various receptors. The knee and ankle contain muscles with muscle spindles which contain mechanoreceptors to allow for proprioceptive feedback when the joint angle changes relative to the trunk (Ivanenko, Grasso & Lacquaniti, 2000). These mechanoreceptors provide the nervous system with information about the muscle's length and velocity of contraction, thus contributing to the individual's ability to discern joint movement and position sense. The muscle spindles also provide afferent feedback that translates it to appropriate reflexive and voluntary movements in adaptation to loss of balance for example (Shaffer & Harrison, 2007). Golgi tendon organs are a proprioceptive sensory receptor organ that sense changes in muscle tension. They are situated in the origin and insertion of skeletal muscles and may be responsible for force feedback about the loading of the body (Pearson, 1995). The skin receptors located in the sole of the foot are sensitive to contact pressure and may be potentially sensitive to changes in distribution of pressure (Kavounoudias & Roll, 1998). Together, these receptors allow for somatosensory information to be gathered and allow the CNS to know where the body's position is relative to the surface it's standing on (Kennedy & Inglis, 2002).

The visual system is regarded as the primary sensory information to maintain postural balance. The visual system can be explained in two parts. The focal system or central visual system as it is also known, specializes in object motion perception and object recognition. Ambient or peripheral vision is sensitive to the movement scene- it is thought to dominate both perception of self-motion and postural control (Gaerlan, 2010). Although vision is not needed to stand upright in the dark for instance (Guerraz & Bronstein, 2008), postural stability has been shown to increase with the improvement of the visual environment. The other contributing parameters of vision that affect posture are: object size and localization, binocular disparity, visual motion, visual acuity, depth of field, and spatial frequency. This all impacts how the visual system and postural control interact. Peripheral vision rather than the central vision has been shown to play an essential role in maintaining stability during static standing balance (Gaerlan, 2010). A study conducted by Berencsi et al. (2005), showed that visual stimulation of the peripheral visual field decreased postural sway in the direction of the observed visual stimulus to the antero-posterior rather than medial-lateral. This indicates that peripheral vision plays an important part in maintaining balance (Berencsi, Ishihara & Imanaka, 2005).

The vestibular system is located in the inner ear and is unique from the other sensory systems as it functions as a multisensory and multimodal system. For example, the vestibular system interacts with the proprioceptive system together with corollary discharge (a copy of a motor command that is sent to the muscles to produce a movement) of a motor plan. This then allows the brain to distinguish an actively generated movement from a passive head movement (Angelaki & Cullen, 2008) (Gaerlan, 2010). The visual and proprioceptive systems interact with the vestibular system throughout the central vestibular pathways and are essential for postural control. The brain stem contains premotor neurons and second-order sensory neurons that receive afferent input and send it directly to the motor neurons. This interaction of multisensory and multimodal pathways is important for higher level of function such as balance and spatial awareness (Gaerlan, 2010).

2.3.2 Muscle system

The muscle system has to put in to action what the nervous system has interpreted. This requires activation, control and endurance especially in a complex task like balance. During standing balance control, coordinated long-latency responses (stretch response) in muscles are recalled to help return the body to postural equilibrium. Coordinated long-latency responses are defined as muscle activity that occurs 50–100 milliseconds after a mechanical perturbation has occurred. These can be coordinated across multiple joints to support goal-directed actions (Weiler, Saravanamuttu, Gribble & Pruszynski, 2016) This requires brainstem integration of multisensory cues (Deliagina, Beloozerova, Zelenin & Orlovsky, 2008). Research has shown that muscles are often grouped in functional groups called muscle synergies. These synergies are proposed to specify a fixed pattern of co-activation across multiple muscles at any given time point. This allows for muscle coordination during a variety of motor movements including balance control (Torres-Oviedo & Ting, 2010).

The biggest group of muscle synergies responsible for postural control is known as the core. The ‘core’ is a system of muscles that comprise of both local stabilisers and global mobilisers. Huxel Bliven et al. (2013) have described the ‘core’ as the foundation of the kinetic chains responsible for facilitating the transfer of force and momentum between the lower and upper extremities for gross motor tasks of daily living. Local stabilisers are needed to provide stability to the body and consist of deep muscles with attachments on or near the vertebrae that primarily function eccentrically. Global mobiliser muscles are typically bi-articular (affect more than one joint) and are superficial muscles that connect the trunk to the extremities and function concentrically (Huxel Bliven & Anderson, 2013). In order for the global mobilisers to function, the local stabilisers need to provide a stable base on which they can act. The proximal foundation becomes unstable or maligned when core muscles are weak or are not recruited appropriately. This causes abnormal movement patterns of the trunk and lower extremity affecting balance as the base is no longer as stable as needed (muscle systems) (Gibbons & Comerford, 2001) and therefore, the sensory information received will be altered based on positioning of the limb relative to rest of the body (proprioceptive input).

2.3.3 The balance of two systems

The cerebellum, located at the base of the brain is responsible for modulating postural control. “It is important for movement control and plays a particularly crucial role in balance and locomotion” (Morton & Bastian, 2004). Features of cerebellum damage are observed typically in gait and balance impairments for example, increased postural sway and ataxic gait pattern (Morton & Bastian, 2004). The cerebellum helps coordinate motions at joints (Earhart & Bastian, 2001) and plays an integral role in the control of upright posture during walking (Morton & Bastian, 2004).

The motor and sensory systems are used together with the planning and execution of flexible movement patterns to achieve many potential postural goals. Postural control is task dependant. During upright stance, the centre of gravity is high and the base of support is small making the maintenance of stability more difficult. Similarly, the more complex the task, the more postural control is needed. For example e.g. standing on one leg is viewed more challenging than standing with both feet close together (Butz, Sweeney, Roberts & Rauh, 2015).

The development of postural control occurs in stages based on the development of these specific systems (Assaiante, Mallau, Viel, Jover & Schmitz, 2005). These develop with age. The somatosensory system matures first and the vestibular system last. Postural control therefore develops as each system reaches the necessary threshold to support the associated behaviour (Butz et al., 2015). While the sensory system is maturing, so too is the muscle system. From four to six years of age, children begin to use somatosensory information appropriately and develop balance strategies for control with altered balance conditions. Seven- to ten-year-old children use more mature strategies with altered conditions such as developing better visual control and integrating vision with other sensory information (Christine Assaiante et al., 2005; Peterson, Christou, & Rosengren, 2006; Woollacott & Shumway-Cook, 1985)). It is believed that children integrate their visual system and develop better control between seven and eight years of age (Nolan, Grigorenko &

Thorstensson, 2005). This then ideally means that a child who is older, should then have better balance than a younger child.

2.4 The function of the foot in balance

The foot is vital in the role of balance as it is the most distal segment of the body and the only part of the body that comes in contact with the ground. This means it needs to provide all the incoming sensory information as well as provide the muscle system for support.

2.4.1 Anatomy and function of the foot

The foot is a specialised asset in the locomotion of humans and serves many diverse functions. The foot acts as a base of support while in standing and in the gait cycle, it must provide stability during push-off and heel-strike and a mobile adaptor during mid-stance. It possesses spring-like characteristics, storing and releasing elastic energy with each foot-strike (Mckeon, Bramble, Davis, Hertel, 2015). All movement within and by the foot is controlled by intrinsic and extrinsic foot muscles, which combined with the somatosensory input (sensory data received from skin, muscles and organs), allow the foot arches to adapt to the function needed (Franklin et al., 2015). The foot comprises of 26 bones, 33 joints and 19 muscles, which are arranged to form four foot arches namely the medial and lateral longitudinal arches as well as the anterior and posterior transverse metatarsal arches (Franklin et al., 2015). Normal foot function requires a stable arch to be formed (Mckeon et al., 2015). The intrinsic foot muscles which include the four layers of plantar muscles, originate and insert on the foot. These are local stabilisers and primarily provide the arches with stability. The first two layers on the plantar aspect align with the medial and lateral longitudinal arches of the foot, whereas the deeper two layers configure more with the anterior and posterior transverse arches. These intrinsic muscles control the degree and velocity of the arch structure (Mckeon et al., 2015). Abnormal movement of the foot occurs when they are not functioning properly, therefore the foundation becomes unstable and misaligned. This generally results in foot-related problems for example, plantar fasciitis (Leetun, Ireland, Willson, Ballantyne, & Davis, 2004). The global movers originate in the lower leg, cross the ankle and insert on the foot. These muscles are the prime movers of the foot and have larger cross-sectional areas with larger moment arms. They allow for absorption and propulsion during dynamic activities (Mckeon et al., 2015). They also provide some stability to the arch.

2.4.2 Role of the foot in balance

Being the most distal segment of the lower limb, the foot has the important role of being the base of support for the rest of the body, especially in single leg stance. During stance phase of the gait cycle, the foot is responsible for adaptation to the ground surface, aids in shock absorption and propels the body forward during push-off in gait. Correct foot motion, especially subtalar pronation and supination is very important in achieving these functions (Cote et al., 2005).

Staheli, Chew & Corbett (1987), looked at 441 normal subjects and documented that longitudinal arch develops between the ages of six to eight years. . Muscles and ligaments support these four arches. These all act as shock absorbers for bodyweight, and preserve stability during both walking and standing (Winter, 1995; Mckeon et al., 2016).

2.4.3 Biomechanics

Achieving balance over various disturbances requires precise and dynamic coordination of multiple muscles not just of the 'core', but also across the limbs and trunk. These are controlled via hierarchical neural pathways (Chvatal & Ting, 2013). As standing balance is maintained in a closed kinetic chain, it relies on the integrated feedback and movement strategies among the hip, knee, and ankle. Balance can be disrupted by decreased afferent feedback, insufficient strength in musculature or decreased mechanical stability of any joint or structure along the lower extremity kinetic chain (Cote et al., 2005).

A study by Wang & Asaka (2008) investigated multi-muscle synergies involved in shifts of the COP while standing on a narrow support. Using electro myography (EMG), they found that the following muscles worked together and contribute to achieving postural control during a standing task: lateral and medial heads of gastrocnemius, soleus, semi-tendinosus, biceps femoris, gluteus medius, erector spinae, tibialis anterior, vastus lateralis, rectus femoris, tensor fasciae latae and rectus abdominus . These muscles all work in synergy with the foot to provide a stable base of support.

2.5 Measurement of balance

When assessing balance, there are numerous methods available. These methods include field-based or clinical-based tests such as Paediatric Balance Scale (PBS), Timed Up and Go (TUG) and Functional Reach Test (FRT) or more research-based technologies using posturography, motion cameras and/or force plates (Westcott et al., 1997). Force plates, often used in research settings, aid in the calculation of joint kinetic variables and other data (East, Noble, Arscott, & Shortland, 2017). There are a few factors to consider when choosing how to measure, such as cost, ease of use, time to complete tests. For example, more research-based technology will be a lot more expensive than clinical based tests but may give more detail needed for measurement, however, may take longer to measure. A clinical based therapist will not require expensive equipment to measure their day-to-day patients (Field & Roxborough, 2011). Force plates are used widely in the assessment of both adults and children (Geldhof et al., 2006). It has been found to be a reliable technique to measure postural stability, both static and dynamic (Geldhof et al., 2006).

2.5.1 Measures of balance used in paediatrics

Analysis of balance is an important component when assessing children with gross motor impairments/dysfunction. Valid and reliable tools to measure balance are crucial for physiotherapists to justify intervention for the child as well as demonstrate if there is improvement with the intervention. Traditional assessments of balance include timed measures of static sitting and standing balance, including single limb stance (Mancini & Horak, 2010). The Bruininks-Oseretsky Test of Motor Proficiency (BOT-MP), the Peabody Development Motor Scale (PDMS) and the Movement- ABC

(MABC) are used to assess balance in children with mild to moderate motor impairment/dysfunction. Not all outcome measures observe functional balance. It is important to be able to observe this as the child's functional balance allows us to measure postural control which allows a child to safely perform activities of daily living (Jantakat, Ramrit, Emasithi, & Siritaratiwat, 2015).

A good assessment tool should include the following: address the area of concern, be valid and reliable, easy to administer and be sensitive to change. In a recent systematic review, 20 clinical balance tools were identified that could be used in children with CP. The strongest level of evidence was found for the Trunk Control Measurement Scale (TCMS), Level of Sitting Scale, Timed Up and Go (TUG) and the Segmental Assessment of Trunk Control (SATCo) (Saether, Helbostad, Riphagen & Vik, 2013). Of these 20 tools, only 11 assessed balance in standing. In 1998, Leemrijse et al., proved that the MABC was sensitive to detect individual change in children with mild to moderate motor impairment (Leemrijse, Meijer, Vermeer, Lambregts & Adèr, 1999). The PBS has been found to have a good test-retest and interrater reliability when assessing school-aged children with mild to moderate motor impairment/dysfunction (Franjoine, Gunther & Taylor, 2003)

2.5.1.1 The Paediatric Balance Scale (PBS)

The PBS was modified from the Berg Balance Scale (BBS) which was found both valid and reliable in geriatric patients. Interrater reliability was 0.98 and test-retest reliability was 0.99 for the PBS. The PBS was developed as the BBS required static postures to be maintained for two minutes and this proved to be difficult for the children based on attention span, behaviour of the child and the ability to follow directions. This time was decreased to 30 seconds. Another modification was the organisation of test items. In the BBS, items were organised by increasing difficulty of the task. In the PBS, the items were organised in functional sequences. Items include: sitting to standing, standing to sitting, transfers, standing unsupported, sitting unsupported, standing with eyes closed, standing with feet together, standing with one foot in front, standing on one foot, turning 360 degrees, turning to look behind, retrieving an object from the floor, placing alternating feet on a stool while reaching forward with an outstretched arm. Test-retest reliability and inter-rater reliability were both high. These scores were 0.998 for test-retest reliability and inter-rater reliability 0.997 in children with CP aged 5–15 years. It also scores an excellent test–retest reliability of 0.923 and inter-rater reliability of 0.972 in young typically-developing children (Jantakat, Ramrit, Emasithi & Siritaratiwat, 2015). PBS can be considered a simple, valid scale for examining functional balance capacity in children with spastic CP (Yi et al, 2012). The use of shoes and orthotics is not mentioned. The test can be administered to children with and without CP from the ages of five to 15 years. The static standing balance items of the PBS are potentially suitable for testing the functional static balance of CP adolescents with GMFCS level III while the BBS is more suitable for adolescents with mild CP (Jantakat et al., 2015). Although the BBS does not specify shoes or not, Kembhavi et al. (2002) allowed children to wear orthoses and shoes when administering the test (Kembhavi, Darrah, Magill-Evans & Loomis, 2002). Darr et al (2015) recommended that the most appropriate applications for the current version of the PBS are: identification of children with balance disorders and the tracking of changes in balance over time. As the PBS is unidimensional, it does not currently help to identify specific aspects or dimensions of balance in need of rehabilitation (Darr, Franjoine, Campbell, & Smith, 2015).

2.5.1.2 The Timed Up and Down Stairs (TUDS)

The TUDS was developed as a functional mobility assessment tool that would reflect improvements in the musculoskeletal and neuromuscular systems that contribute to the control of posture. This outcome measure involves observing the patient ascend one flight of stairs, turn around and descend to the starting point. TUDS requires lower limb and trunk strength, range of motion (ROM), coordination for fast reciprocal movements and postural control- including anticipatory and reactive control (Zaino et al., 2004). Lepage et al. (1998) provided support that there is a relationship between functional abilities and stair-walking tasks in children. They found that a timed up and go stairs task which is similar to the TUDS is associated with the ability to function in various situations, including school and social. These situations were measured by the Life Habits Assessment (version 1). Among locomotor outcome measures used, the timed up and down stairs task accounted for the largest amount of change in disruptions across the four category's including: mobility, community, recreation and residence. The TUDS appears to be an important outcome measure in the functional mobility and balance. This outcome measure is reliable (scores) for children with and without CP between the ages of eight and 14 years. Intra-rater reliability was 0.99 and the test–retest reliability was 0.94. It appears to have preliminary concurrent and construct validity. The test is administered with shoes but no orthoses. It has been analysed that a few tests were moderately and significantly related. This suggests that static control of balance (TOLS), anticipatory control of balance (FRT) and strength, and balance for dynamic movement from sit-to-stand, walking, and turning on a level surface (TUG) were all related components of the TUDS task (Zaino et al., 2004).

2.5.1.3 The Functional Reach Test (FRT) and Paediatric Reach Test (PRT)

The FRT was initially developed for use in an adult population. It measures the distance that an individual is able to reach forward from a starting point in a standing position with a fixed base of support without losing balance. The FRT has been proven reliable in the paediatric population but requires the children to maintain a static standing position, barefoot for at least two minutes as a prerequisite for the test. The FRT is suited for children aged 4.5 to 15 years (Niznik, Turner & Worrell, 1995; Donohoe, Turner & Worrell, 1994). The intra-rater reliability was 0.97 and the interrater reliability was 0.98. In the Paediatric Reach Test (PRT), children stand with their arms at their sides, feet at an equal distance to the foot tracings. Children are instructed to reach forward, moving at their ankles only, as far as possible without lifting their heels off the ground. They are required to maintain this position for at least three seconds. The child is then instructed to lean as far back without letting their toes leave the ground. They are required to maintain this position for three seconds as well. The child then repeats while leaning to the left and to the right. The measure of steadiness of quiet stance (standing still with both feet naturally apart) was tested by asking the child to stand as still as possible for 30 seconds. The PRT is a valid and reliable measure that can be used in children with and without CP. Intra-rater reliability was between 0.54 and 0.88, interrater reliability was 0.50 to 0.93 and test-retest was between 0.71 and 0.97 for the CP population. Sitting and standing balance is tested and permission to use orthoses and gait aides reflect functional aspects of balance in a more typical context than standing barefoot. The

PBS test is suited for typically developing children aged three to 12.5 years and for children with cerebral palsy aged 2.6 to 14.1 years (Bartlett & Birmingham, 2003).

2.5.1.4 Paediatric Clinical Test of Sensory Interaction for Balance (P-CTSIB)

The P-CTSIB was first developed by Shumway-Cook and Horak, in 1986. It is a timed test that observes the visual, vestibular and somatosensory input on standing balance. Children between the ages of four and nine years are suitable for this test. Testing is done barefoot and standing on the floor with eyes open, eyes closed and then wearing a visual-conflict dome. The dome limits peripheral vision and introduces a sway-referenced image. The child is tested on a hard, firm surface and then on a firm but compliant piece of high-density foam. These six conditions are tested with feet together and heel-to-toe standing. Total degrees of anterior/posterior sway are recorded with feet together and total lateral degrees of sway are recorded with heel-to-toe standing (Deitz et al., 1991).

2.5.1.5 Timed One-Leg Stance (TOLS)

This tool has been used extensively in the adult population, however, recently has been used in the paediatric population. It is unspecified for certain ages. The child is barefoot and is instructed to stand on one leg with hands on hips. They are 61cm from the visual target which is located at eye level on a wall. The child may stand on the foot of their choice. No support of the upper extremities or bracing of the unweighted leg against the stance leg was allowed. The patient begins the test with the eyes open, practicing once or twice on each side with his gaze fixed straight ahead. The patient is then instructed to close his eyes and maintain balance for up to 30 seconds. The number of seconds that the patient is able to maintain this position is recorded. Termination or a fail test is recorded if the foot touches the support leg, hopping occurs, the foot touches the floor or the arms touch something for support. This method of timing of the TOLS has been shown to be reliable (0.91 to 0.99) in the paediatric population (Zaino et al., 2004).

The study done by Condon and Cremin (2014) indicate that balance improves with age. They also indicate that vision is an important input to maintain balance and that an unstable surface provides a bigger challenge to maintain balance and thus the times are decreased when standing on a foam surface compared to a flat and stable surface. Static balance tasks on a stable surface for the under seven's is between eight and 32 seconds, increasing to between 20 and 74 seconds by eight to nine years and between 48 and 120 seconds by the age of ten. By the age of 12, the median has reached 120 seconds. This demonstrates that a 12 year old should have significantly better balance than a child under seven.

2.5.1.6 Timed Up and Go (TUG)

The TUG was originally meant for elderly adults and requires a patient on the command of "go" to get up off the chair and walk 3m and return to the chair. They are timed from "go" until they ae seated again (Podsiadlo and Richardson, 1991). This has been slightly modified for the paediatric population. The child starts seated with their feet flat on the floor and their hip and knee remained in 90° of flexion. They are then instructed to stand up from the chair, walk and touch an object (star) on the wall 3m away and then return to being seated on the chair. It has been proven to be both valid and reliable in typically developing children and children with disabilities. Intra-rater reliability was between 0.80 and 0.89 and test-re-test reliability was between 0.61 and 0.89. (Williams et al., 2005). A concrete task was used instead of the more abstract verbal instructions of the standard TUG test. Abstract instructions have been shown to limit performance in children with CP (Dhote, Khatri, & Ganvir, 2012).

2.5.1.7 Bruininks-Oseretsky Test of Motor Proficiency (BOT-MP) and BOT-2

Dr Robert H. Bruininks began to develop the Bruininks-Oseretsky test in 1972. He based his test on the US adaptation of Oseretsky tests (Düger, Bumin, Uyanik, Aki, & Kayihan, 1999). The BOT-MP and its review, the Bruininks-Oseretsky Test of Motor Proficiency second edition (BOT-2), are tools to assess fine and gross movement skill development. They are used to identify individuals with mild to moderate motor coordination deficits. The test is suitable for individuals aged four to 21 years. The BOT-MP comprises of subtests: Running speed and agility, Balance, Bilateral coordination, Strength, Upper-limb coordination, Response speed, Visual motor control, and Upper-limb speed and dexterity. The complete BOT-2 features 53 items and is divided into eight subtests: fine motor precision (seven items), fine motor integration (eight items), manual dexterity (five items), bilateral coordination (seven items), balance (nine items), running speed and agility (five items), upper limb coordination (seven items), strength (five items). The items in every subtest become progressively more difficult. A short form of the BOT-2 can be used as a screening tool to achieve rapid and easy scoring reflecting overall motor proficiency (Cools et al., 2009). Although it is a general outcome test, there is a balance subtest which can be used. Interrater reliability was above 0.90 and test-retest reliability was above 0.80 (Deitz, Kartin & Kopp, 2007)

2.5.1.8 Movement Assessment Battery for Children (MABC)

Both the MABC and the updated version (MABC-2) look to identify and describe motor impairments in children. It was designed from 1966 to 1992. It is a standardised test that divides children in to three age bands: Three to six years, seven to ten years and eleven to 16 years. It provides information on how the child approaches and performs the tasks. Within each age band there are eight items grouped together under three headings: manual dexterity, Aiming and catching and Balance. The MABC was found both valid and reliable. Inter-rater reliability test retest reliability was excellent (ICC <0.95). Inter-rater reliability for the MABC-2 was excellent (ICC between 0.92 and 1.00) and test-retest reliability was fair (ICC between 0.62 and 0.92). The MABC-2 was also found to be valid (MABC-2 manual).

2.5.1.9 Peabody Development Motor Scale (PDMS)

The PDMS-2 is a revision of the original PDMS published in 1983. It consists of six subtests of which four involve gross and two involve fine movement skills. The test is designed to assess movement skills of children from birth to six years of age. The gross movement subtests include: reflexes (eight items), stationary performances (30 items), locomotion (89 items) and object manipulation (24 items). The fine movement subtests include: grasping (26 items) and visual-motor integration (72 items). The stationary performances measures a child's ability to sustain control of the body within its COG and retain equilibrium. The locomotion subtests observe a child in functional tasks such as such as crawling, walking, running, hopping and jumping forward. According to the authors (Folio & Fewell, 2000), the PDMS-2 is a standardized instrument including reliable and valid scales. Administering the whole test varies between 45 and 60 minutes. The PDMS-2 test shows several improvements (Simons, 2004; Vanvuchelen et al., 2003). Firstly, normative data have been expanded to 2003 American and Canadian children (Data collected between 1997-1998). The authors of the PDMS-2 report that reliability and validity have been thoroughly analysed and optimized (Folio & Fewell, 2000). Tavasoli, Azimi & Montazari (2014) found that the intra-rater reliability and test-retest reliability was 0.98 in low weight preterm infants. Also new score criteria have been added to the initial PDMS. Illustrations have been included to clarify assignments (Cools et al., 2009).

Footwear is not consistently standardized in the administration of measures to determine balance, gait and or motor ability in paediatrics (Arnadottir and Mercer, 2000). This study looked at 15 tools/instruments that measure balance in paediatrics and found that only the TUDS and PRT permit the wearing of shoes in the assessment. Barlett et al. (2003) argues that sitting and standing balance can be tested with the use of orthoses and gait aides as it reflects functional aspects of balance in a more typical context than standing barefoot.

2.6 Shoes and Orthotics

2.6.1 History of shoes

Shoes were originally worn to primarily protect the foot (Staheli, 1991). They protect from injuries that can be caused by rough or uneven ground surfaces and environmental conditions such as cold and wet (Trinkaus & Shang, 2008; Wolf et al., 2008). Prehistoric footwear was perishable and therefore hard to preserve, however, the earliest known footwear, dating from approximately 7,500 BC, were either a simple sandal secured around the ankle with rope or a simple slip-on shoe which consisted of sides but no ties or fasteners (Kuttruff, DeHart & O'Brien, 1998). The oldest direct evidence for footwear, in the form of woven sandals, dates to the early Holocene/terminal Pleistocene of North America (Trinkaus & Shang, 2008).

In children shoes were initially created rigid and compressive to provide support for the child's developing foot as it was deemed to need stability. It has however since been argued and found that optimum foot development can only occur in barefoot conditions and that tight footwear may lead to deformity and stiffness in the foot (Staheli, 1991). In a study by Emslie (1939), 80% of the 281 children aged two- four years included in her study, had deformities of the toes. The same deformities were not seen in children without shoes. The shoes that were worn were described as ill-fitting and ill-designed. Sim-Fook and Hodgson (1958), compared 118 shoe-wearing and 107 non-shoe-wearing Chinese people and found that the feet of the barefoot subjects showed greater mobility and fewer deformities than of those wearing shoes.

The foot is a specialised asset in the locomotion and acts as a base of support while in standing, and in the gait cycle it must provide stability during push-off and heel-strike. It is also a mobile 'adaptor' during mid-stance, storing and releasing elastic energy with each foot-strike (Mckeon et al., 2015). Several early studies consistently demonstrate that the bare human foot has excellent mobility, especially of the forefoot; thickening of the plantar skin as great as 1 cm; flexibility of the mid-tarsal joints which cause creases on both the plantar and dorsum of the foot; alignment of the phalanges with the metatarsals causing the toes to spread; and an absence of static deformity (Staheli, 1991).

The foot structure is involved in loadbearing, leverage, shock absorption, balance, and protection (Takata,Matsuoka, Okumura, Iwamoto, Takahashi, 2013). The stretch response in the intrinsic muscles, sends immediate sensory information to the arches of the foot. Headlee, Leonard, Hart, Ingersoll & Hertel, (2008), observed 21 participants and found that the navicular bone dropped during standing after fatigue of the intrinsic foot muscles. Although authors above concluded that the motor contributions of these muscles led to the change in foot posture, it may also be a result in the change of sensory information experienced by the foot (Mckeon et al., 2015). For example, another aspect that has been linked to muscular fatigue in other areas of the lower extremity is decreased proprioception (Hiemstra, Lo & Fowler, 2001). This may indicate that both direct support and sensory information are communicated to the passive subsystem about the foot dome posture. The structure of the foot is specific to its function of both mobility and stability and can impact gross motor milestones in children.

2.6.2 Shoes and balance

Wearing of shoes or not however is controversial. Whitney et al, 2004 found in a group of 30 adults that there was no difference in the wearing of shoes when testing balance and sensory integration using the modified Clinical Test of Sensory Interaction and Balance (CTSIB) which was designed by Shumway-Cook and Horak (1986). Arnadottir and Mercer (2000), however found that wearing shoes may influence measurements of balance. The authors compared shoe wearing with no shoes in 35 adult woman who were tested on the FRT, TUG, and 10-Metre Walk Test (TMW). They recommend that footwear should be carefully documented and should remain constant from one test occasion to another when the FRT, TUG, and TMW are used in the clinic and in research.

Franklin et al. (2015) performed a systematic review on the effect of barefoot versus common footwear on kinematic, kinetic and muscle activity differences during walking. It yielded 15 articles of which five articles observed children. They concluded that long term use of footwear has been shown to result in anatomical and functional changes. These include a reduced foot width and forefoot spreading under load probably due to the constraints of the shoe structure. Walking in footwear is associated with an increase in stride length and greater dorsiflexion at foot-ground contact. Lighter and more flexible footwear appears to elicit similar gait kinematics to walking barefoot. When walking barefoot there is a reduced initial vertical impact force and more even distribution of pressure across the foot is experienced which is likely to be as a result in a larger contact surface area. This results in a flatter foot placement.

Moreno-Hernandez et al. (2010) found in their study of 120 children that the use of shoes increased velocity and normalised cadence, step and stride length. Oeffinger et al. (1999) found that in their study of 14 children, shoes had a surprisingly small impact on gait kinetics and kinematics. Although there were minimal changes in the kinematic and kinetic curves, these changes do not appear to be clinically significant. In Lythgo et al.'s study of 898 children in 2009, they concluded that the wearing of shoes has a significant effect on gait. Gait speed, step length, stride length, support base, step and stride time increased with footwear whereas foot angle and cadence reduced.

In a recent study, 101 men consisting of 75 that were minimally shod and 26 that wore conventional modern shoes, were analysed for foot strength and stiffness of their feet. The results suggested that use of conventional modern shoes was associated with weaker intrinsic foot muscles that may predispose individuals to reduced foot stiffness and potentially flat foot (Holowka, Wallace, & Lieberman, 2018).

2.6.3 Orthotics

Orthotics are a common addition to shoes in order to correct deformity or aid in normal alignment of the foot. They are used with typically developing children and adults as well as children and adults with mild to severe developmental motor disturbances. Orthosis is defined by the International Standards Organisation as 'an externally applied device used to modify the structural and functional characteristics of the neuromuscular and skeletal system' (Eddison, Mulholland & Chockalingam, 2017). Foot orthoses are commonly used devices worn in the shoe to alter loading during walking. Supramalleolar orthosis (SMO) are thought to use compression to promote midline positioning of the foot and enhance receptor function. This is different to the traditional thinking of wedging the foot into a neutral position. The study supports the hypothesis that flexible SMO's have a positive effect on measures of postural stability in children with Down's Syndrome (Martin, 2004). This could then suggest that shoes or orthoses could provide children with improved postural stability and therefore balance.

In 2004, Martin observed the effect of SMO on postural stability in children with Down's syndrome. Seventeen children between the ages of three years six months and ten years participated in the study. Martin (2004) found that there was a positive effect on postural stability when the children wore their SMO. This test only compared shoes and SMO and did not observe barefoot.

The topic of balance in both children and adults have been explored a fair bit in the literature and has caused much discussion. From the literature, we have gathered that balance is a very complex motor skill to assess, however a very necessary one, especially to assess functional ability and development. Balance is a precursor for many motor milestones including walking and thus needs to be assessed. We know that balance requires an intact and well-functioning CNS, sensory system and motor system and it is vital that these systems are integrated to achieve balance. What we are still unsure of from the literature is whether or not shoes impact on the outcome of balance. Many paediatric outcome measures do not specify whether or not shoes are needed for testing and this leaves many clinicians and researchers asking the question if shoes are actually important in balance testing.

2.7 Relationship of age, gender, height and weight on balance in children

As already discussed, balance is a complex skill to master and many components have an effect on it. It has been established that children improve balance scores with an increase in age (see 2.3.3) (Geuze, 2003; Stanek, Truszczyńska, Drzał-Grabiec, & Tarnowski, 2015). The effect of both height and weight have recently been observed and found to have a positive relationship with balance. In 2015, Stanek et al, found that children balanced better when they had a greater body weight and body height. This may be due to these children potentially having a larger BOS. Taller children may have larger feet and thus a larger BOS. Children with a greater body weight may therefore also have better muscle development and be physically stronger and therefore have better balance.

It has also been demonstrated that girls have better balance than their age matched peers for a number of reasons including attention span of younger-aged boys (Lara, Graup, De Souza Balk, Teixeira, Farias, Alves & Leiria, 2018) ; Steindl, Kunz, Schrott-Fischer, & Scholtz, 2006).

Lara et al (2018) also observed a negative relationship between balance and children who were either obese or overweight. She established that children who were classified in these categories tended to have a decrease in balance scores.

Age and gender have been discussed at length with inconclusive results. Nolan et al (2005) found both age and gender to impact standing balance in children aged 9 to 16 years. It has also been found that movements of the COP are stabilised earlier in girls than in boys (Odenrick & Sandstedt, 1984; Riach & Hayes, 1987). However, Donahoe et al (1994) reported that age and not gender, contributed to an improved balance score measured by the FRT and Williams et al (2005) agreed with this finding. Balance has been seen to decrease as BMI increases in children (Franjoine et al., 2010). Static standing balance decreased as BMI increased in boys aged 8 to 10 years (McGraw, McClenaghan, Williams, Dickerson & Ward, 2000) and in teens who are obese when compared with peers of normal weight (Bernard, Geraci, Hue, Amato, Seynnes & Lantieri, 2003). Scores on the balance subtest of the BOT were significantly lower in the boys who were overweight (BMI > 85th percentile) than in the boys of normal weight (BMI < 85th percentile) (Goulding, Jones, Taylor, Piggot & Taylor, (2003).

2.8 Summary

Balance is complex in nature as it involves many systems internally but also dependant on the external environment. Balance is said to be establish between seven to ten years of age when children present with more adult-like stability. The internal systems, namely the sensory system, consist of vision, vestibular and somatosensory components which tell the nervous system and CNS where the body is in relation to the external environment. The CNS then sends out messages to the muscle system to adapt or remain the same in order to keep the COM over the BOS.

It has long been debated whether or not shoes impact/influence balance. This has been explored in the adult stroke population with shoes being prescribed to assist with balance. In the paediatric community, outcome measures used to establish gross motor function levels, with balance being a key factor in these assessments. Something that remains unclear is if children should be wearing their shoes during testing. Common outcome measures remain divided and unclear on this. Also, there is there a relationship with balance and age, gender, height, weight and possibly BMI.

If the wearing of shoes impacts on balance, surely this needs to be explored further and made known to clinical therapists who both assess and treat balance impairments.

Chapter 3: Methodology

3.1 Introduction

This chapter gives an outline of research methods that were followed in the study. It provides information on the participants, including both inclusion and exclusion criteria, who the participants were and how they were sampled. The researcher describes the research design that was chosen for the purpose of this study and the reasons for this choice, including both aims and objectives. The instrument that was used for data collection is also described and the procedures that were followed to carry out this study are included. The researcher also discusses the methods used to analyse the data. Lastly, the ethical issues that were followed in the process are also discussed.

A thorough explorative literature review was done prior to the setting out of this project. This was used to identify any gaps in the literature that would be helpful to explore.

3.2 Research question

What is the effect of wearing shoes on the balance sub-scores of selected outcome measures? And is this effect greater in children with mild motor impairment when compared to age matched peers with typical development (TD)?

3.3 Aims and objectives

The primary aim of this study is to determine whether wearing shoes compared to barefoot affects the scores of selected paediatric balance and motor function measures and to determine whether this effect is greater in children with balance impairments compared to their age matched peers with typical development (TD).

The specific objectives of the study are to determine in a group of pre-adolescent children with impaired balance and or motor function the following:

1. Whether balance scores differ when wearing shoes compared to barefoot testing using the Paediatric Balance Scale (PBS) and the Bruininks-Oseretsky Test of Motor Proficiency (BOT-MP). For reasons why these tests were selected, see Chapter 3.8
2. Whether this effect is greater in children with known mild motor dysfunction compared to their age and gender matched peers with TD.

Secondary objectives:

1. To explore relationships between height, weight, age, gender and diagnosis, and balance.
2. To determine the sensitivity of sub-scores and/or individual items for detecting effect of wearing shoes on balance.

3.4 Study design

A descriptive, cross-sectional study design was used in which the effect of wearing shoes on balance will be compared between children with mild motor dysfunction (case) and typically developing children (control).

3.5 Research population and setting

All pre-adolescent (4-10 years) children with mild motor dysfunction as determined by a referral to either physiotherapy or occupational therapy for postural, gross motor impairments (dysfunction) or balance difficulties were eligible for inclusion in this study. These children were compared to both age and gender matched peers who were typically developing (TD).

Each of the five schools used had a therapy room/ small hall that was used as the research setting. This was for ease of gathering and assessing the children. Each of the rooms used were a similar set up and were open with a fair amount of room. The testing stations were set up by myself as to keep consistent with assessing as much as possible.

3.6 Sampling

For the group with mild motor dysfunction (Group MMD), all those referred to physiotherapy or occupational therapy for mild gross motor dysfunction e.g. abnormal gait, poor posture and/or clumsiness were invited to participate. These children were purposefully age and gender matched with typically developing children (Group TD) from the same school. By selecting children from the same school, it was assumed that they all had similar socio-economic backgrounds and exposure to physical activity (which can influence balance performance). The type of children's physical activities were not explored in this study, nor were if they took part in any physical activities.

3.6.1 Sample size calculations

A sample size of 70 was calculated with the help of a statistician based on the population size (representative), margin of error, confidence level and standard deviation[1]. This included 35 children in the case group and 35 children in the control group.

The specific objectives of the study are to determine in a group of pre-adolescent children with impaired balance and or motor function the following:

[1] Dr Carl Lombard - a statistician from Stellenbosch University

Objective 1:

In order to compare the mean scores with and without shoes within the same child, a sample size for a paired t-test was devised. It was assumed that the mean PBS balance score for wearing shoes was 55 with standard deviation of two versus a mean balanced score of 54 in the barefoot state with the same standard deviation. Power was set at 80% and significance level at 5%.

A sample size of 34 would be able to detect a small difference on this scale.

The same approach for the BOT-MP score was used and a sample size of 34 would have 80% power to detect conservative differences with respect to objective 1.

Objective 2:

For the comparison of the shoe effect between cases and matched controls, mean differences were specified for each group plus standard deviation for comparison using a paired t-test.

A sample size of 34 pairs would have 80% power to detect a difference of 0.5 on the PBS and BOT-MP scales using a standard deviation of 2.

The sample size of 35 case and 35 matched controls would therefore have good power for conservative effect sizes in the planned study.

3.6.2 Inclusion criteria

To be included in this study, children had to be:

- Between ages of four to ten years
  (This is in line with literature where most balance standardised tests or outcome measures in paediatrics include the age range four to ten. This may be due to balance development of children and different strategies recruited for children to maintain balance. Children between four and six years begin to use somatosensory information to develop appropriate balance strategies. Children

seven to ten, begin to use vision integrated with other sensory systems to develop more mature balance strategies (Butz et al., 2015).

- boy or girl
- in good health for at least two weeks prior to testing- this included an absence of ear infections, upper respiratory infections and any other illness that would affect gross motor abilities/balance
- had written informed consent from their parents or legal guardian (Addendum F) and should they be seven years and over, assent for themselves – This is conjunction with the World Medical Association (WMA) Declaration of Helsinki with verbal for children younger than seven and written assent for children seven years and above (Addendum G)

For Group MMD (children with referred mild motor dysfunction), children also had to:

- have been referred to therapy (occupational therapy or physiotherapy) for gross motor milestones delay/problems, including balance difficulties or for poor posture and currently be enrolled in theapy
- Not have received more than one year of therapy intervention. This is due to the rehabilitation of children that may affect their presentation.

For Group TD (age and gender matched children with MMD), children also had to:

- have no history of physiotherapy and/or occupational therapy or any formal diagnosis of mild motor disorder. This was ensured by the headmaster/headmistress

3.6.3 Exclusion criteria

Children that presented with any other associated mental or physical conditions which could affect their balance abilities, including those unable to follow verbal instructions, with CP or other neurological or orthopaedic disorders, were excluded from participating in this study.

Children's physical activities were not taken in to account in this study.

The headmaster/headmistress of each school was presented with this inclusion and exclusion criteria and asked to include children accordingly.

3.7 Research setting

A sample of convenience was selected for this study. The sample was selected from children referred to the Occupational Therapy (OT)/Physiotherapy (PT) practice at the various schools and matched with children (age and gender) from the same school in the Northern Suburbs of Johannesburg. Each Head of School was contacted and permission was obtained (Addendum E). There were five schools used in total. These schools are all mainstream schools with physiotherapy/ occupational therapy based on the school campus. Although the Northern Suburbs of Johannesburg are known to be affluent and these schools were private, there are a mixture of children form all socio-economic backgrounds through sponsorship programs/subsidies who would otherwise have attended public schools. Schools were contacted through their emails and websites.

3.8 Instruments

The two balance outcome measures selected for this study were the Bruininks-Oseretsky Test of Motor Proficiency (BOT-MP or BOT) and Paediatric Balance Scale (PBS).Both these scales are commonly used in testing balance in the paediatric population and have both been shown to be both valid and reliable in the population being tested (Cools, De Martelaer, Samaey & Andries,, 2009; Franjoine, Gunther & Taylor 2003). The PBS is a free scale that can be downloaded, however, the BOT-MP Balance Subtest is part of the BOT-MP and needs to be purchased in order to be used. Both these tests were also quick to administer.

3.8.1 Bruininks-Oseretsky Test of Motor Proficiency (BOT-MP)

The BOT-MP tests motor performance in minors from age four up to 21 years of age. It is commonly used amongst paediatric therapists (Wilson, Polatajko, Kaplan, & Faris, 1995) and may be a useful tool to explore motor development in children (Düger et al., 1999). It consists of eight subtests which collectively infer motor performance across a wide range of functional activities. Each subtest can however also be used independently. The balance subtest consists of eight items and move from a fairly basic balance task to more complex tasks as the test goes on. The tasks involved are: standing on preferred leg on the floor; standing on preferred leg on balance beam; standing on preferred leg on balance beam- eyes closed; walking forward on walking line; walking forward on balance beam; walking forward heel-to-toe on walking line; walking forward heel-to-toe on balance beam; and stepping over response speed stick on balance beam (refer to Chapter 2). This test involves various areas that impact balance including some items of sensory as well as motor systems (Düger et al.1999). It was easy to sort from a fellow physiotherapist so the PI did not need to buy the test herself.

3.8.2 Paediatric Balance Scale (PBS)

The second OM selected to explore the effect of wearing shoes on balance outcome was the PBS. Although originally adapted from the adult version - the BBS - for utility in the paediatric CP population by Franjoine et al. (2003), it has also been shown to be reliable in other populations including typically developing children. In this test the 14 items are organised in functional sequences and include: sitting to standing; standing to sitting; transfers; standing unsupported; sitting unsupported; standing with eyes closed; standing with feet together; standing with one foot in front; standing on one foot; turning 360 degrees; turning to look behind; retrieving an object from the floor; and placing alternating feet on a stool while reaching forward with an outstretched arm. Test-retest reliability and inter-rater reliability were both high. These scores were 0.998 for test-retest reliability and inter-rater reliability 0.997 in children with CP aged 5–15 years. It also scores an excellent test–retest reliability of 0.923 and inter-rater reliability of 0.972 in young typically-developing children

(Franjoine et al., 2003). This measure also explores various systems that impact balance, including removing vision.

3.8.3 Standard tape measure

Children's height (using a measuring tape) measuring in centimetres. The child was barefoot and stood upright against a wall. A mark was made on the wall and then the measuring tape was used to take the measurement in centimetres.

3.8.4 Digital Bathroom weight scale

A recently calibrated Salter Digital Bathroom Scale was used to measure weight. Children's weight (using a scale) measuring in kilograms. The child was barefoot but remained clothed when their weight was recorded in kilograms and grams.

3.9 Procedure

Ethical clearance was first obtained from Stellenbosch University's Health Research Ethics Committee (S16/10/233) (Addendum A) prior to undertaking this study. The Gauteng Department of Education (GDE) also needed to grant permission prior to this study as the testing was going to be held on school premises which fall under Department of Education's jurisdiction (Addendum B). Both these permissions needed to be extended due to not getting enough children tested in the period stated in the original permissions which was one year. See Addendum C for Stellenbosch University's extension and Addendum D for GDE's extension.

Schools in Johannesburg were contacted via email to see if testing could be accommodated on the premises. As schools replied, a meeting was set up with each school's head master/mistress and the PI then met to discuss the requirements for the study and what the study would entail. They were given an explanation of the each of the outcome measures and sent the consent form for parents and children to sign. Once verbal consent was obtained from them, a signed consent form was received from each head of school (Addendum E). The head of school, together with the school Occupational Therapist/Physiotherapist selected children that fitted in to the study with the guidance of the inclusion and exclusion criteria provided to them for the case group (Group MMD). They then sent a consent form home in a sealed envelope with the identified children's parents. This was done to protect anonymity of the families. A total of 42 forms were returned. Seven parents declined and 35 consented. These 35 children were included in the case group of the study.

Once these forms were received back from the various schools, the PI, noted the ages and gender of each participant. The PI then requested a child based on the inclusion criteria to be matched age and gender to each of the participants. The headmaster/ headmistress liaised with the teachers to gather the participants and were responsible for sending out consent to these parents. Based on the ages and genders of the children whose parents returned their consent forms, children not receiving therapy and presumed typically developing were sought to match these. Again, consent forms were sent home with these matched children. 79 consent forms were sent out and 77 consent forms came back with parental consent. Two parents declined. The 77 participants who consented were considered on a first come, first serve basis and 35 were then matched age and gender to the participants in the case group. These matched peers formed the control group or Group TD. Parents were told by the teachers and headmaster/headmistress that their child may not be used for testing, however, this was not communicated with the parents by the PI. On the consent forms, parents were asked to leave their contact details so that they could be contacted to know when testing would be done so appropriate shoes would be worn. This was to standardise the shoes to some degree as children were asked to wear either their normal school shoes, or a tekkie or trainer shoe if school shoes were not part of the uniform.

The children that were matched from each group attended the same school. For example, child A1 in MMD was age and gender matched to child B1 in TD group. They attended the same school.

3.9.1 Testing

All testing using the BOT and PBS was conducted by a registered physiotherapist[2] who was unfamiliar with the children. This was done in the morning so as to test the child when not tired from the school day. Each test was scored on a clear sheet to limit/prevent contamination.

All testing was done at a testing station set up by the Primary Investigator (PI), myself, in the therapy room based on each school's premises. The PI was not blinded as she had to know which children were in each group for documentation of results for between group comparisons. The child's height and weight were measured, by the PI, with no shoes on. The child was instructed to pull out a piece of paper from each of two boxes. From Box 1 (B1), children randomly selected either 'shoes on' or 'shoes off' to start the testing with and from the second box (B2) children selected which test, either 'BOT' or 'PBS', they would first be exposed to. For example, if the child selected 'shoes on' and 'BOT', they were measured using the BOT with their shoes on first. They were then measured with the PBS with their shoes on.

On the second testing day, the child was tested using the same outcome measure first, the BOT in this example, but with shoes off and then with the PBS with shoes off. The second testing day was two days after the first testing day. For example, if the first testing day was a Monday, the second testing day would be a Wednesday. All children were tested four times in total over the two days. Once their testing was complete, they each received a juice and biscuit as a 'thank you' for participating in the study.

3.9.2 Reliability testing

One of the schools allowed for the children to be tested over two days only as a way to minimise disruption to their academic program. In order to meet this request, a second tester[3] - also a registered physiotherapist, was recruited to test the 23

[2] A registered private practice physiotherapist based in Johannesburg

[3] A registered physiotherapist working in government sector in Johannesburg

children, who had parental consent to participate in this study. To check reliability between testers, an inter-rater reliability check was conducted on the first three children enrolled in the third school. Both testers tested the children as per the protocol. Two children presented with mild motor delay and one was typically developing. The two testers had their own testing stations set up where they performed the testing independently at the same time. The Primary Investigator (myself) set up the stations and sent the children to be tested. The sample size of three participants is very limited and can therefore only be considered exploratory and not definitive. See below results of Inter-rater reliability testing in Table 3.1.

Two analyses were performed.

1. A concordance analysis.
   Note: a concordance coefficient of > 0.7 gives moderate concordance (consistency) or higher.
2. A paired t-test

Table 3.1: Inter-rater reliability testing

OM	N	Measurement (tester 1)	Measurement (tester 2)	Difference	Concordance analysis	p-value
BOT-MP (with shoes on)	3	71	85	14	0.28	0.020
BOT-MP (shoes off)	3	74	68	6	0.44	0.438
PBS (with shoes on)	3	168	168	0	No variability thus no inference possible	No inference
PBS (shoes off)	3	168	168	0	No variability thus no inference possible	No inference

Note that for the three participants there were no variability in scores and hence no statistical inference can be done. For the BOT-MP, there was moderate-low reliability found between assessors (0.020-0.438). However, for the PBS, the two assessors scored the same. The statistician concluded that there was no inference (conclusion) as there was no variability and in statistics there must be variability. If more time allowed, a larger group of children would have been tested for this.

3.9.3 Data processing and analysis

All record sheets were carefully reviewed for completeness and checked for missing data. The raw scores and point scores were all checked to make sure they lined up correctly. All scores were added up first on the score sheets and then data was captured on an excel spreadsheet by the PI. This excel spreadsheet was then checked and once reviewed, was sent to the statistician for processing and analysis using Stata 15. Confidentially was kept by replacing the child's name with a letter and numeral so that they could not be identified.

All the children were first compared to themselves, with shoes on and with shoes off using Pearson's Correlation analysis to determine if wearing shoes affected the outcome. This was done for both outcome measures used (BOT-MP and PBS). The level of significance was set at $p<0.05$ (or 5%).

Group MMD and TD were then analysed to see whether the impact of wearing shoes was greater in children with minor motor dysfunction compared to their age and gender matched TD peers. This was done using a paired t-test.

There was also an analysis done to see whether age, gender, height or weight contributed to improved balance. This was done through mixed linear regression. A further grouping was done for 4-6 year olds and 7-10 year olds in line with the groupings of popular outcome measure, the Movement ABC. This is also in line with the development of balance as previously discussed with children aged four to six years demonstrating the beginnings of good static and dynamic balance and children aged seven to ten years demonstrating more mature balance strategies, similar to adults (Christine Assaiante et al., 2005; Peterson, Christou, & Rosengren, 2006; Woollacott & Shumway-Cook, 1985).

Results are described narratively. Tables and graphs were used to display the results for analysis. Both descriptive and inferential analysis were used to explore the results of this study.

Descriptive statistics are used to gain an understanding of the data obtained by generating graphical displays. Inferential statistics allow the researcher to make conclusions on the research population based on the findings.

3.10 Ethical considerations

The following ethical considerations were addressed:

1. The study protocol was submitted to the Ethics Committee at the University of Stellenbosch for approval. An ethics number (S16/10/233) was obtained (Addendum A)
2. Permission was then obtained from the Gauteng Department of Education as the testing was to be done within a school setting (Addendum B)
3. Permission was obtained from each school's principal to carry out the study (Addendum E).
4. Informed consent was be obtained from parents/caregivers of all participants (Addendum F).
5. Assent was be obtained from the participants who were seven years and older. Participants were allowed to refuse to participate. Participation was entirely on a voluntary basis (Addendum G). No one refused to participate.
6. The child was allowed to withdraw at any stage due to illness or being unwilling, however, this did not occur.
7. All personal information was be entered onto a computer onto a password protected excel spreadsheet and data collection sheets was stored in a locked drawer at the researcher's house.
8. Participant identifiers were only known to the research team and should there be any publications, the participant's identity will not be disclosed.

9. Risk - there were no direct risks to the participant and no accidents/injuries occurred during this study.
10. The results were made available to the parents. If parents gave permission, results were also sent to the school.
11. A letter discussing findings was sent out to the parents with their child's specific results and what it means and referred as/if necessary.
12. Data will also be disseminated in the form of a peer-reviewed article.

3.11 Conclusion

After ethical considerations were met and the required approval was gathered, two groups of children with 35 children in each group were included in this study. One group included typically developing children and the other group included children with mild motor dysfunction. Both groups were age and gender matched. They were assessed using two well-known and commonly used outcome measures, the PBS and BOT-MP. Each child was tested with their shoes on and barefoot to establish if indeed shoes impacted their balance scores.

The two groups were also compared with each other to establish if those with mild motor impairments had poorer balance than their typically developing peers. 35 in each group provided a power of 80%, which meant that a small change would be detected.

Both a second tester and an extension on ethical clearance had to be done which was not anticipated for. This was due to one of the schools providing a large number of children for the study but not a lot of time, meaning one tester could physically not test all the children. An extension was required as getting consent from heads of schools took much longer than anticipated.

Once children were tested, data was obtained and checked. It was placed in an excel spreadsheet and analysed by a statistician. The results and analysis are seen in the next chapter (Chapter 4).

Chapter 4: Results

4.1 Introduction

In this chapter the results are reported in line with the objectives set at the onset of the study (refer to Chapter 3). Response rate and demographic data of participants, 70, precede my report on the effect of wearing shoes on balance as measure by the BOT-MP and PBS.

4.2 Response Rate

Forty two information letters and informed consent forms (ICF) were sent out across the five schools identified at the onset of the study, to the parents of children who had been identified by either the PT or OT with having minimal motor dysfunction. The final sample size for this group (Group MMD) was 35. All these children were enrolled in either physiotherapy and/or occupational therapy and had not received more than 6 months of therapy intervention.

A second group of children with typical development (Group TD) was selected – matched based on age and gender with children in the MMD group. These children attended the same school as those with whom they had been matched and whose parents had also consented to their participation following the process described above (n=35). Therefore, the requirements for the power analysis were met meaning that an effect would be detected.

4.3 Participant demographics

Table 4.1 describes the study sample. Forty percent were female and 60% were male. Group MMD did not differ significantly from Group TD in terms of height and weight.

Thirty one percent of the participants were aged five with eleven in each group. This was followed by six year olds (8) and seven year olds (8) making up 22.9% of the sample (Figure 1).

Group MMD were taller than Group TD on average and also weighed more than Group TD (Table 4.1). There were however no significant differences found between the two groups for these two variables.

Table 4.1: Participant demographics

	GROUP MMD	GROUP TD	p-value
Males	21	21	
Females	14	14	
Age (years) mean±SD	5.7±1.34	5.7±1.34	p=1
Height (cm) mean±SD	120.6 ±9.65	119.0±10.9	p=0.16
Weight (kg) mean±SD	23.5 ± 7.0	22.03±5.52	p=0.12

Information on type of school shoe/tekkies was collated. All children wore closed shoes. The older children (aged 6-10 years) wore standard school shoes and the younger children (aged 4-5) wore closed tekkies.

The analysis shows that the mean difference in weight between the matched children is 1.45kg. This is not significantly different. From a statistical perspective they are therefore well matched. This also goes for height with a difference of 1.58 cm.

BMI is a complicated equation in children as weight changes with age during childhood. Weight, therefore, needs to be adjusted to compare an individual child with others of the same age (Cole, Faith, Pietrobelli & Heo, 2005). This would have been too time consuming given that more valuable information could be gathered from using height and weight rather than if BMI was used in this study.

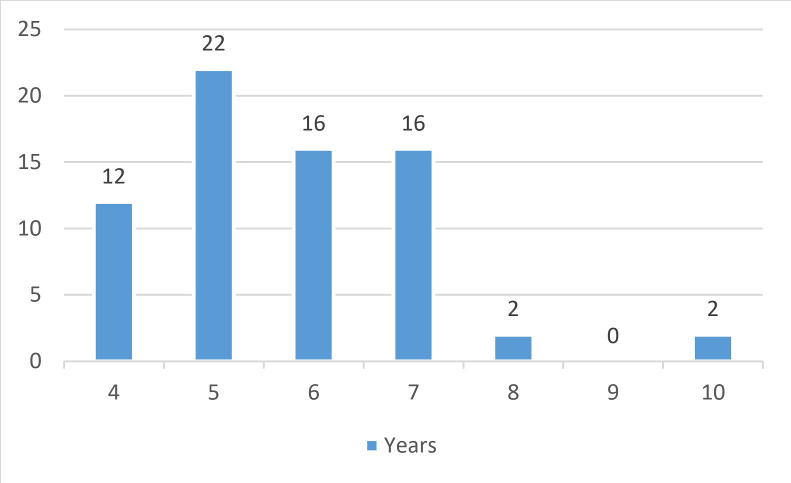

Figure 4.1: Age distribution of study sample

4.4 Item analysis of Bruininks-Oseretsky Test of Motor Proficiency (BOT-MP) and Paediatric Balance Scale (PBS)

A direct item analysis to compare sensitivity for detecting effect of wearing shoes could not be done as the items on the BOT-MP had different scoring scales, e.g. item one was a score out of four and item three was a score out of seven. An item analysis can only be done of the items that have the same scale and number of levels. Therefore, the standardized difference between the two groups with respect to each item was looked at. This allowed us to see which item was the most discriminatory item between the two groups. Below are tables that show the average scores for each item of both the BOT-MP and PBS (Table 4.2, 4.3, 4.4, 4.5).

Table 4.2: Average Item scores and the differences for BOT-MP for Group MMD (N= 35)

Item	Maximum score	Average score with shoes on	Average score with shoes off	Difference
1	4	3.69	3.46	0.23
2	6	4.37	3.80	0.57
3	7	1.91	1.03	0.88
4	3	2.97	2.97	0
5	4	3.46	3	0.46
6	3	2.57	2.54	0.03
7	4	2.66	2.43	0.23
8	1	0.66	0.51	0.15

Table 4.3: Average Item scores and average differences for BOT-MP for Group TD

Item	Maximum score	Average score with shoes on	Average score with shoes off	Difference
1	4	3.83	3.49	0.34
2	6	4.91	3.23	1.68
3	7	1.71	1.17	0.54
4	3	3	3	0
5	4	3.46	3.34	0.12
6	3	2.77	2.71	0.06
7	4	2.69	2.57	0.12
8	1	0.66	0.49	0.17

Table 4.4: Item scores for PBS for average scores and differences Group MMD

Item	Maximum score	Average score with shoes on	Average score with shoes off	Difference
1	4	4	4	0
2	4	4	4	0
3	4	4	4	0
4	4	4	4	0
5	4	4	3.97	0.03
6	4	4	3.94	0.06
7	4	4	3.94	0.06
8	4	3.54	3.37	0.17
9	4	3.82	3.6	0.18
10	4	3.89	3.94	-0.5
11	4	4	3.97	0.03
12	4	4	4	0
13	4	4	4	0
14	4	4	3.97	0.03

Table 4.5: Items scores for PBS and differences for Group TD

Item	Maximum score	Average score with shoes on	Average score with shoes off	Difference
1	4	4	4	0
2	4	4	4	0
3	4	4	4	0
4	4	4	4	0
5	4	4	4	0
6	4	4	4	0
7	4	4	4	0
8	4	3.89	3.66	0.23
9	4	4	3.74	0.26
10	4	4	4	0
11	4	4	4	0
12	4	4	4	0
13	4	4	4	0
14	4	4	4	0

STDDIFF is a program to calculate the standardized difference between two groups for both continuous and categorical variables. Standardized difference estimates are increasingly used to describe to compare groups in clinical trials and observational studies, in preference over p-values (Bayoumi, 2016).

Table 4.6: Standardised differences for each item (BOT-MP)

Item	Shoes on	Shoes off
1	0.357	0.147
2	0.409	0.447
3	0.595	0.614
4	0.243	0.243
5	0.00000	0.554
6	0.482	0.394
7	0.246	0.482
8	0.00000	0.0572

The higher value of the standardised difference indicates which item is the best discriminator. Item three of the BOT-MP: Standing on preferred leg on the balance beam - eyes closed was the best item to use for differentiation for shoes on and barefoot. The next best discriminator for shoes on was item 6: forward heel-to-toe on walking line. Item 5: walking forward on balance beam was the next best discriminator for barefoot testing. Item 8: stepping over response speed stick on balance beam proved to not be discriminatory in both shoes on and barefoot testing.

Table 4.7: Standardised differences for each item (PBS)

Item	Shoes on	Shoes off
1	No difference	No difference
2	No difference	No difference
3	No difference	No difference
4	No difference	No difference
5	No difference	0.239
6	No difference	0.239
7	No difference	0.239
8	0.407	0.270
9	-0.062	0.193
10	0.343	0.239
11	No difference	0.239
12	No difference	No difference
13	No difference	No difference
14	No difference	0.239

Since there was nearly no difference in scoring between the groups the standard difference is undefined for many items. This demonstrates that although the PBS is a valid and reliable measure for testing balance in children, it was largely not sensitive enough to detect change between barefoot testing and wearing shoes.

4.5 Effect of wearing shoes

*4.5.1 When measuring balance using balance sub-scale of **the BOT-MP***

To establish the effect of shoes on each balance outcome measure, each child was tested with their shoes on and barefoot to establish if there was a difference.

Table 4.8: Comparison of shoes on and shoes off when testing with BOT-MP

Group	**Shoes on mean±SD**	**Shoes off mean±SD**	**(within group) p-value**
MMD (n=35)	22.29±5.89	19.74±5.51	**< 0.001**
TD (n=35)	23.03±5.20	20±4.94	**< 0.0001**
p-value (between groups)	0.338	0.776	= 0.55

There was no significant difference found between the two group's scores on the BOT-MP and the PBS for shoes on and shoes off. However, the control group did score higher with both shoes on and shoes off. There was a significant difference found in both groups when comparing scores for shoes on and shoes off. This demonstrates that wearing shoes does result in improved balance scores compared to when barefoot.

*4.5.2 When measuring balance using **PBS***

Table 4.9: Comparison of shoes on and shoes off when testing with PBS

Group	**Shoes on mean±SD**	**Shoes off mean±SD**	**(within group) p-value**
MMD (n=35)	55.26±1.60	54.71±2.84	0.080
TD (n=35)	55.69±0.72	55.4±1.35	0.10
p-value (between groups)	0.083	0.060	0.31

When tested with the PBS, there was a marginal (Group MMD had a p-value of 0.080 and Group TD had a p-value of 0.10) improvement seen when children wore their shoes versus being barefoot. There was again a marginal difference between the case and control group. The control group scored slightly better with and without shoes on. There was, however, no significant difference seen.

4.6 Relationships between gender, age, height, weight and balance test scores

A mixed linear regression model was used with child pairs as the random effect. The regression model included the variables age, weight, height, gender, group, shoes and BOT. The indicators variables are listed below in table:

Table 4.10: Factors impacting balance scores in the BOT-MP and PBS

Test	Factor	Coefficient	p-value	95%CI
PBS (Shoes on)	Age	0.45	**0.016**	0.9 to 0.82
	Gender	-0.38	0.219	-1.00-0.23
	Height	0.001	0.965	-0.06-0.06
	Weight	-0.03	0.495	-0.10-0.05
PBS (Shoes off)	Age	1.08	**0.001**	0.42 to 1.03
	Gender	-0.63	0.313	-1.86-0.60
	Height	-0.50	0.280	-0.14- 0.04
	Weight	-0.02	0.766	-0.14-0.10
BOT (Shoes on)	Age	3.24	**0.000**	1.98 to 4.51
	Gender	-3.61	**0.001**	-5.82 to -1.41
	Height	0.004	0.960	-0.18- 0.19
	Weight	-0.16	0.226	-0.41-0.10
BOT (Shoes off)	Age	2.88	**0.000**	1.53 to 4.22
	Gender	-2.19	0.057	-4.44 to 0.06
	Height	-0.04	0.682	-0.25-0.17
	Weight	-0.08	0.565	-0.37-0.20

Thus for the PBS, age was the only significant factor during both shoes on and barefoot conditions. Older children had better balance than younger children. There was even more prominent (i.e. a stronger effect (slope) in barefoot state.

For the BOT-MP, age and gender both showed a positive relationship. The older the child, the better the balance scores and girls had better balance than their male peers.

Weight and height were not associated with improved balance scores.

4.7 Conclusion

70 children were included in this study based on a power of 80%. There were 42 males and 28 females included. There were 22 children aged five years which was 31% of the participants.

An item analysis revealed that standing on preferred leg on the balance beam with eyes closed was the most sensitive test to establishing whether the child was wearing shoes or not.

The BOT-MP was the only test that found a significant difference on balance when wearing shoes and when barefoot in both the TD group and the MMD group. The p-value was <0.001 in the MMD group and <0.0001 in the TD group. There was no significant difference found between groups ($p=0.55$).

The PBS did not find a significant difference between wearing shoes and being barefoot (MMD: $p=0.080$; TD: $p=0.10$) and it also found little difference between MMD and TD groups ($p=0.31$). The MMD did score slightly better in their balance scores with shoes on, however, was not significant.

There was a positive association made between balance scores and age; as children got older, their scores improved. This is in line with previous research. Girls also scored better than boys in this study which is also in line with previous research. Height and weight did not affect balance scores in this study, however, should looked at in possible future studies.

Chapter 5: Discussion

5.1 Introduction

This chapter presents a discussion of the study findings, which address the research questions related to the relevant literature. Limitations, conclusions and recommendations for further research are also discussed.

The primary aim of this study was to determine whether wearing shoes affects the scores of selected paediatric balance and motor function measures and to determine whether this effect is greater in children with balance impairments compared to their age matched peers with typical development (TD). It looked to further explore relationships between height, weight, age, gender and diagnosis, and balance and to determine the sensitivity of sub-scores and/or individual items for detecting effect of wearing shoes on balance. Two well-known and used outcome measures were used to test the children, the BOT-MP and the PBS.

5.2 Participant demographics

This was in line with what literature said as by age ten, a child has almost adult-like balance (Steindl et al., 2006). Most standardised outcome measures include children from four onwards as these children can generally follow instructions. Only 5.7% of the sample were eight to ten year olds, while the majority of the sample were aged five years old. This is not representative of the population but due to time constraints and the children being included at random, this was hard to avoid. It still allowed a relationship to be established between balance scores and age.

Boys and girls were recruited to assess if gender impacted on balance scores as according to literature, girls do perform better in balance scores than their male peers, especially in the younger population (Lara et al., 2018; Steindl et al., 2006).

Obesity is a serious public health concern worldwide with many children present as either overweight or obese. Many clinical programs focus on weight gain prevention rather than weight loss, allowing the child to become thinner over time as they grow in height (Cole et al., 2005). It is, therefore, important to observe the effect of obesity on children and their function. Although BMI has been found to impact balance scores (Lara et al., 2018), it is a complicated equation within the paediatric setting (Cole et al., 2005). Due to time constraints, this was not done in this particular study, however, it is recommended for future studies as obesity may have an impact on motor skill development in children.

The children used were a representation of a wider population as there was a general no bias on how children were selected other than on motor skills. Some of these children, however, may have worn shoes from a reasonably early age as they were from a slightly more affluent population. The shape of the children's feet were not documented, however, as they all wore shoes from early in childhood, their foot shape may have been affected by their shoes. Another factor that could affect foot shape, particularly those in the MMD group is lower muscle tone and muscle strength, both of intrinsic and extrinsic muscles. It is important to note that foot shape may impact balance (Hertel et al., 2002) and therefore possibly may have impacted these children's balance scores.

The children included also did not have a sensory profile performed as part of this study. This may have impacted their balance scores, especially if they had problems with vestibular, visual or somatosensory input or output. This is due to the sensory system having such an influence on balance (Horak, Henry, & Shumway-Cook, 1997). The ages of the children included in this study were also based on the establishment of all sensory systems integrated and matured by age nine (de Sá et al., 2018). As children were referred from occupational therapy as well as physiotherapy, there may have been some sensory impairments. Visual, vestibular and/or somatosensory impairment would have impacted on balance scores.

5.3 The Bruininks-Oseretsky Test of Motor Proficiency (BOT-MP)

The BOT-MP (Bruininks, 1978) is an outcome measure that is paid for and the PI was able to borrow it for no cost. It is one of the most popular motor assessment batteries for children aged from 4 years 6 months to 14 years 5 months (Venetsanou, Kambas, Aggeloussis, Serbezis, & Taxildaris, 2007). It consists of eight subtests, however, each subtest is valid and reliable and can be used as a stand-alone test.

The Balance Subtest (Subtest 2) consists of eight items including: standing on preferred leg on the floor, standing on preferred leg on the balance beam, standing on preferred leg on the balance beam with eyes closed, walking forward on walking line, walking forward on balance beam, walking forward heel-to-toe on walking line, walking forward heel-to-toe on balance beam and stepping over response speed stick on balance beam. All the items were done using the standardised tool kit and recorded on a score sheet that comes with, when the test is bought. The BOT-MP does not state whether testing should be done barefoot or wearing shoes and thus was used to see if the test was sensitive enough to detect a change when children wore their everyday shoes.

This allows the testing to be more standardised as the height of the balance beam and response speed stick remains the same in all testing. This then allows comparison of children to be more accurate. The BOT-MP has been described as an appropriate descriptive measurement tool of the motor abilities of children based on its reliability and validity (Wilson et al., 1995). It is also believed that standard scores result in better reliability than raw scores.

An item analysis was done to establish which item of each outcome measure was the most sensitive to pick up a change in balance when wearing shoes and when barefoot. It was difficult to do a straight forward item analysis as the BOT-MP had different scoring for each item. In the BOT-MP, standing on preferred leg while eyes closed on the balance beam was the most sensitive to change. This could be as it is a challenging task, including removal of vision, closing eyes and decreased base of support, a narrow balance beam. The visual system is regarded as the primary sensory information to maintain postural balance (Gaerlan, 2010) and therefore by removing vision, the rest of the body needs to work harder to maintain balance or postural control.

The BOT-MP is an all-round test that observes the impact of the sensory system on balance as well as the motor component. The use of eyes closed allowed vision to be removed and children had to rely more heavily on their proprioceptive input and muscle systems. Along with the visual system being impacted, the muscle system was tested as the base of support was made smaller due to a narrower surface which was presented in the balance beam. This task may have been easier with shoes on as a shoe would does provide a larger surface area for the foot and therefore more stability. This may also be the reason why this was the most sensitive item within the BOT-MP balance subtest.

5.4 The Paediatric Balance Scale (PBS)

The PBS was selected as outcome measures to be used as it was also both valid and reliable in the paediatric population with both typically developing children and those with mild motor impairment. The PBS (Franjoine et al., 2003) is a free tool that can be downloaded from the internet and consists of 14 items including: sitting to standing, standing to sitting, transfers from one chair to another, standing unsupported, sitting unsupported, standing with eyes closed, standing with feet together, standing with one foot in front, standing on one foot, turning 360°, turning to look behind, retrieving object from the floor, placing alternate foot on stool and reaching forward with outstretched arm.

Most of the items on the PBS involved static balance or minimal dynamic balance items. This resulted in children not being as challenged, especially functionally, compared to the BOT-MP. Two outcome measures were selected for a more generalised assessment and that findings were not based on only one outcome measure.

Both the PBS and BOT-MP had items that observed standing on one leg (preferred leg) as well as taking vision out of the equation by asking the child to perform a balance task with their eyes closed. Five out of the eight BOT-MP tasks involved functional activities i.e. balance while walking. The PBS involved some transfer tasks, however no walking. This did not affect the study, however, it is interesting to note that in Chapter 2, shoes did impact gait and thus maybe a more functional assessment of balance should be used in future studies.

Both the PBS and the BOT-MP incorporated testing of both static and dynamic balance. This was demonstrated with standing on preferred leg as the static component of balance in both the BOT-MP and PBS. In the BOT-MP, all items that incorporated walking or stepping tested the dynamic component of balance. The PBS consisted of more items that observed examples of static balance and just varied the base of support. For example, standing with feet together, standing with one foot in front and standing on one leg. These all test static standing balance.

5.5 The sensitivity of sub-scores for detecting effect of wearing shoes on balance.

For the PBS, each item was scored out of four which then made an item analysis straight forward. In the PBS, the scores were not very sensitive, however, the item asking the child to stand on their preferred leg was more variable indicating that it was the most sensitive out of the 14 items. The PBS did not combine standing on one leg with eyes closed and based on the literature, this test (standing on one leg with eyes closed) may be a useful quick test to use in the clinical setting (Zumbrunn et al., 2011). The PBS, challenged children in varying their base of support, e.g. standing with one foot in front of the other, however, only one of the 14 items were done on one leg.

Balance is a complex and a variety of internal and external factors have an impact on this. The sensory system has a large impact on the outcome of balance and although the tests used incorporated some of that, for example, excluding vision in some items of the test, they were not able to observe other aspects involved. The peripheral components, including somatosensory and vestibular systems of the nervous system are essential for balance. They are needed to receive information and pass this information along to the CNS which processes it and an appropriate muscle response is selected for control (Cote et al., 2005). This makes it crucial to include when observing balance so that the assessor is able to identify what component of balance is missing in the child and therefore be able to treat the main area of concern.

It would be of interest to use a more sensory-based outcome measure, for example the modified clinical test of sensory interaction on balance (mCTSIB) to assess the effect of shoes on balance to establish if shoes added more than just a wider base of support for the foot. Both these tests may have just included the impact of the visual system as this system is the most dominant and primary sensory component used in balance control (Gaerlan, 2010).

Vision has been showed to not be needed to stand upright, however, postural stability has been shown to improve with the improvement or inclusion of vision (Guerraz & Bronstein, 2008). This demonstrates why the items where vision was removed, were more challenging for the children and resulted in being more sensitive. This may also demonstrate that children, especially those that have grown up wearing shoes, rely heavily on their vision as other systems like the somatosensory system may not be as developed or sensitive to stimuli around the foot as the morphology of the foot can be influenced by habitually wearing shoes (Hollander, de Villiers, Sehner, Wegscheider, Braumann, Venter & Zech, 2017). Previously, peripheral vision has been shown to play an essential role in the maintenance of postural control during static standing balance (Berencsi et al., 2005). Both of these outcome measures did not observe what type of vision impacted balance more and just observed the effect of vision and then no vision.

The somatosensory system probably has the most direct link with the muscle system as it works by making the muscle system aware of the spatial and mechanical status of the body through various receptors (Gaerlan, 2010). Mechanoreceptors are located in the muscles around the knee and ankle and allow for proprioceptive feedback when the joint angle changes relative to the trunk (Ivanenko et al., 2000).

Without vision, the somatosensory system would work extra hard relaying information to the central nervous system and the muscle system to keep the body stable. The 104 cutaneous mechanoreceptors located in the sole of the foot, are sensitive to contact pressure and may be potentially sensitive to changes in distribution of pressure (Kennedy & Inglis, 2002). When balancing on the beam with eyes closed as in the BOT-MP, the somatosensory system will be challenged even more as the body will be relying on those receptors to give adequate feedback to the body to keep it stable. This may be impacted then when barefoot and when wearing a shoe as well as the challenge of the beam as the base of support has narrowed, i.e. standing on one leg as well as the centre of mass is now moved providing a different and more complex environment to maintain stability.

5.6 Effect of wearing shoes on balance

The primary aim of this study was to determine whether wearing shoes affected the scores of selected paediatric balance and motor function measures and to determine whether this effect was greater in children with balance impairments compared to their age matched peers with typical development (TD).

Two outcome measures were selected so as to show a better generalisation of results. This allowed comparison of two balance outcome measures that were commonly used within the paediatric setting, with children who were typically developing and those that had mild motor impairment.

From the two outcome measures used, only the BOT-MP showed a significant difference between wearing shoes and being barefoot. For both groups there was a significant difference noted. In the MMD group, $p<0.001$ and for the TD group, $p<0.0001$. Children did, however, score slightly better when wearing shoes than when barefoot when being tested with the PBS. The MMD group scored $p= 0.080$ and the TD group scored p-value=0.10. This could be due to the PBS being less sensitive to picking up small changes balance with and without shoes. This indicates that wearing shoes aids in balance and could definitely impact the outcome of scores when testing balance. This could be due to the proprioceptive or somatosensory input that shoes contribute to the body system, or due to the fact that the child's base of support is made bigger as shoes provide a larger surface under the foot.

There was no significant difference found between the groups in terms of balance scores. Using the BOT-MP, p=0.338 for shoes on and p=0.776 for shoes off. The PBS p=0.083 for shoes on and p=0.060 for shoes off. The control group, however, did score slightly higher when wearing shoes compared to when testing barefoot. This may have been due to the fact that children in both groups were attending main stream schools and only the case group had mild motor dysfunction or impairment and not a moderate to severe motor impairment. This finding is in line with Geuze (2003), who found very little difference in static balance between a control group and children with Developmental Coordination Disorder (DCD). A larger difference between groups may have been apparent if the impairment was moderate to severe or there was a neurological impairment.

The types of shoes were not documented, however, the younger aged children (from age four to five) generally worn tekkies/soft trainer-like shoes as part of their uniform. This was also requested in the letter they received when asked to join the study. The older children, aged from six to ten years wore their traditional school shoe which has a rubber sole and soft leather on top. It would be valuable to assess closer the type of shoe worn and what the impact of that was on balance.

5.7 The relationship between age, gender, height and weight

This was another objectives as in previous literature: age, height, gender, weight and even BMI was linked to influence balance in some way.

Many studies have observed balance in both adult and paediatric populations. There are many mixed reviews on the relationship and what may influence balance. For example, Steindl et al (2006), found that age and gender had an effect on balance scores in the paediatric population (aged three to 16 years) with girls and older children scoring better. However, Butz et al (2015), demonstrated that only age had a significant effect on balance scores in children aged five to 12 years.

Stanek et al (2015) demonstrated that height and weight influenced balance scores in 148 children aged seven to nine years. Lara et al (2018), demonstrated that only weight influenced balance scores and not height.

The groups were matched very well for age, gender, height and weight which are considered factors that can influence balance in children. In the literature both age and gender as well as height and weight have been said to impact on balance scores. Due to ease and time constraints, children in this study were only matched on age and gender. There was a positive correlation found between age and balance. As the children got older, so their balance scores improved. Girls also performed better than boys in these outcomes which was also in line with literature. There were significant relationships seen between the PBS and age as well as BOT-MP and age and gender. The other factors, height and weight, did not have a positive or negative correlation to balance. This differs from some other literature (Lara et al., 2018).

Based on this finding, it is important for the outcome measures to review if they instruct shoes to be worn or not. Shoes may impact a child’s balance and thus if their balance is being tested, shoes should not be worn to get a more accurate score. The single item that was the most sensitive was standing with eyes closed on preferred leg on a balance beam and if clinicians have reduced time to assess balance, this should be the test done. As there was a difference in balance between eyes open and eyes closed, this should become a practice within the clinical setting so as to determine whether or not the child is relying on their visual system for balance or if they can maintain balance through their other systems, including motor and somatosensory systems. This can be a tool to assess what is influencing the child’s balance and indicate what therapy they need in order to improve their balance and functional skills. As the sensory system has such an influence on balance, it should be part of balance tests and outcome measures in the clinical setting. For example, the relationship between vision and balance should be noted as well as the influence of the somatosensory system and vestibular system be observed when assessing balance. This was seen especially with a complex task that involved many intrinsic and extrinsic factors like standing on one leg, on a balance beam with eyes closed. This task was sensitive to change due to the many factors it challenged.

5.8 Conclusion

Shoes may have an effect on balance in children. The importance of this study involves many aspects. The first is the implication of the findings on clinical practice. The fact that shoes positively impact balance scores needs to be included amongst those developing outcome measures for clinical practitioners to be using. A more standardised approach to the testing of balance needs to be done so that as practitioners, we are universal in our testing.

The importance of the influences of balance need to be taught and established so that practitioners can advise correctly, holistically and within a multi-disciplinary team approach. For example, if shoes, motor components such as intrinsic foot muscles and vision all play a role in balance, then perhaps a podiatrist, physiotherapist and occupational therapist need to be assessing and treating the patient with the impairment.

This also needs to be communicated to parents of younger children and a set of recommendations needs to made regarding when children should start wearing shoes and what types of shoes will impact foot development, sensory experience and ultimately the development of balance. This in turn may impact the development of other gross motor skills and may even impact a skill like walking.

Chapter 6: Conclusion and Recommendations

6.1 Introduction

This chapter concludes the study and explores the strengths and limitations of this thesis. The chapter concludes with recommendations for clinical practitioners who are assessing children in the area of balance and other gross motor skills and suggestions for further research.

6.2 Conclusion of study

Children had significantly better balance when wearing shoes compared to being barefoot when tested with the BOT-MP. This was found across both the typically developing group ($p < 0.0001$) and the group with mild motor dysfunction ($p < 0.001$). Although there was not a significant difference found when testing with the PBS, children in both groups, did score better when wearing shoes compared to being barefoot. There was no significant difference found between groups, however, the typically developing group, did score higher in both the BOT-MP and the PBS. There was also a positive relationship between both age and gender with older children having better balance and girls having better balance than boys their age.

6.3 Strengths and Limitations

As with all studies, there are strengths and limitations. This section briefly explores what some of those were.

6.3.1 Strengths

The study was a well-executed design in that it identified a gap in the literature and was able to answer the aims and objectives that were set out. It used two valid and reliable outcome measures. A pilot study may have been useful as the inter-rater reliability was not strong. The assessors were blinded to the groups the children fell in to and therefore could not be biased in their scores. The children were tested over two days so that they did not fatigue and also did not get too familiar and learn what the tasks they were being tested with expected.

The children were compared to themselves, but also to each other, across groups with age and gender being a constant variable.

6.3.2 Limitations

The exact type of shoe worn was not documented and this would have been helpful to start establishing if it was a particular type of shoe that impacted better balance scores. Also, documenting which the preferred leg was in each test. This would have been helpful in establishing which leg most children deemed their stronger leg.

Having two assessors meant that there was decreased consistency due to human error and based on experience of the assessors. Their inter-rater reliability was not very strong and therefore if the original assessor had have tested all the children, the results may have differed slightly.

Having only 70 children was a limitation as although the power was 80%, more children would have been more reflective of a larger population size.

The majority of the children were aged from four to seven and it would have been better to be more representative of the ages included in the study.

Due to the design of the study, the results should be interpreted with caution as the data collected was a cross sectional sample. This meant the information was only gathered at one point in time, which can be influenced by many factors, not in the researcher’s controlled. A longitudinal study would be more ideal for this type of study because it makes observations at multiple points in time, thereby increasing the chances of eliminating an error.

Another limitation was that the physical activities that children participated both in and out of school were not documented and this may have impacted on the child's ability to balance. The reason this was not looked at, however, was due to time constraints and that the researcher was observing children who were typically developing and those with mild motor impairments and not those that participated or excelled in sports.

It should also be noted that children in the TD group may have had motor and/or other problems that may have impacted scores. The only way these children were classified as TD was based on the fact that they had not been referred for physiotherapy and/or occupational therapy.

6.4 Recommendations for clinical practitioners

It is recommended that all children be tested barefoot when testing balance to get the most accurate scores. This will allow for observations to be made around the foot and ankle to assess for correct biomechanics and balance strategies. It may also be beneficial to assess children's balance in shoes they wear every day to determine if these shoes are providing functional balance. If they are not, recommendations on alternate footwear can be discussed.

6.5 Recommendations for further studies

Further research should be done more specifically looking at type of shoes that children wear as there are a huge variety of shoes worn in the paediatric population. These shoes vary from very supportive shoes to shoes that are very flexible and provide very little support.

Another area that would be beneficial to explore is the effect of shoes on other functional and gross motor tasks. So explore the relationship between shoes, balance and function. A further area to explore would be children who participated in physical activities that required better balance, e.g. gymnastics and those that did not to see if the balance scores were different.

It would also be beneficial to assess children that have not worn shoes or have had limited time in shoes to see if there is an impact on what shoes do to their balance.

The effect of sensory systems on balance could be explored more and it would be beneficial to observe what shoes do to balance from a sensory point of view, focusing on the somatosensory system especially.

All this information may be useful in guiding physiotherapists and other professionals involved in the assessment and treatment of balance to a standardised approach to balance as well as assist in advising when prescribing shoes or making recommendations for their patients.

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Addenda

Addendum A

UNIVERSITEIT•STELLENBOSCH•UNIVERSITY
jou kennisvennoot • your knowledge partner

Approval Notice
Response to Modifications- (New Application)

13-Dec-2016
Stowell, Michelle M

Ethics Reference #: S16/10/233

Title: **The effect of wearing shoes on the outcome of selected balance measures in children with typical development and with motor dysfunction**

Dear Mrs Michelle Stowell,

The Response to Modifications - *(New Application)* received on **09-Dec-2016**, was reviewed by members of **Health Research Ethics Committee 1** via Expedited review procedures on **13-Dec-2016** and was approved.
Please note the following information about your approved research protocol:

Protocol Approval Period: **13-Dec-2016 -12-Dec-2017**

Please remember to use your **protocol number** (S16/10/233) on any documents or correspondence with the HREC concerning your research protocol.

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

After Ethical Review:
Please note a template of the progress report is obtainable on www.sun.ac.za/rds and should be submitted to the Committee before the year has expired. The Committee will then consider the continuation of the project for a further year (if necessary). Annually a number of projects may be selected randomly for an external audit.
Translation of the consent document to the language applicable to the study participants should be submitted.

Federal Wide Assurance Number: 00001372
Institutional Review Board (IRB) Number: IRB0005239

The Health Research Ethics Committee complies with the SA National Health Act No.61 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 Part 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes 2004 (Department of Health).

Provincial and City of Cape Town Approval

Please note that for research at a primary or secondary healthcare facility permission must still be obtained from the relevant authorities (Western Cape Department of Health and/or City Health) to conduct the research as stated in the protocol. Contact persons are Ms Claudette Abrahams at Western Cape Department of Health (healthres@pgwc.gov.za Tel: +27 21 483 9907) and Dr Helene Visser at City Health (Helene.Visser@capetown.gov.za Tel:

+27 21 400 3981). Research that will be conducted at any tertiary academic institution requires approval from the relevant hospital manager. Ethics approval is required BEFORE approval can be obtained from these health authorities.

We wish you the best as you conduct your research.
For standard HREC forms and documents please visit: www.sun.ac.za/rds

If you have any questions or need further assistance, please contact the HREC office at 0219389819.

Included Documents:
Synopsis of proposal_Michelle Stowell.pdf
Addendum C- Parent Informed Consent form.pdf
20161212 MOD HREC Modifications Required.pdf
Proposal_Michelle Stowell.pdf
Application Form_Michelle Stowell.pdf
Investigator's Declaration_Sue Statham.pdf
20161212 MOD Proposal_Michelle Stowell.docx
CV_Sue Statham.pdf
CV_Marianne Unger.pdf
Investigator Declaration_Marianne Unger.pdf
HREC PaymentInstruction_Michelle Stowell.pdf
20161212 MOD Application Form_Michelle Stowell.doc
General Checklist_Michelle Stowell.pdf
CV_Michelle Stowell.pdf
Addendum D-Child Assent Form.pdf
20161212 MOD Cover letter.docx
20161212 MOD Addendum C- Parent Informed Consent form.doc
Addendum B- HOS permission request.pdf
Investigator's Declaration_Michelle Stowell.pdf
Addendum A- DOE permission request.pdf

Sincerely,

Ashleen Fortuin
HREC Coordinator
Health Research Ethics Committee 1

Addendum B

GAUTENG PROVINCE
Department: Education
REPUBLIC OF SOUTH AFRICA

For administrative use:
Reference no. M2017/ 401

GDE RESEARCH APPROVAL LETTER

Date:	07 March 2017
Validity of Research Approval:	06 February 2017 – 29 September 2017
Name of Researcher:	Stowell M
Address of Researcher:	P O Box 643
	Pinegowrie
	Johanesburg,2123
Telephone Number:	073 177 2622
Email address:	michelle.stowell89@gmail.com
Research Topic:	The effect of wearing shoes on the outcome of selected balance measures in children with typical development and with motor dysfunction
Number and type of schools:	Two Primary Schools
District/s/HO	Johannesburg East

Re: Approval in Respect of Request to Conduct Research

This letter serves to indicate that approval is hereby granted to the above-mentioned researcher to proceed with research in respect of the study indicated above. The onus rests with the researcher to negotiate appropriate and relevant time schedules with the school/s and/or offices involved to conduct the research. A separate copy of this letter must be presented to both the School (both Principal and SGB) and the District/Head Office Senior Manager confirming that permission has been granted for the research to be conducted.

08/03/2017

The following conditions apply to GDE research. The researcher may proceed with the above study subject to the conditions listed below being met. Approval may be withdrawn should any of the conditions listed below be flouted:

Making education a societal priority

1

Office of the Director: Education Research and Knowledge Management
7th Floor, 17 Simmonds Street, Johannesburg, 2001
Tel: (011) 355 0488
Email: Faith.Tshabalala@gauteng.gov.za
Website: www.education.gpg.gov.za

1. The District/Head Office Senior Manager/s concerned must be presented with a copy of this letter that would indicate that the said researcher/s has/have been granted permission from the Gauteng Department of Education to conduct the research study.
2. The District/Head Office Senior Manager/s must be approached separately, and in writing, for permission to involve District/Head Office Officials in the project.
3. A copy of this letter must be forwarded to the school principal and the chairperson of the School Governing Body (SGB) that would indicate that the researcher/s have been granted permission from the Gauteng Department of Education to conduct the research study.
4. A letter / document that outlines the purpose of the research and the anticipated outcomes of such research must be made available to the principals, SGBs and District/Head Office Senior Managers of the schools and districts/offices concerned, respectively.
5. The Researcher will make every effort obtain the goodwill and co-operation of all the GDE officials, principals, and chairpersons of the SGBs, teachers and learners involved. Persons who offer their co-operation will not receive additional remuneration from the Department while those that opt not to participate will not be penalised in any way.
6. Research may only be conducted after school hours so that the normal school programme is not interrupted. The Principal (if at a school) and/or Director (if at a district/head office) must be consulted about an appropriate time when the researcher/s may carry out their research at the sites that they manage.
7. Research may only commence from the second week of February and must be concluded before the beginning of the last quarter of the academic year. If incomplete, an amended Research Approval letter may be requested to conduct research in the following year.
8. Items 6 and 7 will not apply to any research effort being undertaken on behalf of the GDE. Such research will have been commissioned and be paid for by the Gauteng Department of Education.
9. It is the researcher's responsibility to obtain written parental consent of all learners that are expected to participate in the study.
10. The researcher is responsible for supplying and utilising his/her own research resources, such as stationery, photocopies, transport, faxes and telephones and should not depend on the goodwill of the institutions and/or the offices visited for supplying such resources.
11. The names of the GDE officials, schools, principals, parents, teachers and learners that participate in the study may not appear in the research report without the written consent of each of these individuals and/or organisations.
12. On completion of the study the researcher/s must supply the Director: Knowledge Management & Research with one Hard Cover bound and an electronic copy of the research.
13. The researcher may be expected to provide short presentations on the purpose, findings and recommendations of his/her research to both GDE officials and the schools concerned.
14. Should the researcher have been involved with research at a school and/or a district/head office level, the Director concerned must also be supplied with a brief summary of the purpose, findings and recommendations of the research study.

The Gauteng Department of Education wishes you well in this important undertaking and looks forward to examining the findings of your research study.

Kind regards

....

Ms Faith Tshabalala
CES: Education Research and Knowledge Management

DATE: 08/03/2017

Office of the Director: Education Research and Knowledge Management
7th Floor, 17 Simmonds Street, Johannesburg, 2001
Tel: (011) 355 0488
Email: Faith.Tshabalala@gauteng.gov.za
Website: www.education.gpg.gov.za

Addendum C

UNIVERSITEIT-STELLENBOSCH-UNIVERSITY
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Ethics Letter

3 November 2017

Ethics Reference #: S16/10/233

Title: The effect of wearing shoes on the outcome of selected balance measures in children with typical development and with motor dysfunction

Dear Mrs Michelle Stowell

The Health Research Ethics Committee reviewed and approved the annual progress report you submitted through an expedited review process.

Progress Report dated 9 October 2017

The approval of this project is extended for a further year.

Approval date: 3 November 2017

Expiry date: 2 November 2018

Kindly be reminded to submit progress reports two (2) months before expiry date.

Where to submit any documentation:
Kindly submit **ONE HARD COPY** to Elvira Rohland, RDSD, Room 5007, Teaching Building, and **ONE ELECTRONIC COPY** to ethics@sun.ac.za .

Please remember to use your **protocol number (S16/10/233)** on any documents or correspondence with the HREC concerning your research protocol.

Federal Wide Assurance Number: 00001372
Institutional Review Board (IRB) Number: IRB0005240 for HREC1
Institutional Review Board (IRB) Number: IRB0005239 for HREC2

The Health Research Ethics Committee complies with the SA National Health Act No. 61 of 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 Part 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki and the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles, Structures and Processes 2015 (Department of Health).

Yours sincerely,

Ashleen Fortuin
HREC Coordinator,
Health Research Ethics Committee 1

STELLENBOSCH UNIVERSITY
Health Research Ethics Committee
03 NOV 2017
STELLENBOSCH UNIVERSITEIT
Gesondheidsnavorsing Etiekkomitee

Fakulteit Geneeskunde en Gesondheidswetenskappe
•
Faculty of Medicine and Health Sciences

Afdeling Navorsingsontwikkeling en -Steun • Research Development and Support Division

Posbus/PO Box 241 • Cape Town 8000 • Suid-Afrika/South Africa
Tel: +27 (0) 21 938 9677

Addendum D

GAUTENG PROVINCE
Department: Education
REPUBLIC OF SOUTH AFRICA

8/4/4/1/2

GDE RESEARCH APPROVAL LETTER

Date:	**02 October 2017**
Validity of Research Approval:	**05 February 2018– 28 September 2018** **M2017/401A**
Name of Researcher:	**Stowell M.**
Address of Researcher:	**P.O Box 643**
	Pinegowrie
	Johannesburg, 2123
Telephone Number:	**073 177 2622**
Email address:	**michelle.stowell89@gmail.com**
Research Topic:	**The effect of wearing shoes on the outcome of selected balance measures in children with typical development and with motor dysfunction.**
Number and type of schools:	**Two Primary Schools**
District/s/HO	**Johannesburg East**

Re: Approval in Respect of Request to Conduct Research

This letter serves to indicate that approval is hereby granted to the above-mentioned researcher to proceed with research in respect of the study indicated above. The onus rests with the researcher to negotiate appropriate and relevant time schedules with the school/s and/or offices involved to conduct the research. A separate copy of this letter must be presented to both the School (both Principal and SGB) and the District/Head Office Senior Manager confirming that permission has been granted for the research to be conducted.

03/10/2017

The following conditions apply to GDE research. The researcher may proceed with the above study subject to the conditions listed below being met. Approval may be withdrawn should any of the conditions listed below be flouted:

1

Making education a societal priority

Office of the Director: Education Research and Knowledge Management
7th Floor, 17 Simmonds Street, Johannesburg, 2001
Tel: (011) 355 0488
Email: Faith.Tshabalala@gauteng.gov.za
Website: www.education.gpg.gov.za

1. *The District/Head Office Senior Manager/s concerned must be presented with a copy of this letter that would indicate that the said researcher/s has/have been granted permission from the Gauteng Department of Education to conduct the research study.*
2. *The District/Head Office Senior Manager/s must be approached separately, and in writing, for permission to involve District/Head Office Officials in the project.*
3. *A copy of this letter must be forwarded to the school principal and the chairperson of the School Governing Body (SGB) that would indicate that the researcher/s have been granted permission from the Gauteng Department of Education to conduct the research study.*
4. *A letter / document that outlines the purpose of the research and the anticipated outcomes of such research must be made available to the principals, SGBs and District/Head Office Senior Managers of the schools and districts/offices concerned, respectively.*
5. *The Researcher will make every effort obtain the goodwill and co-operation of all the GDE officials, principals, and chairpersons of the SGBs, teachers and learners involved. Persons who offer their co-operation will not receive additional remuneration from the Department while those that opt not to participate will not be penalised in any way.*
6. *Research may only be conducted after school hours so that the normal school programme is not interrupted. The Principal (if at a school) and/or Director (if at a district/head office) must be consulted about an appropriate time when the researcher/s may carry out their research at the sites that they manage.*
7. *Research may only commence from the second week of February and must be concluded before the beginning of the last quarter of the academic year. If incomplete, an amended Research Approval letter may be requested to conduct research in the following year.*
8. *Items 6 and 7 will not apply to any research effort being undertaken on behalf of the GDE. Such research will have been commissioned and be paid for by the Gauteng Department of Education.*
9. *It is the researcher's responsibility to obtain written parental consent of all learners that are expected to participate in the study.*
10. *The researcher is responsible for supplying and utilising his/her own research resources, such as stationery, photocopies, transport, faxes and telephones and should not depend on the goodwill of the institutions and/or the offices visited for supplying such resources.*
11. *The names of the GDE officials, schools, principals, parents, teachers and learners that participate in the study may not appear in the research report without the written consent of each of these individuals and/or organisations.*
12. *On completion of the study the researcher/s must supply the Director: Knowledge Management & Research with one Hard Cover bound and an electronic copy of the research.*
13. *The researcher may be expected to provide short presentations on the purpose, findings and recommendations of his/her research to both GDE officials and the schools concerned.*
14. *Should the researcher have been involved with research at a school and/or a district/head office level, the Director concerned must also be supplied with a brief summary of the purpose, findings and recommendations of the research study.*

The Gauteng Department of Education wishes you well in this important undertaking and looks forward to examining the findings of your research study.

Kind regards

....

Ms Faith Tshabalala
CES: Education Research and Knowledge Management

DATE: 03/10/2017

Office of the Director: Education Research and Knowledge Management
7th Floor, 17 Simmonds Street, Johannesburg, 2001
Tel: (011) 355 0488
Email: Faith.Tshabalala@gauteng.gov.za
Website: www.education.gpg.gov.za

Addendum E

Date: ____________

To whom it may concern,

My name is Michelle Stowell and I am currently doing my Masters in Physiotherapy through the University of Stellenbosch.

As part of my degree, I need to complete research. I have chosen to observe the effect of wearing shoes on balance in children.

I have received approval from the University of Stellenbosch (S16/10/233) as well as the Department of Education.

I hereby would like permission to test some of the learners from your school. I will be testing learners who comply with my inclusion criteria from the ages of 4-10. They will be subjected to a few balance tests (e.g. standing on 1 leg) by a physiotherapist, Andrea Fraser-Aldridge (research assistant). The testing should take about 30 minutes per test. Each child will undergo four tests – two on consecutive or within 2 weeks of each other. I would like to do the testing commencing on the as soon as possible. Testing will be done at the school in a period convenient to the timetable or after school if more convenient. Only I will have access to the child's information and it will be kept in a closed envelope at my house or stored on my computer as a password protected document. If the research is published, the child's name and school will be kept out of the publication. Publication will only contain group statistics and individual children will remain anonymous.

Participation is entirely voluntary and there are no cost to the child or family or remuneration to be paid for participation.

Signed at (*place*) ....…........…………….. on (*date*) …………...……….......

....

Signature of Principal **Signature of witness**

Addendum F

PARTICIPANT INFORMATION LEAFLET AND CONSENT FORM

TITLE OF THE RESEARCH PROJECT: The effect of wearing shoes on the outcome of selected balance measures in children with typical development and with motor dysfunction.

REFERENCE NUMBER:

PRINCIPAL INVESTIGATOR: Michelle Stowell

ADDRESS: Unit 9 La Piazza, 7 Whelan Close, Edenburg, Johannesburg

CONTACT NUMBER: 0731772622

You are being invited to take part in a research project. Please take some time to read the information presented here, which will explain the details of this project. Please ask the study staff any questions about any part of this project that you do not fully understand. It is very important that you are fully satisfied that you clearly understand what this research entails and how you could be involved. Also, your child's participation is **entirely voluntary** and you are free to decline their participation. If you say no, this will not affect you or your child negatively in any way whatsoever. Your child is also free to withdraw from the study at any point, even if you do agree to take part.

This study has been approved by the **Health Research Ethics Committee at Stellenbosch University** and will be conducted according to the ethical guidelines and principles of the international Declaration of Helsinki, South African Guidelines for Good Clinical Practice and the Medical Research Council (MRC) Ethical Guidelines for Research.

What is this research study all about?

- This study will take place at two schools in Johannesburg (a private and a government school). The total number of children participating are 70.
- I am looking at the effect of shoes on balance in children and whether it makes a difference on the way in which we score balance when testing children. I am also looking to see whether this effect is the same for children who have motor problems.
- Your child will be asked to do a series of exercises with their shoes off e.g. balancing on one leg, walking forwards on a line, walking on a balance beam. These will all be scored according to the standardised measures. They will then come back another day and do the same set of activities with their shoes on. This will be repeated again using another test for balance.

- The person doing the scores of the test will not know who is in each group and she will not know any personal information on your child.

Why has your child been invited to participate?

- I am observing children between 4 and 10 years of age. I need children who have been referred to therapy due to gross motor problems (e.g. like clumsiness, poor posture, abnormal walking pattern etc.) and children who match their age and gender.

What will your responsibilities be?

- To ensure your child wears his / her normal school shoes on the days of testing.

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

- There are no personal benefits to taking part in this study. If shoes are found to affect balance, this information will be useful to therapists when assessing balance in children.

Are there in risks involved in your child taking part in this research?

- There are no risks. All the activities your child will be asked to do are similar to what he/she most likely does during play.

Who will have access to your child's medical records?

- Only I will have access to your child's information and it will be kept in a closed envelope at my house. If the research is published, your child's name will be kept out of the publication. On the data collection form, your child's name will not appear and it will be coded with a letter and number.

What will happen in the unlikely event of some form injury occurring as a direct result of your child taking part in this research study?

- This is highly unlikely but if it does happen the school nurse/teacher will be informed and I will also contact you.

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

No you will not be paid to take part in the study. The tests will all happen at the school. Your child will receive refreshments as a gesture of thanks for participating in this study.

Is there any thing else that you should know or do?

- You can contact me for more information or my supervisor Dr Marianne Unger at 021 9389302
- You can also contact the Health Research Ethics Committee at 021-938 9207 if you have any concerns or complaints that have not been adequately addressed by myself.
- You will receive a copy of this information and consent form for your own records.

Declaration by parent

By signing below, I …………………………………..………… agree for my child, ………………………………………… to take part in a research study entitled: The effect of wearing shoes on the outcome of selected balance measures in children with typical development and with motor dysfunction.

.

I declare that:

- I have read or had read to me this information and consent form and it is written in a language with which I am fluent and comfortable.
- I have had a chance to ask questions and all my questions have been adequately answered.
- I understand that my child taking part in this study is **voluntary** and I have not been pressurised to take part.
- My child may choose to leave the study at any time and will not be penalised or prejudiced in any way.
- My child may be asked to leave the study before it has finished, if the study doctor or researcher feels it is in my best interests, or if I do not follow the study plan, as agreed to.

Signed at (*place*) ....…........…………… on (*date*) …………....……….. 2017.

....	....
Signature of parent	**Signature of witness**

Contact email/number:____

Declaration by investigator

I *(name)* ……………………………………………..……… declare that:

- I explained the information in this document to …………………………………..
- 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 did/did not use an interpreter.

Signed at (*place*) .... on (*date*) .... 2017.

.... **Signature of investigator**

.... **Signature of witness**

Declaration by interpreter

I *(name)* .... declare that:

- I assisted the investigator (*name*) .... to explain the information in this document to (*name of participant*) .... using the language medium of Afrikaans/Zulu.
- We encouraged him/her to ask questions and took adequate time to answer them.
- I conveyed a factually correct version of what was related to me.
- I am satisfied that the participant fully understands the content of this informed consent document and has had all his/her question satisfactorily answered.

Signed at (*place*) .... on (*date*) ....

.... **Signature of interpreter**

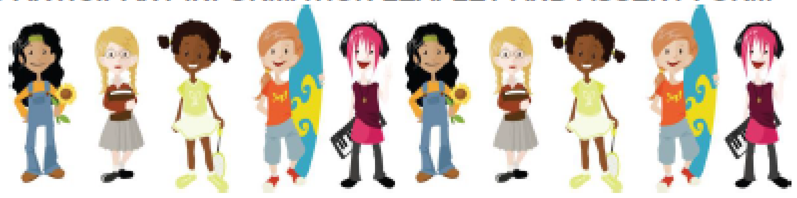
.... **Signature of witness**

Addendum G

STELLENBOSCH UNIVERSITY

FACULTY OF HEALTH SCIENCES

PARTICIPANT INFORMATION LEAFLET AND ASSENT FORM



TITLE OF THE RESEARCH PROJECT: Do shoes help children balance better?

RESEARCHERS NAME(S): Michelle Stowell

ADDRESS: Unit 9, La Piazza, 7 Whelan Close, Johannesburg

CONTACT NUMBER: 0731772622

What is RESEARCH?

Research is something we do to find new knowledge about the way things (and people) work. We use research projects or studies to help us find out more about disease or illness. Research also helps us to find better ways of helping, or treating children who are sick.

What is this research project all about?
I would like to find out if wearing shoes helps you to balance better

Why have I been invited to take part in this research project?
You have been asked to help me because you are aged between 4 and 10 years old.

Who is doing the research?
My name is Michelle and I am a physiotherapist who helps children become strong.

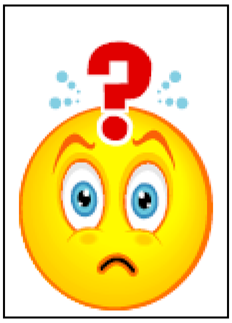
What will happen to me in this study?
You will be asked to do different balance exercises first with your shoes off. Some of these exercises are standing on one leg and walking forward on a line. This will take about 30 minutes. Once we have done the test with shoes off, I will ask you to come back another day and do the same test with your shoes on.

Can anything bad happen to me?
Nothing bad can happen to you. If you feel sick or sore after the tests, please tell your me, mom or dad.

Assent template. Faculty of Health Sciences SU. Version 1. June 2009

Can anything good happen to me?
There are no benefits. We may be able to help children with wearing better shoes if we find they help with balance.

Will anyone know I am in the study?
No one will know your name. Some of your information like height and how much you weigh will be used but your name will not be used.



Who can I talk to about the study?
You may talk to me if you have any questions

What if I do not want to do this?
You will not be forced to be in this study. If you start the tests and feel you don't want to anymore, you may stop at any time..

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

YES NO

Has the researcher answered all your questions?

YES NO

Do you understand that you can pull out of the study at any time?

YES NO

Signature of Child ____________ Date ____________

Assent template. Faculty of Health Sciences SU. Version 1. June 2009

Addendum H

PAEDIATRIC BALANCE SCALE

Name:
Location:
Examiner:

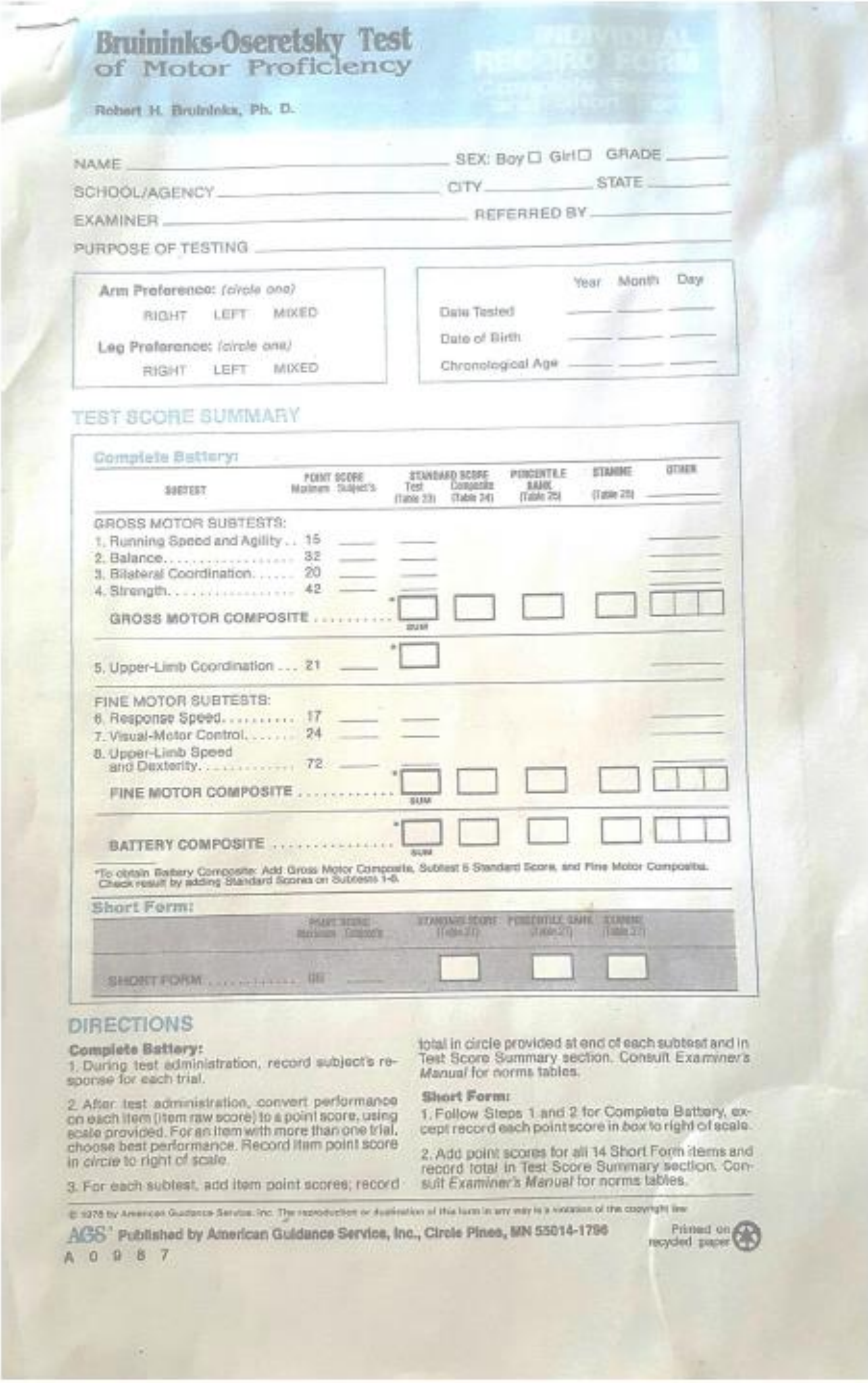
		Date:	**Date:**	**Date:**
		Score 0-4 (time- optional)	Score 0-4 (time- optional)	Score 0-4 (time- optional)
1.	Sitting to standing **" Hold your arms up and stand up"** 4- able to stand without using hands and stabilize independently 3- able to stand independently using hands 2- able to stand using hands after several tries 1- needs minimal assist to stand or to stabilize 0- needs moderate or maximal assist to stand			
2.	Standing to sitting **"Sit down slowly without using your hands"** 4- sits safely with minimal use of hands 3- controls descent by using hands 2- uses back of legs against chair to control descent 1- sits independently, but has uncontrolled descent 0- needs assistance to sit			
3.	Transfers 4- able to transfer safely with minor use of hands 3- able to transfer safely; definite need of hands 2- able to transfer with verbal cuing and/or supervision (spotting) 1- needs one person to assist 0- needs two people to assist or supervise (close guard) to be safe			
4.	Standing unsupported 4- able to stand safely 30 seconds 3- able to stand 30 seconds with supervision (spotting) 2- able to stand 15 seconds unsupported 1- needs several tries to stand 10 seconds unsupported 0- unable to stand 10 seconds unassisted	(___ sec.)	(___ sec.)	(___ sec.)

5.	Sitting unsupported **"Sit with your arms folded on your chest for 30 seconds"** 4- able to sit safely and securely 30 seconds 3- able to sit 30 seconds under supervision (spotting) or may require definite use of upper extremities to maintain sitting position 2- able to sit 15 seconds 1- able to sit 10 seconds 0- unable to sit 10 seconds without support	(__ sec.)	(__ sec.)	(__ sec.)
6.	Standing with eyes closed **"When I say close your eyes, I want you to stand still, close your eyes, and keep them closed until I say open"** 4- able to stand 10 seconds safely 3- able to stand 10 seconds with supervision (spotting) 2- able to stand 3 seconds 1-unable to keep eyes closed 3 seconds but stays steady 0- needs help to keep from falling	(__ sec.)	(__ sec.)	(__ sec.)
7.	Standing with feet together 4- able to place feet together independently and stand 30 seconds safely 3- able to place feet together independently and stand for 30 seconds with supervision (spotting) 2- able to place feet together independently but unable to hold for 30 seconds 1- needs help to attain position but able to stand 30 seconds with feet together 0- needs help to attain position and/or unable to hold for 30 seconds	(__ sec.)	(__ sec.)	(__ sec.)
8.	Standing with one foot in front 4- able to place feet tandem independently and hold 30 seconds 3- able to place foot ahead of other independently and hold 30 seconds 2- able to take small step independently and hold 30 seconds, or required assistance to place foot in front, but can stand for 30 seconds 1- needs help to step, but can hold 15 seconds 0- loses balance while stepping or standing	(__ sec.)	(__ sec.)	(__ sec.)

9.	Standing on one foot 4- able to lift leg independently and hold 10 seconds 3- able to lift leg independently and hold 5-9 seconds 2- able to lift leg independently and hold 3-4 seconds 1- tries to lift leg; unable to hold 3 seconds but remains standing 0- unable to try or needs assist to prevent fall	(___ sec.)	(___ sec.)	(___ sec.)
10.	Turning 360 degrees **" Turn completely around in a full circle, STOP, and then turn a full circle in the other direction"** 4- able to turn 360 degrees safely in 4 seconds or less each way 3- able to turn 360 degrees safely in one direction only in 4 seconds or less 2- able to turn 360 degrees safely but slowly 1- needs close supervision (spotting) or constant verbal cuing 0- needs assistance while turning	(___ sec.)	(___ sec.)	(___ sec.)
11.	Turning to look behind **" Follow this object as I move it. Keep watching it as I move it, but don't move your feet."** 4- looks behind/over each shoulder; weight shifts include trunk rotation 3- looks behind/over one shoulder with trunk rotation 2- turns head to look to level of shoulders, no trunk rotation 1- needs supervision (spotting) when turning; the chin moves greater than half the distance to the shoulder 0- needs assistance to keep from losing balance or falling; movement of the chin is less than half the distance to the shoulder			
12.	Retrieving object from floor 4- able to pick up chalk board eraser safely and easily 3- able to pick up eraser but needs supervision (spotting) 2- unable to pick up eraser but reaches 1-2 inches from eraser and keeps balance independently 1- unable to pick up eraser; needs spotting while attempting 0- unable to try, needs assist to keep from losing balance or falling			

13.	Placing alternate foot on stool 4- stands independently and safely and completes 8 steps in 20 seconds 3- able to stand independently and complete 8 steps >20 seconds 2- able to complete 4 steps without assistance, but requires close supervision (spotting) 1- able to complete 2 steps; needs minimal assistance 0- needs assistance to maintain balance or keep from falling, unable to try	(___ sec.)	(___ sec.)	(___ sec.)
14.	Reaching forward with outstretched arm **" Stretch out your fingers, make a fist, and reach forward as far as you can without moving your feet"** 4- reaches forward confidently >10 inches 3- reaches forward >5 inches, safely 2- reaches forward >2 inches, safely 1- reaches forward but needs supervision (spotting) 0- loses balance while trying, requires external support	(___ in.)	(___ in.)	(___ in.)
	TOTAL SCORE			

Addendum I



Bruininks-Oseretsky Test of Motor Proficiency

Robert H. Bruininks, Ph. D.

INDIVIDUAL RECORD FORM

NAME ______ SEX: Boy ☐ Girl ☐ GRADE ______

SCHOOL/AGENCY ______ CITY ______ STATE ______

EXAMINER ______ REFERRED BY ______

PURPOSE OF TESTING ______

Arm Preference: *(circle one)*
RIGHT LEFT MIXED

Leg Preference: *(circle one)*
RIGHT LEFT MIXED

	Year	Month	Day
Date Tested			
Date of Birth			
Chronological Age			

TEST SCORE SUMMARY

Complete Battery:

SUBTEST	POINT SCORE Maximum	POINT SCORE Subject's	STANDARD SCORE Test (Table 23)	STANDARD SCORE Composite (Table 24)	PERCENTILE RANK (Table 25)	STANINE (Table 25)	OTHER
GROSS MOTOR SUBTESTS:							
1. Running Speed and Agility	15						
2. Balance	32						
3. Bilateral Coordination	20						
4. Strength	42						
GROSS MOTOR COMPOSITE			*SUM				
5. Upper-Limb Coordination	21		*				
FINE MOTOR SUBTESTS:							
6. Response Speed	17						
7. Visual-Motor Control	24						
8. Upper-Limb Speed and Dexterity	72						
FINE MOTOR COMPOSITE			*SUM				
BATTERY COMPOSITE			*SUM				

*To obtain Battery Composite: Add Gross Motor Composite, Subtest 5 Standard Score, and Fine Motor Composite. Check result by adding Standard Scores on Subtests 1-8.

Short Form:

	POINT SCORE Maximum	POINT SCORE Subject's	STANDARD SCORE (Table 27)	PERCENTILE RANK (Table 27)	STANINE (Table 27)
SHORT FORM	98				

DIRECTIONS

Complete Battery:

1. During test administration, record subject's response for each trial.

2. After test administration, convert performance on each item (item raw score) to a point score, using scale provided. For an item with more than one trial, choose best performance. Record item point score in *circle* to right of scale.

3. For each subtest, add item point scores; record total in circle provided at end of each subtest and in Test Score Summary section. Consult Examiner's *Manual* for norms tables.

Short Form:

1. Follow Steps 1 and 2 for Complete Battery, except record each point score in *box* to right of scale.

2. Add point scores for all 14 Short Form items and record total in Test Score Summary section. Consult *Examiner's Manual* for norms tables.

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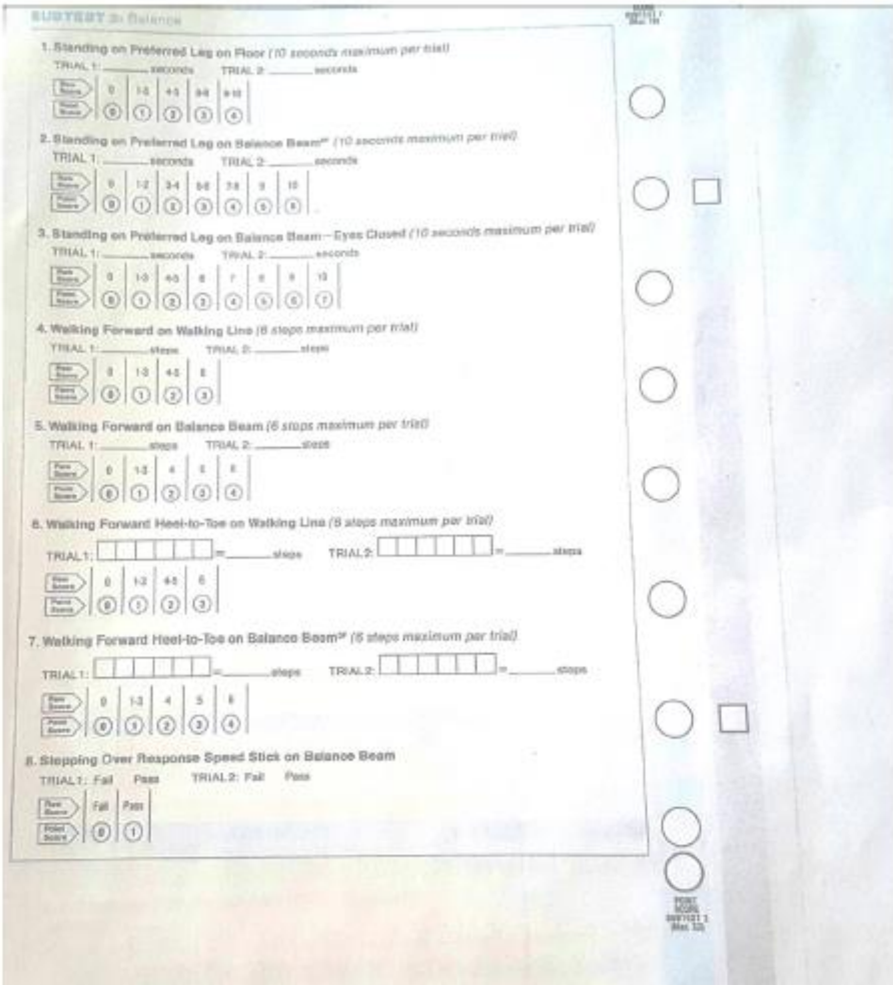

SUBTEST 3: Balance

1. Standing on Preferred Leg on Floor *(10 seconds maximum per trial)*

TRIAL 1: ______ seconds TRIAL 2: ______ seconds

Raw Score	0	1-3	4-5	6-8	9-10
Point Score	0	1	2	3	4

2. Standing on Preferred Leg on Balance Beam* *(10 seconds maximum per trial)*

TRIAL 1: ______ seconds TRIAL 2: ______ seconds

Raw Score	0	1-2	3-4	5-6	7-8	9	10
Point Score	0	1	2	3	4	5	6

3. Standing on Preferred Leg on Balance Beam—Eyes Closed *(10 seconds maximum per trial)*

TRIAL 1: ______ seconds TRIAL 2: ______ seconds

Raw Score	0	1-3	4-5	6	7	8	9	10
Point Score	0	1	2	3	4	5	6	7

4. Walking Forward on Walking Line *(6 steps maximum per trial)*

TRIAL 1: ______ steps TRIAL 2: ______ steps

Raw Score	0	1-3	4-5	6
Point Score	0	1	2	3

5. Walking Forward on Balance Beam *(6 steps maximum per trial)*

TRIAL 1: ______ steps TRIAL 2: ______ steps

Raw Score	0	1-3	4	5	6
Point Score	0	1	2	3	4

6. Walking Forward Heel-to-Toe on Walking Line *(6 steps maximum per trial)*

TRIAL 1: ☐☐☐☐☐☐ = ______ steps TRIAL 2: ☐☐☐☐☐☐ = ______ steps

Raw Score	0	1-2	4-5	6
Point Score	0	1	2	3

7. Walking Forward Heel-to-Toe on Balance Beam* *(6 steps maximum per trial)*

TRIAL 1: ☐☐☐☐☐☐ = ______ steps TRIAL 2: ☐☐☐☐☐☐ = ______ steps

Raw Score	0	1-3	4	5	6
Point Score	0	1	2	3	4

8. Stepping Over Response Speed Stick on Balance Beam

TRIAL 1: Fail Pass TRIAL 2: Fail Pass

Raw Score	Fail	Pass
Point Score	0	1

POINT SCORE