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Date	February 2025
Title	A functional balance profile of school aged children and adolescents diagnosed with Down Syndrome, schooled in the Eastern Cape province of South Africa: A pilot study.

Plagiarism Declaration

I, Ciljé Josephus Johannes Nolte, hereby declare that the work on which this dissertation/thesis is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

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Abstract

Children and adolescents with Down Syndrome (DS) are at a higher risk of falls due to impaired balance and gait patterns, which complicates their ability to safely engage in daily activities (Jung, Chung & Lee, 2017). Assessing balance function in children is not only important for identifying balance deficits, but also to inform and highlight integral areas of balance function that should be addressed during rehabilitation. Although various outcome measures have demonstrated acceptable reliability and validity in typically developing children, the applicability of outcome measures in children with DS has not been fully established. This pilot study aimed to evaluate the clinimetric properties, including reliability, validity, and practicality, of four functional balance outcome measures: the Paediatric Balance Scale (PBS), the second edition of the Bruininks-Oseretsky Test of Motor Proficiency (BOT-2, Subtest 5), the full Children's Balance Evaluation Systems Test (Kids-BESTest), and its shortened version (Kids Mini-BESTest). To contextualise the results, a control group of age- and sex-matched typically developing peers was included for comparison. The primary objectives were to assess reliability (inter-rater and test-retest), known-groups validity, criterion validity (via correlations with Timed Up & Go (TUG) scores), and internal consistency (using Cronbach's alpha) of each measure. Outcome measures used in real-world settings like schools and clinics require qualities beyond being clinimetrially sound. Aspects regarding the practical applicability of these outcome measures should also be considered. Thus, this study evaluated the accessibility, safety, and practicality of administering these tests in a DS population, including time requirements, cost-effectiveness, and participant acceptability.

The secondary objectives were to describe the balance profile of the DS group and explore the effects of potential confounders, including middle ear function, cochlear outer hair cell function, and Body Mass Index (BMI), on balance performance and test outcomes.

Children from the Merryvale School for Special Education in Gqeberha, Eastern Cape (EC), South Africa (SA), participated in this study, while typically developing controls were sourced from local schools in the same area. Safety measures, such as gait belts and close guarding, were implemented to ensure participant safety and minimise fall risk during assessments. Data confidentiality and participant welfare were prioritised throughout the study.

The results demonstrated significant differences in balance performance between children with DS and typically developing peers across all four assessment tools. The DS group exhibited lower mean scores and shorter durations for balance tasks, with notable floor effects in specific items, particularly within the Kids-BESTest and PBS. Independent t-tests revealed statistically significant group differences ($p < 0.001$), with large effect sizes (e.g., Cohen's d = 3.94 for BOT-2 Subtest 5). Reliability analysis showed good inter-rater and test-retest reliability for all tools, with Cronbach's alpha values ranging from 0.867 to 0.971, indicating strong internal consistency. Validity testing confirmed known-groups validity, with balance assessments effectively differentiating between DS and typically developing groups, while criterion validity demonstrated a significant association between balance test scores and TUG performance (e.g., Kids-BESTest $R^2 = 0.536$, $p < 0.001$). Health-related variables, such as BMI and middle ear status, significantly correlated with poorer balance outcomes. This correlation further emphasises the multifactorial nature of balance impairments in children with DS.

This study offers initial insights into effective, safe balance assessment methods which audiologists can use for DS populations. These insights ultimately pave the way for future research to support balance related interventions.

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Glossary

Acceptability: The degree to which ministrations, services, operations, or innovations are perceived as satisfactory or agreeable by the individuals engaging with it (Proctor et al., 2010). In the context of this study, acceptability was evaluated by examining participants' willingness and ability to engage with balance assessment tasks, as well as their comfort and compliance with safety measures such as wearing gait belts during the procedures.

Accessibility: The ease with which individuals or institutions can access and utilize healthcare services or assessment tools (Levesque, Harris & Russel, 2013). This includes factors such as cost, availability, and the ability to obtain or use the required resources. In the context of this study, accessibility was influenced by the financial costs associated with different outcome measures, as well as the availability of equipment through retailers

Attention Deficit-Hyperactivity Disorder (ADHD): A condition affecting children that can last into adulthood, associated with inattention, hyperactivity and impulsivity that limits their functioning in daily living (World Health Organization (WHO), 2019).

Autism spectrum disorder (ASD): A diverse group of neuro-developmental disorders associated with a degree of difficulty with communication and social interactions (WHO, 2022).

Body Mass Index (BMI): A calculation of a person's body fatness, by dividing a person's weight by the square of their height. In this research, the Centers for Disease Control and Prevention's (CDC) paediatric scale for BMI calculation was used (CDC, 2022).

Clinimetrics: A field focussed on rating scales, indices and other tools used for describing or measuring symptoms, physical signs and additional clinical occurrences (Feinstein, 1982).

Cochlear outer hair cells: Cochlear outer hair cells are specialized sensory cells in the inner ear's organ of Corti that play a crucial role in enhancing hearing sensitivity and frequency selectivity. Unlike inner hair cells, which primarily transmit auditory information to the brain, the cochlear outer hair cells amplify vibrations od sound within the cochlea through their ability to change length in response to electrical stimulation (Ashmore, 2008).

Down Syndrome (DS): A human being born with cells in their body that contain an extra copy of chromosome 21. DS can be classified into 3 categories viz. Trisomy 21, Translocation DS and Mosaicism, with Trisomy 21 and Translocation DS being clinically identical and Mosaicism can have a milder phenotype. The diagnosis is associated with physical manifestations including a flat facial profile, small and low set displastic ears, an upward slant evident in the palpebral fissures, a short and broad neck with abundant neck skin, developmental delay and neurobehavioral problems (Agarwal Gupta & Kabra, 2014).

Gait: Gait refers to the pattern of walking or running and is an essential component of human movement. Any alterations in this pattern may indicate underlying health conditions across different medical fields. Gait disturbances encompass any deviations from typical walking patterns (Ataullah & De Jesus, 2024).

Hearing loss (HL): Refers to either a limited or entire inability to hear resulting from pathologies affecting the ear, vestibulocochlear nerve and/or auditory pathways (American Speech-Language-Hearing Association (ASHA), 2023).

Human balance: The body’s ability to maintain its centre of mass (COM) over its base of support, allowing stable vision, orientation to gravity, and postural adjustments necessary for various activities (Vestibular Disorders Association (VeDA), 2021). This ability depends on sensory integration from vision, proprioception, and the vestibular system, along with motor responses to adjust posture (VeDA, 2021). Balance can be affected by congenital factors, particularly in individuals with DS, where atypical sensory processing and motor function contribute to balance deficits (Jung et al., 2017; Aly & Abonour, 2016).

Intellectual Disability Disorder (IDD): A term used when a person has limited abilities to function in daily life and learn at a standard level with severity of disability varying across populations (CDC, 2022).

Middle Ear Effusion (MEE): An infection or inflammation occurring in the middle ear as a result of possible Eustachian tube dysfunction commonly caused by respiratory infections (Johns Hopkins Medicine, 2023).

Near miss: A near miss is an incident in which a fall was likely but was prevented by the actions of staff, the individual, or other factors. An event does not qualify as a near miss if the individual sustained harm or injury or if a fall actually occurred (South Australian Department of Health and Wellbeing, 2024).

Obesity: An abnormal accumulation of excessive body fat that poses a risk to a person’s health (WHO, 2020).

Otoacoustic Emissions (OAE): A diagnostic or screening assessment eliciting measurable sounds from the outer hair cells of the cochlea by presenting a low intensity click or pure tone stimulus (Joint Committee on Infant Hearing (JCIH), 2019).

Otoscopy: A basic examination of the outer ear and ear drum (tympanic membrane) for signs of malformation, blockage, cerumen, foreign bodies and other debris (Diefendorf, 2015).

Pes planus: Pes planus, also known as flat feet, refers to a condition characterised by a flattened arch in the sole of the foot. This may be present in one or both feet and can occur from childhood or develop later in life due to medical conditions. The condition affects the biomechanics of walking, potentially leading to pain or gait issues. Pes planus, which is a common abnormality in people with DS, can be classified into flexible (arches visible when not weight-bearing) or rigid (arches absent regardless of weight-bearing), and it may be congenital or acquired. In severe cases, inward ankle rolling or outward-pointing heels may result in additional changes (Cleveland Clinic, 2024).

Postural control: The ability to maintain balance by stabilizing the centre of gravity over the base of support. It requires continuous adjustments driven by physiological processes, body mechanics, and sensory input (Paillard, 2011).

Romberg test: Romberg testing assesses the patient's ability to use visual, vestibular, and proprioceptive cues to maintain balance. The test should be carried out with the feet positioned as close together as possible and the arms crossed over the chest. It can also be done in the Jendrassic position, but for the purpose of this study it was done with arms crossed over the chest. Interpreting the results of the Romberg test enables the clinician to evaluate the patient's capacity to rely on these cues to maintain balance (Mattingly, Wazen & Cass, 2017).

Sharpened Romberg: Building on the previously mentioned Romberg test, the Sharpened Romberg reduces proprioceptive feedback, thereby increasing the reliance on vestibular information to maintain balance (Hale, Trahan & Parent-Buck, 2015).

Somatosensory system: The somatosensory system processes sensory input from receptors in the skin, joints, muscles and deeper tissues, allowing perception of touch, temperature, pain, and body position and movement (Rees, Walker & Jennings, 2010).

SWOT Analysis: A strategic evaluation tool used to identify the Strengths, Weaknesses, Opportunities, and Threats associated with a particular initiative or subject (The Chartered Institute of Personnel and Development (CIPD) & Haan, 2024). In this study, the SWOT analysis was applied to assess the findings on the clinimetric qualities and practical applicability of balance assessment tools used for children with DS. It provided a framework for evaluating the tools' performance, usability, and feasibility in relation to the unique needs of this population and the specific context in which these assessments are conducted.

Tympanometry: A diagnostic audiological procedure assessing the movement of the middle ear system, providing information with regards to middle ear pressure, static compliance and ear canal volume (Joint Committee on Infant Hearing (JCIH), 2019).

Vestibular system: The peripheral vestibular system consists of sensory organs, namely the otolith organs and semicircular canals, which are responsible for detecting head movements. This system plays a crucial role in maintaining postural control and ensuring clear vision on the retina's central point during motion. Secondary vestibular afferents transmit signals to the extraocular motor nuclei, the spinal cord, or the flocculus of the cerebellum from the vestibular nuclei. Numerous vestibular reflexes are regulated by mechanisms that are primarily located in the brainstem (Bogle & Burkard, 2021).

List of Abbreviations

Abbreviation	Meaning
ADHD	Attention Deficit-Hyperactivity Disorder
ADL	Activities of Daily Living
ANOVA	Analysis of variance
AP	Antero-posterior
ASD	Autism Spectrum Disorder
ASHA	American Speech-Language-Hearing Association
BBS	Berg Balance Scale
BMI	Body Mass Index
BOT-2	Bruininks-Oseretsky Test of Motor Proficiency, Second edition
BOT-2 SF	BOT-2 short form
BPFT	Brockport Physical Fitness Test
BSA	British Society of Audiology
CAPS	Curriculum and Policy Statement
CDC	Centers for Disease Control and Prevention[1]

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[1] South African English spelling which is based on British English, will be used throughout this paper, unless the name of an instrument or institution originates from a different dialect.

CHL	Conductive hearing loss
CI	Confidence interval
CIPD	Chartered Institute of Personnel and Development
cm	Centimetre
COM	Centre of mass
CP	Cerebral palsy
CSR	Corporate social responsibility
DALYs	Disability-adjusted life years
DoH	Department of Health
DPOAE	Distortion Product Otoacoustic Emission
DS	Down Syndrome
DSSA	Down Syndrome South Africa
EC	Eastern Cape
ECD	Early childhood development
ENT	Ear, nose and throat specialist (otorhinolaryngologist)
FET	Further Education and Training
FRT	Functional Reach Test
GMFM-88	Gross Motor Function Measure-88

GP	General practitioner
HL	Hearing loss
HPCSA	Health Professions Council of South Africa
HREC	Human Research Ethics Committee
ICC	Intraclass Correlation Coefficients
IDD	Intellectual Disability Disorder
JCIH	Joint Committee on Infant Hearing
kg	kilogram
Kids-BESTest	Children’s-Balance Evaluations Systems Test
Kids Mini-BESTest	Shortened version of the Kids-BESTest
KZN	Kwa-Zulu Natal
LMIC	Low- and middle-income country
m	metre
MDC	Minimal Detectable Change
MCID	Minimal clinically important difference
mCTSIB	Modified Clinical Test of Sensory Integration of Balance
MEE	Middle ear effusion
ML	Medio-lateral

Movement-ABC	Movement Assessment Battery for Children
NAD	No abnormalities detected
NGO	Non-Governmental Organisation
NHI	National health insurance
NPO	Non-Profit Organisation
OAE	Otoacoustic Emissions
PDMS-2	Peabody Developmental Motor Scales
PBS	Pediatric Balance Scale
POPIA	Protection of Personal Information Act
SA	South Africa
SD	Standard Deviation
SDC	Smallest Detectable Change
s	Second/s
SES	Socio-economic status
SFT	Senior Fitness Test
SLS	Single leg stance
SNHL	Sensorineural hearing loss
SPM	Sensory Processing Measure

SRM	Standard response mean
SWOT	Strengths, weaknesses, opportunities and threats
TUG	Timed Up & Go
TVMR-R	Test of Visual-Motor Skills-Revised
UCT	The University of Cape Town
UK	United Kingdom
USA	United States of America
VART	Vestibular Assessment and Rehabilitation Therapy (Course)
VeDA	Vestibular Disorders Association
WHO	World Health Organization
WMA	World Medical Association

Introduction

This pilot study aimed to evaluate the clinimetric properties of four distinct assessment tools used to measure the functional balance abilities of children and adolescents diagnosed with Down Syndrome (DS) aged six to eighteen years in the Eastern Cape (EC) province of South Africa (SA). The study assessed aspects of reliability and validity, including inter-rater reliability, test-retest reliability, internal consistency, floor-ceiling effects and criterion validity. Additionally, practical applicability was also assessed in terms of acceptability, accessibility and time efficiency. This study has also considered the impact of various risk factors, such as obesity, middle ear status, and cochlear outer hair cell function (as a proxy for ear disease and possible hearing loss). To contextualise the DS group, age and sex matched typically developing participants were assessed with the same instruments.

Audiologists in SA are tasked with the assessment and rehabilitation of individuals at risk for balance and vestibular deficits, including those with an increased risk of falls (Department of Health (DoH), 2011). For audiologists working in both clinical and educational settings, being able to choose from instruments which are applicable to the local context, and suitable for diverse groups of patients, is vital. The healthcare context in SA is challenging, thus, this study hopes to highlight potential outcome measures to equip audiologists in fulfilling the scope of their profession by adopting appropriate, robust and suitable outcome measures.

The literature review will focus extensively on DS, covering its global and South African prevalence rates, associated consequences, and risk factors. Additionally, the review will examine the impact of DS on health care provision at both global and local levels. A key area of focus will be the functional balance abilities of children and adolescents with DS, highlighting how these abilities affect their developmental trajectory and capacity to navigate their environment. The prevalence and risks of falls within this population and the broader paediatric demographic will be highlighted.

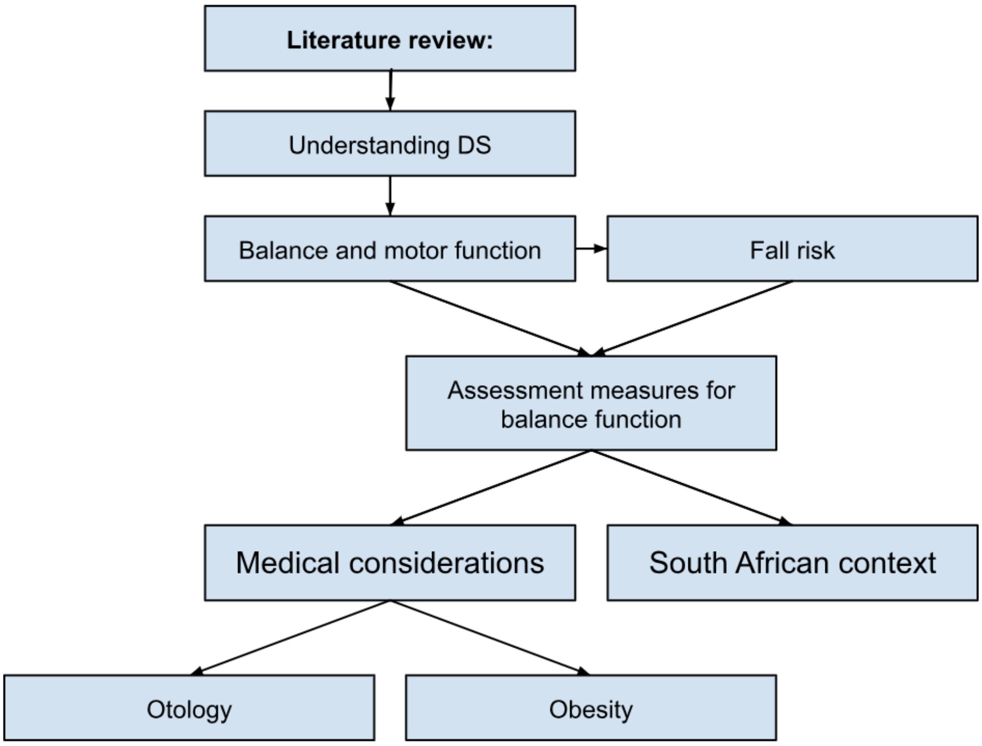
Returning to the role of audiologists, the review will explore the prevalence of middle ear disorders and hearing loss and their potential influence on balance abilities in children with DS, as well as the general paediatric population. Obesity, a prevalent condition among individuals with DS and a rising epidemic in low- and middle-income countries (LMIC), will also be discussed, particularly in terms of its potential effects on balance. These discussions underscore the importance of considering these factors when assessing balance abilities in these populations.

Moving to appropriate assessment tools for evaluating balance in children and adolescents the review will highlight potentially suitable tests for use in the research protocol. The Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2), Subtest 5: Balance; the Children's Balance Evaluation Systems Test, and its shortened versions (Kids-BESTest and Kids-Mini-BESTest); and the Pediatric Balance Scale (PBS), will be discussed. Finally, the review will examine the existing research on the research topic within the South African context, reinforcing the necessity of this study within our specific population.

This report will follow the structure as laid out in Figure 1:

Figure 1:

Structure of the literature review chapter



Chapter 1: Literature Review

Understanding Down Syndrome[2]: Prevalence, risk factors, consequences, and healthcare burden.

Down Syndrome (DS) is the most prevalent chromosomal disorder among live births, with an estimated global prevalence of 1 in every 700 live births (Asim, Kumar, Muthusamy, Jain & Argawal, 2015). In South Africa (SA), this incidence is slightly higher, at approximately 1 in 500 live births (Down Syndrome South Africa (DSSA), 2021). While advances in healthcare have improved outcomes for individuals with DS in higher-income nations like the United States of America (USA) and the United Kingdom (UK), significant disparities persist in resource availability and quality of life for those living in low- and middle-income countries (LMIC), including SA. For instance, individuals with DS in higher-income countries often have better access to robust healthcare systems that lead to lower mortality rates and reduced disability-adjusted life years (DALYs) (Chen et al., 2022). Conversely, South Africans with DS face systemic barriers to accessing essential healthcare services (Mahlaule, McCrindle & Napoles, 2024).

In SA, the legacy of apartheid and colonialism continues to exacerbate inequities in public sector resources, impacting both education and healthcare systems (Walton & Engelbracht, 2022). While social grants such as child support and disability benefits offer financial assistance, these measures are insufficient to address the broader social exclusion and marginalisation faced by individuals with DS (Mahlaule et al., 2024). Inclusive policies in special needs schools and public healthcare facilities often fail due to inadequate funding, limited infrastructure, and a lack of specialised training for both educators and healthcare providers (Walton & Engelbrecht, 2022). These resource limitations result in inconsistent implementation of inclusivity measures, leaving individuals with DS vulnerable to gaps in

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[2] This spelling is used to have better alignment and consistency with global trends in medical and scientific writing. However, “Down’s Syndrome” is more commonly used within the UK and Commonwealth countries.

medical care and education. Unlike high-income countries where comprehensive support networks often exist, South Africans with DS face barriers that hinder their development and overall integration into society. Improved funding, targeted training, and infrastructural upgrades in both sectors are essential to improve access to services and social inclusion, ultimately improving overall health outcomes for individuals with DS in SA (Walton & Engelbrecht, 2022; Mahlaule et al., 2024).

One of the critical challenges faced by individuals with DS is the high prevalence of comorbid conditions such as Attention-Deficit/Hyperactivity Disorder (ADHD), Autism Spectrum Disorder (ASD), and Intellectual Disability Disorder (IDD), which can significantly impact their development, daily functioning, and ability to interact with society (Antonarakis et al., 2021; Abd El-Hady, Abd El-Azim, Abd El-Aziem & El-Talawy, 2018). The pervasive impact of IDD extends beyond cognitive and developmental delays to specific, often overlooked issues such as balance deficits and increased fall risks. In industrialised countries, approximately one in three older adults experiences a fall each year, representing a significant drain on healthcare resources (James et al., 2020). Interestingly, adult individuals with IDD have a fall rate comparable to that of typically developing older adults, highlighting the need for similar efforts in fall risk identification and management for this population (Finlayson, Morrison, Jackson, Mantry & Cooper, 2010). (Falls and fall risk will be examined and discussed in greater detail later in this literature review). Addressing these challenges requires not only understanding their prevalence and impact but also prioritising research into effective balance related interventions that mitigate these risks. A preventative approach is essential for reducing both the medical and social burdens of DS while improving overall quality of life, particularly in resource-constrained settings like SA (Chen et al., 2022). Addressing the challenges related to balance and motor function in children with DS is critical, as deficits in these areas likely exacerbate the risk of falls and injuries, while also significantly impacting their quality of life and ability to participate in daily activities. The next section will discuss the balance abilities of children and adolescents with DS, as reported by existing studies.

Balance and motor function in children with DS: Challenges and rehabilitation

Human balance is described as an outcome of the postural control system that is clinically observable (Şimşek & Şimşek, 2020). Children with DS have decreased balance ability and abnormal gait patterns as well as delayed psychomotor development, especially with regards to standing and walking abilities (Jung et al., 2017). For example, a five year old child with DS has the motor abilities of a two year old typically developing child; however, motor abilities increase with maturation (Malak, Kostiukow, Krawczyk-Wasielewska, Mojs & Samborski, 2015; Aly & Abonour, 2016). Limits in motor abilities cause an increased strain in maintaining balance and postural stability in an ever-changing environment, especially in the DS population (Jung et al., 2017; Malak, Kotwicka, Krawczyk-Wasielewska, Mojs & Samborski, 2013).

This delay in motor function and balance skill is partially due to the reduced volume of brain structures in people with DS, including a decrease in cerebellar size (Carducci et al., 2013). The cerebellum plays a vital role in balance function, limb coordination and locomotion as well as the development of gross motor skills, thus explaining much of the decreased function and delay in these areas as well as interactive effects (Carducci et al., 2013; Malak et al., 2015). Individuals with DS often exhibit a range of musculoskeletal and medical comorbidities, including ligamentous laxity, joint hypermobility, and hypotonia (Rako, Ranade & Allen, 2021). Common orthopaedic issues include patellar instability, hip instability, spinal abnormalities, and foot deformities (such as pes planus[3]), which may have a direct effect on balance function and activities of daily living (ADLs) (Rako et al., 2021). Balance function ultimately influences the proficiency in which children with DS conduct fundamental movement skills, thus balance is an integral skill that they should possess

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[3] Refer to glossary

(Capio, Mak, Tse & Masters, 2018). Comprehensive and standardised assessment tools are thus essential to assess balance performance and understand the specific challenges faced by the DS population.

Development of better balance through rehabilitation strategies in children with DS has proven to be potentially effective. A systematic review by Stander et al. (2021) however revealed significant variability in results across studies on this topic, underscoring the importance of using clinimetrically robust outcome measures to evaluate balance performance of children and adolescents with DS reliably. Jung et al. (2017) observed significant differences in static balance abilities between typically developing children and children with DS when using the Romberg and Sharpened Romberg[4] tests, particularly under eyes-closed conditions. These tests evaluate proprioceptive loss by assessing postural control in darkness, requiring the integration of somatosensory, vestibular, and visual systems (Lanska & Goetz, 2000). However, real-life situations invariably challenge dynamic balance, so there is a need to move beyond tests that have repeatedly been reported as flawed. Further, the Romberg test also has low sensitivity to vestibular lesions, specifically compared to caloric irrigation, thus lacking sensitivity to optimally diagnose vestibular lesions (Moghadasi-Boroujeni & Adel-Ghahraman, 2021). Therefore, selecting clinically appropriate outcome measures is a crucial first step for effective rehabilitation strategies, as accurate tools enable meaningful assessment of balance deficits and recovery over time. Establishing the reliability, validity, and feasibility of these instruments cements the groundwork for future research. This foundation is integral to explore the outcome measures' responsiveness to change and establish minimal clinically important differences (MCID), essential for measuring the impact of rehabilitation interventions in this group. This study aimed to evaluate the clinimetric properties of various assessment scales to identify

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[4] Refer to glossary

balance deficits in children with DS, paving the way for improved interventions and better understanding of balance function in the DS population.

The importance of targeted interventions to address balance deficits has also been underscored, as children with DS often present poor postural control strategies, increasing their risk of falls (Aly & Abonour, 2016). Improving balance and motor function is essential for the safety and development of children with DS, emphasizing the need for effective rehabilitation strategies, possibly through play, to reduce fall risks and enhance daily functioning. The prevalence of fall risks in the broader paediatric population as well as DS population is integral to understand and will be discussed next.

The interplay between gait, balance and fall risk in children with DS

It is essential to explore the interplay between gait, balance, and fall risk, particularly within diverse socio-economic contexts. Childhood falls are common among typically developing children, particularly when they are active and playing. These falls often result in injuries to the limbs, including fractures, and in severe cases, even death (Shi et al., 2018; Wang et al., 2017). Interestingly, children from lower socio-economic backgrounds often experience more severe injuries compared to their higher-income peers, with males being more frequently affected by injuries (Wang et al., 2017). Socio-economic factors, such as family income and education levels, play a critical role in determining injury outcomes. Mahboob, Richmond, Harkins & Macpherson (2021) highlighted that children from lower-income families are at an increased risk of unintentional injuries, including falls, due to limited access to safety measures and healthcare. Additionally, Dorney et al. (2020) emphasise the importance of prioritising injury prevention, particularly in vulnerable populations, such as children with disabilities like DS. Although the World Bank (2022) classifies SA as an upper-middle-income country, its healthcare system, which serves the majority of the population, faces severe challenges, including limited funding, inadequate infrastructure, and systemic inequities. Such issues are compounded by repeated scandals and inefficiencies in service delivery (Walton & Engelbrecht, 2022; Mahlaule et al., 2024). Such barriers contribute to the increasing need for studies that identify and address fall risks, particularly among children with DS, who are affected by gaps in healthcare and education. While social support, such as government issued child support and disability benefits, can provide some assistance, it remains insufficient in alleviating the financial strain on families. These support grants are typically seen as a supplementary source of financial assistance, rather than a primary source of income. In such environments, the lack of fall prevention education for teachers, parents, and children remains a significant barrier and this challenge is particularly evident in countries with limited resources, where access to fall prevention knowledge is often scarce (Shi et al., 2018).

Falls in children are often linked to their developmental stages, curiosity about their environment, and a natural increase in risk-taking behaviours as they gain independence (World Health Organization (WHO), 2021). For children with DS, this risk is heightened due to their reduced gait and balance abilities, which are further exacerbated by cognitive limitations. These challenges limit their ability to adapt to sudden environmental changes and affect their participation in ADLs (Jung et al., 2017). Cognitive impairments, such as difficulties in attention and concentration, also influence motor coordination and balance, making children with DS more prone to falls (Malak et al., 2013). The combination of cognitive delay and impaired balance places children with DS at an increased risk of falling (Bull, Trotter, Santoro, Christensen & Grout, 2022; Jung et al., 2017). This elevated risk is compounded by the lack of early intervention and support services, especially for children from lower socio-economic backgrounds (Mahboob et al., 2021).

Although existing studies highlight the high fall risk in children with DS and the importance of early interventions (Matheis & Estabillo, 2018; Karakoc & Mujdeci, 2020), there remains a gap in understanding the specific functional deficits that contribute to these risks. Furthermore, limited research explores the effectiveness of balance assessments tailored to children with DS in identifying fall risks and informing targeted intervention strategies. This gap underscores the necessity of the present study, which aims to evaluate the feasibility and clinimetric properties of functional balance assessments as potential tools for predicting fall risk in children with DS. Balance assessments are crucial for developing targeted intervention strategies to improve balance function from a young age, ultimately aiding children with DS as they transition into adulthood (Matheis & Estabillo, 2018; Karakoc & Mujdeci, 2020). The methods of evaluating balance function, particularly children and adolescents with DS, will be discussed next.

Evaluating balance function in children and adolescents with DS: Assessment tools and considerations

South African audiologists often face significant barriers, such as limited access to equipment and inadequate training, which hinder their capacity to conduct comprehensive assessments. Historically, vestibular and balance assessments, and rehabilitation were excluded from undergraduate audiology curricula, and although this has been addressed in recent years, many professionals must seek additional training through accredited courses like the South African Vestibular Assessment and Rehabilitation Therapy (VART) course (Seedat, Khoza-Shangase & Sebothoma, 2018; Swanepoel, 2006). The slow adoption of vestibular practices reflects a critical gap in service provision, leaving patients underserved in this essential aspect of care (Seedat et al., 2018; Rogers, 2021). Audiologists have a professional and ethical duty to provide more holistic balance assessments, which encompass fall risk assessments, prevention and management as critical components (Rogers, 2021). Simplified, low-tech tests which require minimal equipment and are relatively easy to administer, are frequently employed in practice due to the fact that multiple of these tests show good reliability and validity along with good specificity and sensitivity (Cohen, 2019). Integrating these quick-and-easy tests into routine practice makes balance assessments more accessible for clinicians, particularly in LMICs such as SA, where resource constraints are prevalent. The accessible nature and relative ease of administration of the outcome measures motivate audiologists to include balance assessments and rehabilitation in their professional practices. Audiologists thus have a crucial role in promoting vestibular and balance health. There is however an increasing need for professional development initiatives to bridge existing gaps in knowledge and practice.

Assessments of balance function in children are typically conducted using standardized scales such as the Paediatric Balance Scale (PBS), Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2) Subtest 5: Balance, the Children's Balance Evaluation Systems Test (Kids-BESTest), the Timed Up & Go (TUG) test, and the Movement Assessment Battery for Children (Movement ABC) (Matheis & Estabillo, 2018; Karakoc & Mujdeci, 2020; Dewar, Claus, Tucker, Ware & Johnston, 2017). A systematic review by Johnson et al. (2023) highlighted the necessity for comprehensive assessment tools that evaluate postural control in various domains, including sensory integration, reactive postural responses, and dynamics. These tools should offer strong clinimetric properties such as reliability, validity, and responsiveness, crucial for discriminating between different levels of postural control deficits, especially in populations with developmental disabilities like DS (Johnson et al., 2023). While instrumented tests like posturography and others would give such comprehensive insights into balance, these are not feasible in LMIC due to the scarcity of resources (Naidoo, 2012). Thus, low-tech tests which are suited for school-based evaluations, for example, are preferable and the focus of this study. While the tests are familiar to paediatric vestibular clinicians, their utility in a DS population is largely unknown. The specific tests used in this research are discussed next.

The PBS, derived from the Berg Balance Scale (BBS), is commonly used to assess balance in children, particularly those with motor impairments such as DS. It consists of 14 tasks designed to evaluate various balance abilities. Initial studies focused on its reliability and validity for children aged 1 - 15 years (Franjoine, Gunther & Taylor, 2003; Leite, De

Jesus Neves, Vitor & Fujisawa, 2018). For children with DS, the PBS has shown particular utility, with studies indicating significantly lower scores among children aged 8 - 12 years compared to typically developing peers, suggesting a lack of vestibular maturation (Leite et al., 2018). These findings underscore the PBS's sensitivity to identifying balance deficits in populations with motor impairments, although further validation of its clinimetric properties in older children or those with significant balance challenges remains necessary (Johnson et al., 2023). Preliminary evidence also suggests the PBS's potential for monitoring functional changes over time, making it a valuable tool for both clinical assessments and tracking progress in therapeutic programmes (Franjoine et al., 2003). However, the scale's limitations (such as its exclusion of tasks involving balance during locomotion) highlight areas for future refinement, or indeed, the need to use a test battery approach. Expanding the PBS to include these domains could enhance this outcome measure's utility for more comprehensive balance evaluations. Evidence supports the inclusion of the PBS in studies focusing on balance assessment across a broader age range, particularly in children with motor impairments like DS, to identify deficits, guide interventions, and monitor developmental progress.

The BOT-2, specifically Subtest 5: Balance, is a tool widely used in assessing motor coordination in children, including both static and dynamic balance tasks such as single-leg standing, walking, and maintaining posture during dynamic movements (Bruininks & Bruininks, 2005). Its application in children with DS has been less extensively studied. Nocera, Wood, Wozencroft & Coe (2021) reported varied reliability for the balance subtests of the BOT-2 short form (BOT-2 SF) within their pilot study involving ten participants with DS aged 13.1 to 20.7 years, this study is however limited to their small sample size. This disparity likely reflects the well-documented balance deficits inherent to DS, characterized by delayed motor development, hypotonia, and joint hypermobility, rather than issues with the BOT-2's sensitivity. These physiological and motor challenges make tasks requiring balance and coordination particularly difficult for the DS population (Malak et al., 2013; Jung et al., 2017). While the lower scores on the BOT-2 in children with DS highlight their significant balance impairments, they also highlight this outcome measure’s ability to differentiate between varying levels of balance dysfunction within this group. This issue warrants further investigation to determine whether the BOT-2 can effectively capture subtle improvements in balance and motor coordination following targeted interventions. Thus, its utility in assessing balance deficits and tracking progress in children with DS remains a critical area of study.

The Kids-BESTest assesses balance using tasks that challenge dynamic postural control and sensory integration, including the Modified Clinical Test of Sensory Integration in Balance (mCTSIB), single-leg stance (SLS), pivot turn, and TUG test. All the former tests are well recognised tests and frequently used in both clinical and research domains, and are discussed in more detail later. Dewar et al. (2017) demonstrated its strong validity and responsiveness in children aged 6–12 years with motor impairments, indicating its potential to detect meaningful changes in balance performance. However, its feasibility for children with severe disabilities remains an area needing further study, particularly in populations with limited mobility or cognitive challenges (Dewar, Tucker, Claus, Ware & Johnston, 2021). Rutka & Pałac (2020) reported high intra- and inter-rater reliability for the Kids-BESTest in children with DS, particularly in domains like stability limits and reactive postural control. Yet, they identified practical challenges when using the test with younger children or those with severe intellectual disabilities. These difficulties often arose due to short attention spans and limited cooperation, which could compromise scoring accuracy. To address this, they highlighted the value of video recordings of the children performing the tests to enhance precision and mitigate variability in test administration (Rutka & Pałac 2020). The Kids Mini-BESTest, a shorter version of the Kids-BESTest, demonstrated excellent reliability, especially in dynamic gait tasks. However, it was less effective than the full Kids-BESTest in identifying nuanced issues with postural control (Rutka & Pałac 2020). These findings suggest that while both tools are clinically useful for evaluating postural control and even monitoring therapy effects in children with DS, their effectiveness may depend on the child's cognitive and behavioural capabilities. For children with mild intellectual disabilities or sufficient cooperation, the Kids-BESTest offers a comprehensive assessment of balance impairments and treatment outcomes (Rutka & Pałac, 2020; Dewar et al., 2017). This study compared the PBS, BOT-2, Subtest 5, Kids-BESTest and Kids Mini-BESTest in order to assess their clinimetric value in evaluating balance function in children and adolescents with DS, with the aim of identifying the most effective tool for this population.

The mCTSIB is another well-studied tool for assessing postural control, focusing on the interaction of sensory inputs (viz., visual, vestibular, and somatosensory) for maintaining balance. It has been shown to have excellent validity and reliability, particularly for children with vestibular issues (Shumway-Cook & Horak, 1986; Christy et al., 2014). However, its use in children with DS has been less explored, and it is unclear whether it can reliably detect deficits in balance that are not related to sensory integration but to other factors such as strength or coordination (Orendorz-Frączkowska & Kubacka, 2019). All conditions of the mCTSIB is embedded in the Kids-BESTest, while standing on a firm surface with eyes open and eyes closed respectively is embedded in the PBS and BOT-2, Subtest 5. Further, the Kids Mini-BESTest only includes the eyes open on a firm surface and eyes closed on a compliant surface conditions.

The SLS is another commonly used static test, evaluating the ability to maintain balance on one leg for 10-30s (Dewar et al., 2017). For the purpose of this study, the flamingo stance was adopted, although both the flamingo and stork stance positions have been proven to be highly valid when assessing static balance (Panta, Arulsingh, Raj, Sinha, & Rahman, 2015). Studies have demonstrated its good test-retest reliability and validity in assessing postural control, although certain authors suggest it may be too challenging for children with DS due to their decreased balance capacity, depending on the duration that the stance must be held (Leite et al., 2018; Bruininks & Bruininks, 2005). The SLS is embedded in the PBS, BOT-2 (Subtest 5), Kids-BESTest and Kids Mini-BESTest as part of the protocol, but can be used as a stand-alone test in its own right, as is true for the mCTSIB previously described and TUG test, which will be discussed next.

The TUG test, which assesses functional mobility, is widely used in paediatric populations. It is considered an effective and efficient test for assessing dynamic balance and mobility and has demonstrated good reliability and validity across different age groups (McGrath et al., 2011). In children with DS, the TUG test has been shown to be a good predictor of mobility challenges, taking significantly longer to complete the task compared to typically developing children (Itzkowitz et al., 2016). This test is embedded in the Kids-BESTest with and without a cognitive dual task. The Kids Mini-BESTest only includes the test with a dual task. The TUG test assesses motor functions such as strength, balance, and coordination, making it a valuable tool for evaluating fall risk. While extensively validated in older adults, where scores of ≥12s have been associated with moderate specificity but poor sensitivity for predicting falls (Centers for Disease Control and Prevention (CDC), 2017), its application in children is gaining traction. Itzkowitz et al. (2016) demonstrated that TUG times vary by age, showing a trend of decreasing times between ages 5 and 9 years and increasing times thereafter, which correlates weakly but significantly with age. Average TUG times ranged from 5.85 s for 9 year old males to 7.24 s for 13 year old males, with no clinically meaningful differences observed between sexes. Although body mass index (BMI) was positively correlated with TUG times in some age groups, the relationship was weak and inconsistent, further supporting the multifactorial nature of fall risk (Itzkowitz et al., 2016). For children with developmental conditions such as DS, where balance and motor impairments are prevalent, the TUG offers a simple, reliable method for identifying mobility deficits. However, the inclusion of other standardised balance assessments alongside the

TUG could improve predictive accuracy, particularly in contexts where intrinsic as well as extrinsic factors, such as obesity and delayed motor development, may compound fall risk.

The use of these tools in children with DS requires a thorough understanding of their clinimetric properties. While most of these tools have demonstrated acceptable validity and reliability for typically developing children, their applicability to children with DS has not been fully established, especially when considering the impact of various medical conditions on balance performance. Specifically, in children and adolescents with DS, health factors including weight and hearing loss (HL) can exacerbate balance difficulties, further complicating the use of standard assessment tools in this population. HL and obesity specific to DS children are discussed next.

Possible impact of HL on balance

Conductive, sensorineural and mixed HL affects about three-quarters of children with DS, with the majority of these cases involving fluid buildup in the middle ear (middle ear effusion (MEE)) (Agarwal Gupta & Kabra, 2014). Contributing factors include congenital structural abnormalities in both the external and middle ear, as well as dysplastic inner ear structures. These abnormalities often involve the mid-face and Eustachian tubes. In the inner ear, common issues include dilations in the internal auditory canals and vestibules, enlarged vestibular aqueducts and cystic malformations of the horizontal semicircular canals (Clark, Patel, Kanekar & Isildak, 2016). Such abnormalities affect up to half of the DS population and have significant implications for auditory and vestibular function (Clark et al., 2016). Conductive hearing loss is particularly prevalent in early childhood due to persistent otitis media with effusion and Eustachian tube dysfunction, while sensorineural hearing loss tends to emerge later and may reflect progressive inner ear or vestibular pathology, highlighting the importance of considering potential vestibular involvement in this population (Yahia et al., 2025).

HL and MEE are some of the most important factors for audiologists to consider, due to the fact that they not only affect hearing and communication abilities, but could also have an effect on balance and vestibular function (Goiacchini, Alicandri-Ciufelli & Kaleci, 2014). De Souza Melo et al. (2017) found that otherwise typically developing children with sensorineural hearing loss (SNHL) between the ages of 7 and 18 years present with more alterations in both static and dynamic balance compared to that of age- and sex matched participants with normal hearing (De Souza Melo., 2017). However, a review by Carpenter & Campos (2020) argued that although numerous theories have been developed to make the potential causal links between HL, balance and fall risk clear, there are still significant gaps and limitations in the literature (Carpenter & Campos, 2020). Studies have shown that conductive HL, even when not linked to middle ear pathology, including cerumen impaction, otitis externa, exostosis, stenosis or atresia, can negatively impact balance (Horowitz, Ungar, Levit, Himmelfarb & Handzel, 2019). Additionally, previous research has highlighted a significant association between MEE, particularly with MEE, and balance dysfunction in typically developing populations (Golz et al., 1998). Further research is needed to establish the correlation between abnormal balance and middle ear pathologies in the DS population. Specifically, pathologies affecting middle ear pressure, as highlighted by El Shennawy (2015), require more detailed exploration. This research may be complicated by the prevalence of narrowed ear canals in up to half of the DS population, which frequently leads to cerumen impaction (Clark et al., 2016). The need for innovative approaches to assess and address middle ear conditions in this group is underscored by these structural abnormalities. Due to the DS population’s increased risk to otologic pathologies, it is necessary to assess middle- and inner ear function in conjunction with any assessments of balance function (Kaga, 2014; Goiacchini et al., 2014). This study employed objective measures to explore ear function.

Such an assessment may incorporate an array of measures, including otoscopy, tympanometry and otoacoustic emissions (OAE); all of which are suitable for DS individuals as they require only passive cooperation (Diefendorf, 2015; Chen et al., 2014). Using the findings obtained from each test stresses the importance of a variety of tests to assess the potential of issues involving the outer-, middle- and/or inner ear structures (Chen et al., 2014). Considering that the likelihood of hearing and ear related disorders are higher in children with DS, it highlights the necessity of regular and quality hearing services in conjunction with balance and vestibular services (Chen et al., 2014). In addition to the challenges posed by HL and middle ear pathologies, obesity emerges as another significant risk factor that can further compromise balance and gait in children and adolescents with DS, and is discussed next.

The influence of obesity on balance in children and adolescents with DS

Studies have shown that individuals with DS are more likely to be overweight or obese compared to the general population, which exacerbates challenges related to motor function, including balance and gait. For instance, Martínez-Espinosa, Vila & García-Galbis (2020) highlighted the increased risk of obesity among individuals with DS due to factors such as reduced physical activity and altered metabolic rates, which in turn significantly impact balance and gait patterns.

Galli, Cimolin, Rigoldi, Condoluci & Albertini (2015) found that children with DS who were classified as obese exhibited slower walking speeds, shorter stride lengths, and less efficient movement than their non-obese counterparts, with obese females demonstrating more pronounced gait alterations. These changes in gait are linked to poorer balance outcomes, as demonstrated by Malak et al. (2013), who showed that poor gait is associated with compromised balance and fall risk in the DS population. However, the evidence on this relationship is not entirely consistent. Leite et al. (2018) found no significant differences in balance function between obese and non-obese children with DS, possibly due to methodological limitations such as a small sample size and lack of a control group of typically developing children. Similarly, Itzkowitz et al. (2016) found no significant differences in TUG scores across various BMI categories in typically developing children, though they observed a positive correlation between BMI and TUG performance in some age groups, suggesting that BMI could potentially influence TUG scores in certain age groups. This suggests that the relationship between BMI and balance may be more complex and age-dependent, highlighting the need for further investigation.

An important consideration when examining obesity's impact on balance is the broader socio-economic context. Dogbe (2020) found that in Ghana, a developing country, poverty was negatively correlated with obesity. Specifically, individuals in poorer households were less likely to be obese, which contrasts with the situation in wealthier countries where higher socio-economic status (SES) is typically associated with higher rates of obesity, but recent literature revealed that obesity is on the rise in LMICs (Okunogbe, Nugent, Spencer, Ralston & Wilding, 2021). This suggests that the relationship between poverty and obesity may differ between developed and developing nations. In Ghana, for instance, urban dwellers, particularly those in higher SES groups, have higher obesity rates (Dogbe, 2020). This socio-economic variation highlights the complexity of obesity as a public health issue, indicating that its relationship with balance in children with DS may also be influenced by socio-economic factors specific to the region under study.

Thus, while there is growing evidence that obesity adversely affects balance and gait in children with DS, the influence of socio-economic factors must be considered. In LMICs like SA, it is essential to examine how local socio-economic conditions might influence the prevalence of obesity and its subsequent impact on balance. Further research to clarify these relationships and provide more robust evidence is needed, particularly within the South African context.

A critical look at South African studies on balance function in children and adolescents with DS

Studies by Terblanche & Boer (2013) and Boer & Moss (2016) focused on the functional fitness abilities of South African adults with DS and both static and dynamic balance was assessed and reported on using test items in the Brockport Physical Fitness Test (BPFT) and Senior Fitness Test (SFT). van Jaarsveld et al. (2016) was the only study found that specifically described the topic of balance function of South African children diagnosed with DS. This study was limited by a small sample size and the absence of a direct measurement of balance function (van Jaarsveld et al., 2016). Instead, it relied on a parent- or caregiver- completed scale (Sensory Processing Measure (SPM)), which introduces a level of subjectivity by proxy, rather than using a direct measure of balance function (van Jaarsveld et al., 2016). Reyneke & Hoosain (2020) assessed whether task performance and classroom behaviour of children with DS would improve when a stability ball is used as a classroom chair. Adequate natural postural feedback is required when sitting on a stability ball to be able to detect balance requirements and appropriately respond to changing balance demands (Umeda & Deitz, 2011). Reyneke & Hoosain's (2020) work was limited by excluding children with balance or equilibrium related issues due to their higher risk of falling. It is thus reasonable to assume, given the scant and flawed research already done, that further detailed knowledge is required to explore balance deficits and possible remediation strategies, specifically in a South African context.

Rationale

This pilot study aims to evaluate the clinimetric[5] properties - specifically, reliability and validity - of four commonly used balance assessment tools: the PBS (Appendix A), BOT-2, subtest 5 (Appendix B), full Kids-BESTest (Appendix C), and Kids Mini-BESTest (Appendix D). Selecting appropriate assessment tools for balance evaluation in children with

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[5] Refer to Glossary

DS is essential for accurate baseline measurements and monitoring rehabilitation outcomes. Key clinimetric properties, such as inter-rater reliability, test-retest reliability, and internal consistency, are crucial to determine whether these tools yield consistent, reliable results when applied to children with DS in a South African context (El Shennawy, 2015; Bull et al., 2022). The study will focus on children and adolescents diagnosed with DS, aged six to eighteen years, attending special education schools in the Eastern Cape (EC) province of SA. By investigating these clinimetric properties, the research will provide insights into the applicability of these tools in this particular population. Although these tools have shown promise in other populations, their suitability in children with DS remains underexplored (Goiacchini et al., 2014; Horowitz et al., 2019).

The study will also investigate how factors such as middle- and inner ear function, along with BMI, influence functional balance outcomes in children with DS. Previous research has demonstrated that sensory impairments and obesity can significantly impact balance performance (Kaga, 2014; Umeda & Deitz, 2011). By comparing balance function in children with DS to typically developing children, this study will offer new insights into how these variables may affect balance performance and influence the clinimetric properties of balance assessments. The findings from this study aims to contribute to the body of knowledge on balance function in children with DS, especially in the context of SA, where such research is limited.

Chapter 2: Methodology

The methodology chapter details the study's aim, objectives, and overall design. It describes the study setting, population, and sampling methods, including participant recruitment and selection criteria. Procedures for obtaining permissions and consent, implementing the study, and managing data are outlined, along with descriptions of the materials and tools used. This chapter also elaborates on the methods of data analysis, reliability, and validity, including inter-rater and test-retest reliability, known-groups validity, and measures of score distribution. Ethical considerations are also addressed.

Aim and Objectives

Aim:

The aim of this pilot study was to evaluate the clinimetric properties of the Bruininks-Oseretsky Test of Motor Proficiency, Second edition (BOT-2) (Subtest 5), Paediatric Balance Scale (PBS), full Children's-Balance Evaluations Systems Test (Kids-BESTest), and shortened version of the Kids-BESTest (Kids Mini-BESTest) when applied to children diagnosed with Down syndrome (DS), aged six to eighteen years, attending the Merryvale School for Special Education in the Eastern Cape (EC) province of South Africa (SA). To provide context for the results of the DS group, a control group of typically developing children was included for comparison. Additionally, the study examined whether the outcome measures were sensitive to potential confounders such as middle ear function, cochlear outer hair cell function, and body mass index (BMI), which may influence balance performance in the DS population.

Objectives:

Primary Objectives

- Evaluate the clinimetric properties in terms of reliability and validity of the BOT-2, PBS, Kids-BESTest, and Kids-Mini-BESTest by assessing:

    - Inter-rater and test-retest reliability.
    - Known-groups validity by comparing DS participants to typically developing children.
    - Criterion validity by analysing correlations with the Timed Up & Go (TUG) test scores (as stipulated by the Kids-BESTest) and timing.
    - Possible floor and/or ceiling effects and score distributions for each test and sub-test.
    - To evaluate the internal consistency using Cronbach's alpha, a statistical measure that assesses the extent to which items within each outcome measure are correlated and reliably measure the same underlying construct.
- Assess the accessibility of the BOT-2, PBS, Kids-BESTest, and Kids-Mini-BESTest by evaluating cost-effectiveness and the availability of necessary supplies and equipment.
- Explore the acceptability and safety of these measures in the DS population by tracking refusals, non-compliance, and adverse events, including stumbling or falling during assessments.
- Assess the time required to administer each test to evaluate practicality.
- Identify potential risk factors, such as additional disabilities or sensory impairments, that may influence balance or the outcomes of the outcome measures.

Secondary Objectives

- Describe the balance profile of children with DS and compare it to an age- and sex-matched typically developing cohort.
- Investigate the possible impact of middle ear function and cochlear outer hair cell function on balance performance and their potential influence on the reliability and validity of the outcome measures in the DS group.

- Examine the possible influence of obesity on balance performance and its potential impact on the reliability and validity of the outcome measures.

Study Design

This pilot study makes use of a clinimetric study design (Fava, 2021). Pilot studies are preliminary investigations intended to assess the potential of study design, methodologies, protocols, participant selection criteria and implementation tactics that are being contemplated for utilisation in a subsequent, more extensive, research study (Moore, Carter, Nietert & Stewart, 2011). Pilot studies can aid in refining the research questions and hypotheses, while informing the selection outcome measures and statistical analysis, ultimately enhancing the quality and precision of the research, ultimately leading to more robust and reliable findings in potential future studies (Moore et al., 2011; Brink, Van Der Walt & Van Rensburg, 2018).

Pilot studies' drawbacks include that generalisability of the results might be limited, due to the typically small sample size that is used, thus potentially causing the results to not be representative of the larger population in similar settings or contexts (Brink et al., 2018). Further, the potential for bias in selection of the participants or in the interpretation of the results is heightened in pilot studies, again due to the small sample size, the impact of sample size on power and statistical analysis and potential researcher bias that may occur (Brink et al., 2018). While pilot studies offer numerous benefits, such as assessing the validity and reliability, honing the focus of a larger scale study and evaluating feasibility, they do not assure the success of a larger scale study and researchers should be mindful of the potential drawbacks by considering them when planning and interpreting the results of a pilot study (Brink et al., 2018).

The term "clinimetrics" refers to a field focussed on rating scales, indices and other tools used for describing or measuring symptoms, physical signs and additional clinical occurrences (Feinstein, 1982). Traditional psychometric methods focus on the homogeneity of rating scale components, potentially hindering the ability to detect changes in clinical status (Fava, Ruini & Rafanelli, 2004; Wright & Feinstein, 1992). Unlike traditional methods, the clinimetric approach does not mandate homogeneity or unidimensionality, aligning better with the diverse nature of clinical variables (Fava, 2021). Moreover, in traditional psychometrics, each item on a rating scale carries equal weight and assesses similar forms of the same symptom (Fava et al., 2004; Wright & Feinstein, 1992). However, in clinical practice, as demonstrated in the clinimetric approach, not all symptoms hold the same significance, allowing for the differentiation between major and minor symptoms (Fava, 2021). The clinimetric and psychometric approaches are however not in conflict with each other, but rather serve distinct purposes: the clinimetric approach focuses on using a single index to create instruments that assess numerous constructs, whereas the psychometric approach is better suited for developing instruments that evaluate a single construct using various items (De Vet, Terwee & Bouter, 2003). This differentiation is based on the inclusion of two types of variables in measurement tools, namely indicator variables and causal variables (Fayers & Hand, 2002). Indicator variables has a correlation with the construct being measured but has no influence on it, while causal variables impacts the construct through a causal relationship, such as being a symptom of a disease or treatment side effects (Fayers & Hand, 2002). Typically psychometric instruments include only indicator variables, whereas clinimetric instruments may also incorporate causal variables (Fayers and Hand, 2002).

Since this study aims to determine suitable and robust outcome measures to use in children and adolescents with DS by evaluating clinical tools (Kids-BESTest, Kids-Mini-BESTest, PBS and BOT-2) commonly used in healthcare settings, the focus is on evaluating the measurement properties of these tools in a pragmatic, real world context, that is, the participants’ schools. Additionally, considering factors such as middle ear function, outer hair cell function of the cochlea and BMI further emphasises the clinical aspect of the study.

Therefore, a clinimetric approach would be most suitable for assessing the reliability and validity of these clinical tools in the target population. This approach enables the consideration of various variables and their potential causal relationships.

Study Setting

Schools were focussed on as a familiar setting where all the participants congregate regularly, making data collection easier and more efficient. The government funded Merryvale School for Special Education in Gqeberha, EC, SA was contacted to recruit participants diagnosed with DS for the study. At the Merryvale School for Special Education the students receive physiotherapy and occupational therapy intervention, by means of weekly gross motor activity programmes and hydro-therapy done in group settings, amongst other activities. Pupils are largely excluded from any extracurricular sports, due to physical and cognitive limitations.

The participants in the control group were recruited from the Westering Primary School and Westering High School, which are mainstream public schools situated in the same geographical area as the Merryvale School for Special Education. The control schools chosen follow the Curriculum and Policy Statement (CAPS) as stipulated by the Department of Basic Education, which includes “life skills” or “life orientation” for children in all phases of education (Department of Basic Education, 2011). The CAPS curriculum stipulates that children in the foundation phase receive at least 2 hours of physical education per week and children in the intermediate phase receive 1.5 hours (Department of Basic Education, 2011). Students in the senior phase and further education and training (FET) phase are only required to complete 1 hour of physical education a week (Department of Basic Education, 2011). An array of extracurricular sport activities, including hockey, rugby, netball and tennis is also available for all students.

Study Population and Sampling

Study Population

The populations of interest were children aged 6-18 years who are diagnosed with Down Syndrome and typically developing children in the same age bracket. Vestibular maturation is established and adult-like at 15-17 years in typically developing children (Sinno et al., 2020). Visual function follows a similarly protracted developmental trajectory, with early maturation of visual acuity, contrast sensitivity, motion perception, and binocular integration occurring within the first year of life, while higher-order visual abilities such as contour integration, biological motion perception, and face recognition continue to mature into adolescence (Siu & Murphy, 2018). Somatosensory contributions to postural control begin to stabilise around seven years of age, with functional integration of somatosensory cues typically reaching maturity by approximately nine years, when children demonstrate the ability to effectively integrate sensory input from multiple sources to maintain balance (De Sá et al., 2017). Due to the established developmental delays in children diagnosed with DS, especially with regards to motor function, it is important to include participants over a wide age range, to determine the extent of balance dysfunction between age bands and developmental stages.

Sampling Method

Total population sampling method was employed for the DS group. Purposive sampling was used to identify participants who meet the eligibility criteria. Thus, the complete population of children aged 6 to 18 years diagnosed with DS and from whom informed consent was received from their parent or legal guardian was included in this study (Brink et al., 2018). The control group was chosen by dividing the typically developing children, who meet the criteria and have received consent from their parent/legal guardian, into smaller groups (strata) based on age and sex and then randomly selecting participants to form an exact age and sex matched control group when compared to the DS group. This was done using simple random sampling, where each participant in a stratum received their own number, which was randomly selected from a vessel containing the numbers (bowl).

Sample Size

The Merryvale School for Special Education had 34 students with DS between the ages of 6 and 18 years of age that were enrolled at the time of the study, thus the sample size of necessity was 34 or less. The final number of participants was 24 of whom 14 were female and 10 were male. The sample size of the control group was matched to the number of DS children that took part in the study in terms of age and sex.

Recruitment

Participant Selection Criteria

Keeping in line with the pilot study design and focus on clinimetrics, this study employed deliberately relaxed inclusion and exclusion criteria to ensure a diverse and representative range of participants.

Inclusion criteria:

- Children aged six to eighteen years; providing their parents/legal guardians have given their informed consent and the potential participant gives assent.
- Children who have been formally diagnosed with DS/typically developing. DS participants were identified by the school.

Exclusion criteria:

- Any participants who were unable to give verbal or written assent, or participants who withdrew their assent were not included in this study. This includes children with profound untreated communication disorders.
- Individuals with blindness, amputated, injured or absent limbs, inability to walk and/or acute illness as observed by the researcher on the day of data collection were not considered due to their inability to safely complete the tasks at hand.

Procedures

Permissions and Consent

- **Ethical approval**: Permission was obtained from the University of Cape Town (UCT) Faculty of Health Sciences Human Research Ethics Committee (HREC) (HREC REF 934/2023) (Appendix E).
- **Department of Basic Education**: Approval was obtained from the EC Department of Basic Education (Appendix F &Appendix ***G***).
- **Insurance**: UCT No-fault insurance was obtained with the HREC application (Appendix H), but was not required as there were no adverse events.
- **School permission**: Letters were written to the principals of Merryvale School for Special Education, Westering Primary School, and Westering High School to gain permission for data collection on their premises (Appendix I, Appendix J & Appendix K).
- **Police clearance**: Police clearance for the primary researcher was obtained, as requested by the schools before commencing data collection.
- **Parental consent**: A letter explaining the study's purpose and procedures was provided to the parents/legal guardians of all potential participants to inform them and obtain consent Appendix L for DS children, Appendix M for typically developing children). Only children whose parents provided consent were included in the study. Proxy consent was not sought due to legal constraints.
- **Information sheet**: An information sheet outlining the study activities was provided alongside all consent letters (Appendix N).

Study Logistics

- **Participant assessment**: Participants were assessed individually during break times, free periods, or before/after school to avoid compromising their learning.

- **Private area**: Assessments took place in a private area on school premises with at least a 3-meter open space. At the Merryvale School for Special Education the physiotherapy room was used, at the Westering Primary School the aftercare centre was used and at the Westering high School the sports centre was used.
- **Assent**: Each activity was demonstrated to the participants to obtain assent. Video demonstrations were available and used if needed.
- **Assessment schedule**: The assessments were conducted over two consecutive days for each participant. On the first day, a hearing screening (otoscopy, tympanometry, distortion product otoacoustic emissions (DPOAE) screening) was followed by functional balance assessments using PBS and BOT-2. On the second day, participants were weighed and measured for height, followed by the full Kids-BESTest assessment. The Kids Mini-BESTest was not directly administered to avoid fatigue with repeated measures. The items from the Kids Mini-BESTest are embedded in the full version of the test and were extracted post-data collection for statistical analysis. This schedule was also used for retesting selected DS participants for test-retest reliability. These participants were selected using random sampling and were re-tested one week later.
- **Breaks and engagement**: Multiple breaks with water and fruit were provided to minimize fatigue and ensure willing participation. Stickers were given to each participant after tests, and older children in the control group received a chocolate bar.
- **Data collection environment:** All testing was conducted in familiar environments, such as school physiotherapy rooms, to reduce participant anxiety and enhance engagement. Observations and scoring were conducted in a standardised manner, with children rewarded for participation to maintain motivation and minimise attrition.

- **Fall risk management**: To reduce fall risk, a gait belt was used with close guarding, and a first aid kit was available. All falls were to be reported within 24 hours to the study supervisor, with the HREC notified. No falls occurred during the data collection.
- **Chaperones**: For the DS group, the school's speech therapist or physiotherapist was present to act as a chaperone during assessments. For the control group, a teacher or assistant teacher was present.
- **Test-retest reliability**: A subset (33.33%) of randomly selected DS participants repeated the balance assessments one week later to measure test-retest reliability.
- **Referral letters**: Children with abnormal middle ear function received results with a referral letter to their clinic, general practitioner (GP), or ear-, nose- and throat (ENT) specialist (Appendix O), along with fact sheets on treating and preventing middle ear infections (Appendix P), if appropriate. Children meeting the criteria for underweight, overweight, obesity, or extreme obesity received results and information letters to their parents (Appendix Q), along with a fact sheet on healthy eating (Appendix R).

Instruments

Paediatric Balance Scale (PBS)

The PBS is a criterion-referenced functional balance assessment tool adapted from the Berg Balance Scale (BBS). Designed specifically for school-age children with mild to moderate motor impairments, the PBS evaluates static and dynamic balance through 14 everyday tasks, such as sitting, standing, and reaching. Scored on a 0 - 4 ordinal scale, it reflects variability in motor development, with higher scores indicating better balance performance. The PBS requires no specialised equipment and can be administered within 15 minutes, making it accessible for clinical and educational settings (Franjoine et al., 2003).

Reliability

- **Inter-rater reliability**: The PBS demonstrates exceptional inter-rater reliability, with ICCs ranging from 0.98 to 0.99, underscoring the consistency of scoring across different raters (Franjoine et al., 2003). This high reliability ensures that the results remain reproducible and unbiased, regardless of who is administering the test. Recent studies further corroborate these findings. For instance, Erden, Arslan, Dündar, Topbaş & Cavlak (2020) reported interobserver reliability of the Turkish version of the PBS with ICC values as high as 0.915 when evaluated by eight observers, highlighting the scale's robustness across diverse evaluators. Additionally, a perfect agreement between experienced and less experienced observers (ICC = 0.970) reinforces the reliability of the scale, even in settings with varying levels of evaluator expertise.

- **Test-retest reliability**: ICCs of 0.96 to 0.99 validate the stability of PBS scores over time, providing confidence in its reliability for repeated assessments (Franjoine et al., 2003). This consistency is crucial for monitoring progress or evaluating the effectiveness of therapeutic interventions, as it eliminates concerns about variability due to the measurement tool itself. Supporting this, Erden et al. (2020) demonstrated high intra-observer reliability of the Turkish version of the PBS with an ICC of 0.927 for the PBS.
- **Individual item reliability**: Spearman's correlations of 0.89 to 1.0 and kappa coefficients of 0.87 to 1.0 highlight the robust reliability of individual test items (Franjoine et al., 2003). This reliability ensures that each component task, such as standing on one foot or retrieving an object, consistently reflects a child's balance capabilities, providing detailed insights into their functional abilities. Erden et al. (2020) added to this evidence by examining individual item reliability and finding perfect reliability for some items (e.g., item 5) while noting moderate or poor reliability for others, emphasising the need to consider item-level variability in clinical and research contexts.

Validity

- **Construct validity**: The PBS effectively differentiates children with motor impairments from their typically developing peers, with statistically significant differences in total scores (Franjoine, Darr, Held, Knott & Young, 2010). The PBS' ability to distinguish between children with and without motor impairments highlights its relevance in assessing balance in these populations.
- **Criterion-related validity**: The PBS shows strong correlations with established balance measures, including the BOT-2 and the Functional Reach Test (FRT), supporting its utility in diverse clinical contexts (Franjoine et al., 2003). These correlations highlight the PBS' effectiveness in assessing balance. Erden et al. (2020) confirmed this through a concurrent validity analysis of the Turkish version of the PBS, reporting a strong correlation ($r = 0.692$, $p < 0.001$) between the PBS and the FRT, which provides further evidence for its applicability in different populations and cultural contexts.
- **Known-groups validity**: The PBS has demonstrated the ability to distinguish between typically developing children and those with moderate motor impairments (Franjoine et al., 2010). This known-groups validity confirms its sensitivity to motor ability differences, making it a reliable tool for distinguishing between children with and without motor impairments.
- **Content and face validity**: Tasks included in the PBS, such as sitting to standing, reaching forward, and retrieving objects from the floor, are reflective of everyday activities (Franjoine et al., 2003). This alignment with functional tasks ensures the test's relevance for real-world balance assessment, reinforcing its practicality in evaluating children's ability to perform age-appropriate motor tasks. Furthermore, Erden et al. (2020) noted that the PBS's applicability extends to children with mild to

moderate motor impairments, offering a reliable and valid option for balance assessment in diverse paediatric populations.

Strengths

- **Ease of administration**: With no requirement for specialised equipment and a concise 15-minute administration time, the PBS is a practical assessment for clinicians and researchers alike (Franjoine et al., 2003).
- **Sensitivity to change**: The PBS has shown preliminary promise in detecting functional balance improvements with maturity, making it a useful tool for monitoring therapy outcomes (Franjoine et al., 2003). Moderate to good responsiveness (Standard response mean (SRM) = 0.748-0.754) was reported for children with cerebral palsy (CP), reflecting the PBS' moderate to high ability to detect changes in balance function in this population (Chen et al., 2013).
- **Developmental progression**: Scores increase non-linearly with age, reflecting developmental milestones in balance acquisition (Franjoine et al., 2010). Additionally, the inclusion of cognitive and motor impairment considerations, as reported by Erden et al. (2020), highlights the PBS' relevance to specific clinical populations.

Limitations

- **Focus on static tasks**: The PBS emphasises static and anticipatory balance tasks, with fewer items assessing dynamic postural control, such as balance during locomotion or complex movements (Franjoine et al., 2003).
- **Age sensitivity**: Variability in performance is highest in younger children (e.g., those aged 2–3 years), partly due to developmental challenges and difficulties following instructions (Franjoine et al., 2010).
- **Scoring increments**: The use of a 0-4 scale may not capture subtle changes in balance performance, limiting its granularity for assessing small improvements (Franjoine et al., 2003). Erden et al. (2020) identified variability in item-level reliability,

which could contribute to differential outcomes depending on task-specific challenges, particularly in children with cerebral palsy or related impairments.

Children’s-Balance Evaluations Systems Test (Kids-BESTest) & it’s shortened version (Kids Mini-BESTest)

The Kids-BESTest, a paediatric adaptation of the BESTest, evaluates multiple balance domains, including biomechanical constraints, stability limits, postural control, and sensory integration, using 36 items across six domains (Dewar et al., 2017; Dewar et al., 2021). The Kids Mini-BESTest is a shortened version derived from the full test and contains 14 items that focus primarily on dynamic balance tasks across four of the six domains.

Both the full and mini versions were included in this study to compare their clinimetric properties within a DS population and to explore their feasibility in a resource-limited clinical context.

Reliability

- **Inter-rater reliability**: The Kids-BESTest demonstrates excellent inter-rater reliability with an ICC of 0.96, indicating strong agreement between different evaluators, which is crucial in both clinical and research settings, particularly when multiple professionals assess balance function (Dewar et al., 2017).
- **Test-retest reliability**: The tool’s high test-retest reliability (ICC = 0.93) confirms its stability when administered repeatedly over time. This reliability suggests that changes in scores are more likely to reflect genuine improvements or declines in balance function rather than variability in test administration (Dewar et al., 2017).
- **Test-retest reproducibility**:
    - For real-time assessments, the Kids Mini-BESTest total score showed slightly better agreement, with 100% of scores falling within 2 points across sessions, highlighting its precision for repeated clinical use.

  - In contrast, video assessments demonstrated slightly lower agreement (91% within 2 points), though the reliability was still good (ICC = 0.74, 95% Confidence interval (CI) 0.55–0.93) compared to excellent reliability for real-time assessments (ICC = 0.84, 95% CI 0.72–0.96).
  - Domain scores in real-time assessments also showed excellent agreement (100% within 2 points), while video assessments ranged from good to excellent (91–100% within 2 points). However, ceiling effects were observed in the Sensory Orientation domain during real-time testing, limiting its ability to detect subtle differences in higher-functioning children (Dewar et al., 2021).
- **Smallest Detectable Change (SDC)**:
  - For real-time assessments, the smallest detectable change (SDC) was 1.3 points (5% of the 28-point scale), reflecting excellent sensitivity for detecting small, clinically relevant changes.

Validity

- **Construct validity**: The Kids-BESTest effectively differentiates children with CP from typically developing children, demonstrating its utility in identifying motor impairments. This differentiation supports the test's robustness in measuring underlying balance constructs and its applicability across diverse populations with varying motor abilities (Dewar et al., 2021).
- **Criterion validity**: Strong correlations with established balance measures, including the PBS and FRT, validate the tool's effectiveness. These correlations confirm that the Kids-BESTest aligns with widely accepted standards in balance assessment, enhancing its credibility in clinical practice (Dewar et al., 2021).
- **Face validity**: The Kids-BESTest shows strong face validity through its tasks. For example, on the FRT tasks, children with CP performed significantly worse than their typically developing peers, highlighting the test's sensitivity in detecting postural

control and stability deficits. However, in tasks like the lateral FRT, its ability to capture compensatory strategies was limited, suggesting a need for refinement in specific tasks (Dewar et al., 2021).

Strengths

- **Comprehensive Framework:** By evaluating multiple domains of balance, it provides a holistic understanding of balance impairments.
- **High Reliability and Reproducibility:** The tool shows strong inter-rater, test-retest, and reproducibility metrics, particularly for real-time assessments when compared to assessments done using pre-recorded videos of participants completing the tests.
- **Robust Validity:** Its ability to distinguish between children with and without motor impairments underscores its utility in both clinical and research contexts.
- **Clinical Applicability**: High agreement between clinical and digital measurements support the assessment measures' practicality, with minimal need for advanced equipment.
- **Smallest Detectable Change:** The excellent SDC for real-time assessments provides clinicians with a clear threshold for identifying meaningful improvements in balance performance.

Limitations

- **Lengthy assessment:** Younger children or those with attention difficulties may find the Kids-BESTest lengthy or complex.
- **Ceiling effects:** Some domains, particularly sensory orientation, exhibited ceiling effects.
- **Scoring sensitivity:** Scoring may not fully capture compensatory strategies, suggesting a need for qualitative descriptors to enhance the understanding of postural control mechanisms (Dewar et al., 2021).

Bruininks-Oseretsky Test of Motor Proficiency, Second edition (BOT-2)

The BOT-2 is a comprehensive assessment tool designed to measure motor proficiency in children and adolescents aged 4 to 21 years. It consists of eight subtests, one of which (Subtest 5) focuses on balance and is discussed here. The tool evaluates fine and gross motor skills, providing a detailed analysis of motor performance.

Reliability

- **Inter-rater reliability**: The BOT-2 demonstrates excellent inter-rater reliability. Pearson correlation coefficients for inter-rater reliability generally exceed 0.90, which suggests high consistency between different raters (Deitz, Kartin & Kopp, 2007). This level of reliability is crucial for ensuring that the results of the test are not influenced by the individual administering the assessment, making the tool more robust for use in various settings.
- **Test-retest reliability**: The BOT-2 also demonstrates strong test-retest reliability across different age groups (4–7, 8–12, and 13–21 years), with coefficients of 0.80 or higher for both the Total Motor Composite and the Short Form. Subtests focusing on strength and agility tend to show coefficients above 0.80, reflecting consistent performance over time. However, variability is observed in some other composites, particularly for younger children (Deitz et al., 2007). This strong test-retest reliability supports the BOT-2's use as a dependable measure of motor performance over time.
- **Internal consistency**: The internal consistency of the BOT-2 is high, with a Cronbach's alpha of 0.93 or greater for the Total Motor Composite across age groups. Subtests and composite scores generally show acceptable internal consistency (Cronbach's alpha ≥ 0.80), although variability is more evident in younger age groups (Deitz et al., 2007). High internal consistency means that the subtests within the BOT-2 are measuring related constructs, adding to the test's reliability as a whole.

- **Confidence intervals**: The BOT-2 provides confidence intervals based on the standard error of measurement, which offers an estimate of measurement error for each subtest and composite score. This allows for more nuanced interpretation of the test results, acknowledging the inherent variability in individual performance (Deitz et al., 2007).

Validity

- **Content validity**: The BOT-2 has undergone extensive development through processes like item analysis, Rasch analysis, factor analysis, and feedback from users. This rigorous development ensures that the items within the test accurately measure the theoretical constructs of motor skills (Deitz et al., 2007). Content validity ensures that the test is measuring what it is intended to assess, making it an effective tool for evaluating motor proficiency.
- **Construct validity**: The BOT-2 has demonstrated strong construct validity, effectively distinguishing between typically developing children and those with motor deficits, such as those diagnosed with developmental coordination disorder, intellectual disabilities, or autism spectrum disorder (Deitz et al., 2007). This capability allows the BOT-2 to be useful for identifying motor skill deficits in clinical populations, which is important for both diagnosis and intervention planning.
- **Criterion-related validity**: The BOT-2 shows moderate to strong correlations with other established motor assessments, such as the Peabody Developmental Motor Scales (PDMS-2) and Test of Visual-Motor Skills-Revised (TVMS-R), reinforcing its validity as a measure of motor proficiency (Deitz et al., 2007). These correlations indicate that the BOT-2 yields results that are consistent with other validated tools in the field, enhancing its credibility as a reliable assessment tool.
- **Internal structure validity**: Confirmatory factor analysis has supported the internal structure of the BOT-2, confirming a four-factor model that represents distinct motor

domains: fine motor, gross motor, balance, and strength/agility. This validation reinforces the notion that the test accurately measures multiple aspects of motor proficiency, rather than relying on a single, oversimplified construct (Deitz et al., 2007).

- **Feasibility and applicability**: The BOT-2 has been found to be an effective and feasible tool for monitoring motor competence in healthy children, as confirmed by Radanović et al. (2021). The test is easy to administer, with a structure that engages children in a game-like manner. This makes it particularly suitable for both clinical and educational settings. Its broad applicability in cross-sectional studies and pre-post designs further emphasizes its practicality for use in diverse research contexts.

Strengths

- **Comprehensive evaluation of fine and gross motor skills**: The BOT-2 is capable of assessing a wide range of motor abilities, providing a holistic measure of motor proficiency.
- **Age applicability**: It covers a wide age range (4–21 years), making it adaptable for various developmental stages.
- **Sex differences**: The BOT-2 effectively captures sex-related motor skill differences, with studies showing that females tend to outperform males in fine motor skills, while males excel in gross motor skills (Radanović et al., 2021).

Limitations

- **Time-consuming**: Due to the wide range of motor skills assessed, the full test can be time-intensive, which may be a limitation in settings where time is a constraint.
- **Focus on static balance**: The balance subtest primarily assesses static balance, which may not fully capture dynamic postural control or real-world functional balance (Deitz et al., 2007).

- **Reliability variability**: There is some variability in reliability for certain subtests, particularly in younger children and those with motor impairments (Deitz et al., 2007).

Materials

- An otoscopy was done using a standardised Welch Allyn 23810 Diagnostic Otoscope with a rechargeable 719 series Lithium Ion handle.
- Tympanometry and the DPOAE screening was done using the standardised and calibrated tympanometry and otoacoustic emissions (OAE) modules on the Sentiero Advanced by Path Medical. Results were used to infer tympanic membrane mobility (an indication of middle ear status) and cochlear outer hair-cell function respectively.
- Weight in kilograms (kg) was determined using a standard bathroom scale. An informal calibration was done between sites, using a 10kg bag of mielie (maize) meal placed on the scale and then adjusting the scale accordingly.
- Height was measured in centimetres using a standard tape measure on a wall.
- The PBS, BOT-2 balance subtest (5), Kids BESTest and Kids Mini-BESTest was used to assess functional balance.
- Equipment for the balance tests was purchased from local stores or online, with little difficulty. Table 1 tabulates the materials required, while Figure 2 depicts one of the pieces of equipment.

Figure 2:

Water adjustable kettlebell/dumbbell

Table 1:

Equipment needed per outcome measure

Outcome measure	PBS	BOT-2, subtest 5	Kids-BESTest	Kids Mini-BESTest
Equipment needed	• 35 cm armless chair • 45 cm armless chair • 35 cm chair with armrest • 45 cm chair with armrests • Stopwatch • A step stool 15.24cm (6 inches) in height • Chalkboard eraser • 2m measuring tape • Masking tape • Blindfold • Adjustable gait belt • A3 sheets of paper • Pen	• Blindfold • Stopwatch • Masking tape • Balance beam • Adjustable gait belt	• Stopwatch • 35 cm armless chair • 45 cm armless chair • 2m measuring tape • A step stool 15.24cm (6 inches) in height • Water adjustable kettlebell/dumbbell[6] • Medium density 10cm thick foam • Adjustable incline ramp • Masking tape • Small traffic cone • Adjustable gait belt • A3 sheets of paper • Pen • Blindfold	• Stopwatch • 35 cm armless chair • 45 cm armless chair • Medium density 10cm thick foam • Adjustable incline ramp • Masking tape • Small traffic cone • Adjustable gait belt • Blindfold

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[6] See Figure 2

Data Management and Storage

Assessment sheets were completed by hand and are kept in a passcode protected safe. Each participant received a study number which, for the purpose of data management, was used to identify the individual participants ensuring anonymity. The participants' scores obtained for each subtest were captured on an Excel spreadsheet with their study number, for the purpose of statistical analysis. The data capturing was confirmed by the primary researcher re-entering and comparing it to a 10% subset of the data.

Once the captured data was confirmed, the physical copies of the assessment sheets were destroyed by the primary researcher through shredding and disposal. The digitally captured data is password protected and stored on a computer with anti-hacking software installed, ensuring the safety of the data and confidentiality of the participants. The data will be stored until data synthesis and statistical analysis is completed and then kept for a further five years as per the UCT's data management policy. Only the primary researcher and research supervisor will have access to the raw data.

Data Analysis

Statistical analysis was conducted to evaluate the balance outcome measures, participant characteristics, and the influence of various risk factors. Descriptive statistics, including mean, standard deviation (SD), and range, were used to summarise participant demographics (e.g., age) and performance across assessment tools. Percentages were calculated to report recruitment, attrition rates, and the distribution of participant characteristics such as otoscopic findings, tympanometry results, and DPOAE screening outcomes. BMI was calculated using the Centers for Disease Control and Prevention's (CDC) Child and Teen BMI Calculator (CDC, 2024). Tympanometry results were interpreted according to the British Society of Audiology's (BSA) recommended procedures for tympanometry and acoustic reflex thresholds (BSA, 2024).

Inferential statistics were used to compare balance performance between the DS and control groups. Independent t-tests assessed mean differences in scores or timings, with p-values determining statistical significance and effect sizes (Cohen's d) indicating the magnitude of differences. To account for the multiple statistical analyses conducted, a Bonferroni-corrected significance threshold of $p = 0.01$ was applied, replacing the conventional threshold of $p = 0.05$. Analysis of variance (ANOVA) and post hoc tests evaluated differences in balance scores across health variable subgroups (e.g., tympanometry types), while correlation analysis (Pearson's r and partial correlations) examined relationships between BMI and balance outcomes.

Inter-rater reliability was assessed using intraclass correlation coefficients (ICC) and test-retest reliability was assessed using Pearson's correlation. Validity was explored through criterion validity and known-groups validity. Criterion validity was assessed via regression analysis. Known-groups validity, assessed using t-tests and Cohen's d. Floor and ceiling effects were examined by analysing score distributions and mean values. Time efficiency was evaluated using mean completion times, SDs, and ranges.

Reliability and Validity

Reliability refers to the consistency and dependability of a measurement tool, while validity ensures the tool measures what it is intended to measure (Brink et al., 2018).

Inter-Rater Reliability

To ensure consistency between assessors, inter-rater reliability was evaluated for all outcome measures. The primary researcher, who had received specialised postgraduate training at the 4th South African Vestibular Assessment and Rehabilitation Therapy (VART) Course, conducted all observations and scoring. An audiologist registered with the Health Professions Council of South Africa (HPCSA) with experience in working with children with special needs and balance-related conditions, independently assessed a subset of participants. This second rater also received postgraduate training at the VART Course.

ICCs were used to quantify agreement between raters. ICC values were interpreted as follows: poor reliability (<0.50), moderate reliability (0.50–0.75), good reliability (0.75–0.90), and excellent reliability (>0.90) (Koo & Li, 2016). The data will be presented in the results section

Test-Retest Reliability

Test-retest reliability was assessed by re-administering the functional balance assessments to a subset of participants within the DS group one week after the initial testing. Pearson's correlation coefficients were used to evaluate the degree of agreement between the initial and follow-up test scores. Correlations were interpreted as very strong (≥0.90), strong (0.70–0.89), moderate (0.40–0.69), weak (0.20–0.39), or negligible (<0.20) (Mukaka, 2012). The data will be presented in the results section.

Criterion Validity

Criterion validity refers to the extent to which the results of an assessment tool correspond to an established gold standard or measure with known validity (Portney & Watkins, 2020). Regression analyses were performed to determine the strength and direction of the association between each balance assessment and the TUG scores and timing. In this study, criterion validity was assessed by examining the relationships between the scores of the balance outcome measures (Kids-BESTest, Kids Mini-BESTest, BOT-2 Subtest 5, and PBS) and the TUG test.

The TUG outcome measures the time it takes for an individual to stand from a seated position, walk 3m, turn around, walk back to the starting point and sit down again, providing an objective measure of balance and functional mobility (Itzkowitz et al., 2016). It has been validated in various populations, including children, as a reliable indicator of dynamic balance and fall risk (Barry, Galvin, Keogh, Horgan & Fahey, 2014). The TUG test was chosen as the criterion for this study due to its simplicity, clinical relevance, and established use in paediatric and special needs populations.

For the regression analyses, the TUG scores and TUG timing (duration in s) were used as dependent variables, while the balance assessment scores were included as independent variables. Separate analyses were conducted for children with DS and typically developing controls to account for differences in balance abilities between the groups. The regression models also provided R^2 values, indicating the proportion of variance in the TUG performance explained by each balance outcome measure.

Known-Groups Validity

Known-groups validity was evaluated by comparing the performance of children with DS and their typically developing peers across the PBS, BOT-2 subtest 5, Kids-BESTest, and Kids Mini-BESTest. This approach evaluates whether the tests can differentiate between groups with expected differences in balance function. Group means were compared using statistical analysis, with significant differences and large effect sizes interpreted as evidence of robust known-groups validity (Terwee et al., 2007). These differences support the use of these measures to assess balance function in diverse populations. Measures with strong known-groups validity are better suited for evaluating functional differences between distinct groups (Terwee et al., 2007).

Floor and Ceiling Effects

Floor and ceiling effects were examined to determine the range and sensitivity of the outcome measures. A floor effect was identified when a significant proportion (≤ 15%) of scores clustered at the lowest possible value, while a ceiling effect was noted when scores clustered (≥ 15%) at the highest possible value (Terwee et al., 2007). These effects were identified using descriptive statistics and frequency analyses for item-level scores across the DS and control groups. Tools with pronounced floor or ceiling effects may have limited utility in distinguishing performance differences, particularly in heterogeneous groups (Terwee et al., 2007).

Internal Consistency

Internal consistency was evaluated using Cronbach's alpha, a measure of the extent to which items within a tool are interrelated and measure the same construct. Scores were interpreted as follows: unacceptable (<0.50), poor (0.50–0.69), acceptable (0.70–0.79), good (0.80–0.89), and excellent (≥0.90) (Tavakol & Dennick, 2011). A high Cronbach's alpha value indicated that the items within each test were aligned and contributed meaningfully to the overall score.

Ethical Considerations

The following ethical aspects were considered during this study as stipulated in the Declaration of Helsinki (World Medical Association (WMA). 2013):

- Vulnerable population: Children diagnosed with DS are vulnerable as they are minors and mentally handicapped (Vohora, 2018). Only informed consent given by a parent or a legal guardian was accepted to ensure that they were aware of the purpose of the study and all it entailed. The control population was similarly regarded as vulnerable due to their minority status.
- Autonomy: Individuals have the right to self-determination, referring to that person's right of choice to participate in a study without risk of prejudice or penalty (Brink et al., 2018). This directly ties in with the assent required from each participant in this study.
- Assent: The participants gave verbal or written assent after watching a brief video demonstrating the expected tasks that they need to complete. Assent was regarded as a continuous process, to ensure that the participants were comfortable with going forward with every task. Assent was renewed when the second data collection session was conducted the following day, and in the sub-set of participants, one week later.

- Anonymity & Confidentiality: Participants remained anonymous. Anonymity ensured confidentiality of their personal information and data obtained during the study as each participant's private information and data should always be respected and never be divulged or made available to any other person or entity (Brink et al., 2018). Although the chaperones accompanying the children could identify the children during the data collection, the results obtained were kept confidential and were never divulged to any other party. Moreover, the chaperones were staff employed at the sites and of necessity, were familiar with the participants to ensure their comfort and confidence.
- Maleficence & Beneficence: Participants were always protected from possible harm during the research process by ensuring a first aid kit was on site and participants used a correctly fitted gait belt when completing the tasks. They were closely guarded throughout. Any and all falls were to have been reported to the study supervisor within 24 hours of it occurring and the HREC. If a fall should have occurred, the particular individual would not have been expected to continue with any activities. Water was made available throughout the process. The tasks completed were based on activities of daily living (ADL) and posed no heightened risk to the participants. The individual results of each participant were made available to the parents or legal guardians as well as the school nurse (with parental agreement) to keep as a medical record and to use in aid of fall prevention measures and promote physical activity. This study was done to further professional knowledge regarding the functional balance abilities of South African school-aged children and adolescents diagnosed with DS and to provide information, which will further the research field and profession while providing data which is essential to providing evidence-based practice. Thus, the construct of beneficence has been observed.

- Risk/Benefit ratio: Due to the participants' diagnosis of DS, a functional balance deficit is present, as documented in the literature, which increases their likelihood of falling (Jung et al., 2017; Aly & Abonour, 2016). While the activities involved are typical of ADLs, such as hopping and jumping, safety measures were implemented to mitigate risks. The risk/benefit ratio is considered favourable, taking into account both the potential harm and benefits for the participants. For the control group, the risk/benefit ratio was similarly favourable, with careful monitoring ensuring their safety during participation.
- Justice: All participants who meet the inclusion and exclusion criteria were given equal opportunities to participate and were safeguarded from any potential harm. This study will also contribute to advocating for children with DS, particularly in low-middle income countries (LMICs) like SA, as previously noted.

Chapter 3: Results

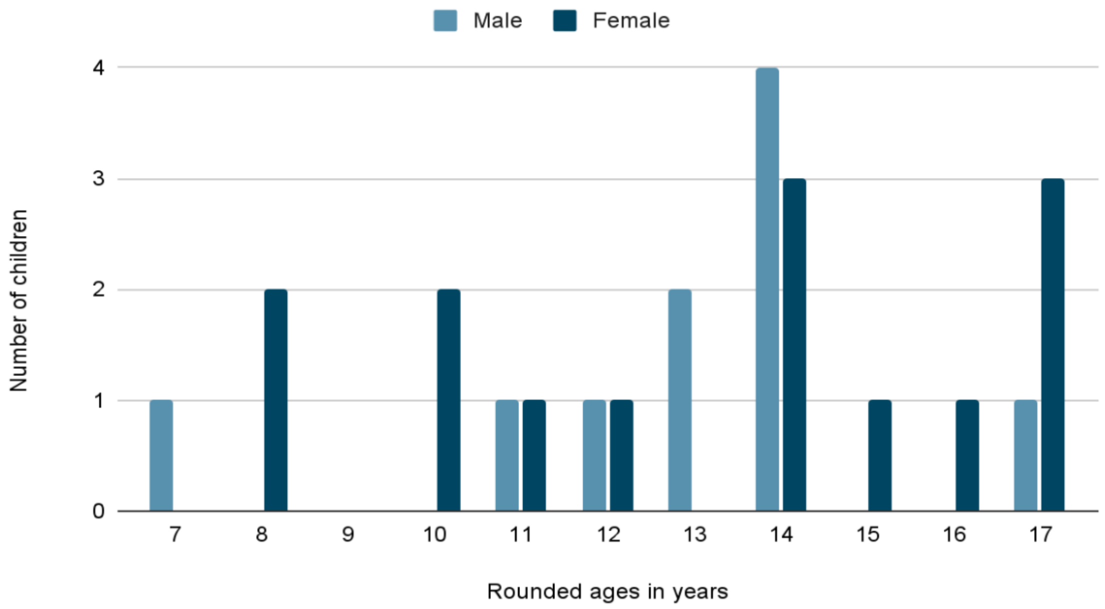
This section details the findings of the study in a structured format, aligning them to the outcome measures and key objectives. A basic overview of the results obtained for each outcome measure are discussed first, followed by detailed review of the results obtained for the Pediatric Balance Scale (PBS), Bruininks-Oseretsky Test of Motor Proficiency, Second edition (BOT-2) (Subtest 5), full Children's-Balance Evaluations Systems Test (Kids-BESTest), and shortened version of the Kids-BESTest (Kids Mini-BESTest). The results for the clinimetric properties of these tools are presented next, which include inter-rater reliability; test-retest reliability, floor and ceiling effects, internal consistency, and both criterion and construct validity. Additionally, practical considerations such as accessibility, acceptability, and time efficiency of the tools are also reported. Finally, the influence of otologic factors and body mass index (BMI) on balance performance in both groups is reported on.

Prior to describing the physical outcome measures, a description of the participants is outlined. Of the 48 participants that participated in this study, 24 participants were children with Down Syndrome (DS) and 24 were typically developing children that were age- and sex-matched to the DS group. Each group comprised 10 male and 14 female participants and the mean age of the participants was 13.3 years (standard deviation (SD) 2.75, range 7 to 18) (Figure 3).

Of the 34 potential participants with DS initially identified for the study, all met the inclusion criteria, yielding an eligibility fraction of 100%. However, seven children (20.59%) were not recruited, due to their parents not providing consent for participation, resulting in a final recruitment rate of 79.41%. Among the 27 children whose parents provided consent, three participants (attrition rate of 11.11%) were withdrawn or were unable to complete the study. Of these, two children were absent from school for the duration of the data collection period and one child did not assent to further participation after attempting a few tasks.

Figure 3:

Rounded ages of the participants in the study



A basic overview of the results obtained for each outcome measure

For the PBS, higher scores indicate better balance, and typically developing children score between 45.4 (81.07%) (age 3 years) and 54.6 (97.5%) (age 7 years and older), with lower scores suggesting balance impairments. The Kids-BESTest and Kids Mini-BESTest use percentage-based scoring systems, categorised as excellent (>90%), good (>80%), fair (>60%), and poor (<60%). Higher percentages reflect better balance, with the Kids-BESTest comprising more items than the Kids Mini-BESTest. The BOT-2, Subtest 5, uses raw scores with a maximum of 37 points, where higher scores represent better balance function. Across all measures, higher scores or percentages indicate better balance performance, while lower values highlight balance impairments.

The mean scores for each balance outcome measure differed significantly between the DS group and the control group (Table 2). The smallest difference was observed in the PBS, with a mean difference of 19.57 points, while the largest difference was recorded in the

BOT-2, Subtest 5, with a mean difference of 54.28 points. The Kids-BESTest and Kids Mini-BESTest demonstrated mean differences of 37.17 points and 42.71 points, respectively. Although each outcome measure has its own individualized scoring system and maximum scores, the data are presented as a percentage value to better aid comparison.

Table 2:

Mean percentage scores obtained for each outcome measure

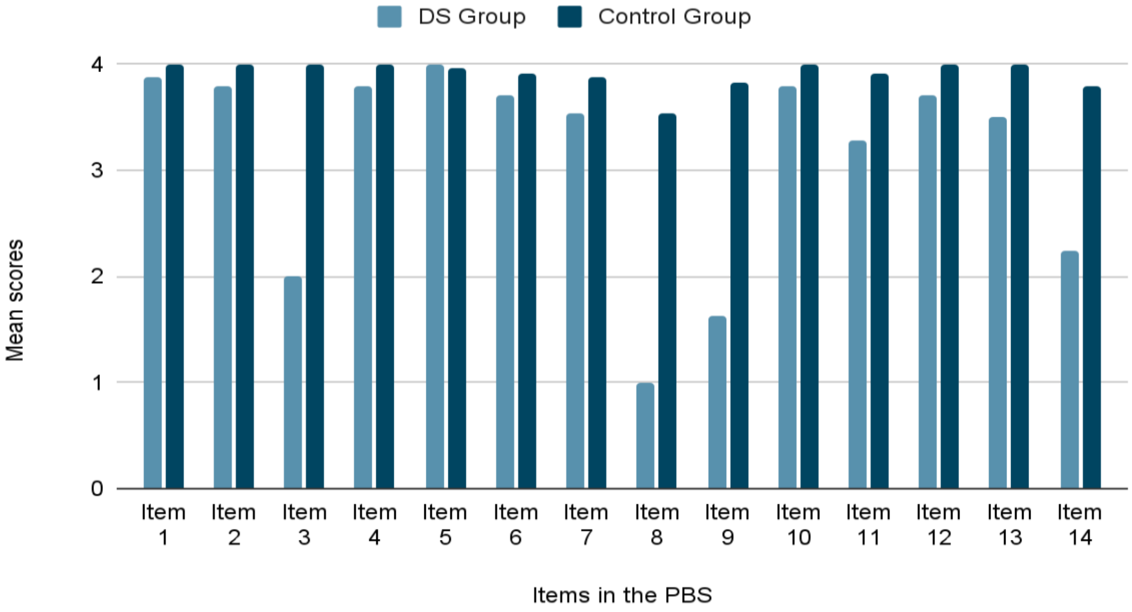
Outcome measure	DS Group Total (%) (SD)	Control Group Total (%) (SD)	*t*	*p*	*d*
PBS	78.35 (14.25)	98 (3)	6.39	< 0.001	1.84
BOT-2, Subtest 5	39.64 (17.87)	93.41 (7.26)	13.65	< 0.001	3.94
Kids-BESTest	54.19 (16.69)	98.61 (4.44)	10.74	< 0.001	3.10
Kids Mini-BESTest	43.88 (14.5)	86.55 (7.83)	13.27	< 0.001	3.83

Paediatric Balance Scale (PBS)

The control group achieved superior scores for all the items in the PBS with the mean score for each item never dropping below 3 (the maximum score that could be obtained was 4 and the minimum score was 0) (Figure 4). Similarly, DS participants presented good performance but struggled with certain items in the scale. Specifically, items 3 (Transferring from one chair to another), 8 (Standing unsupported with one foot in front of the other, 9 (Standing on one leg) and 14 (Reaching forward with an outstretched arm while standing), which will be discussed in detail next (Table 3).

Figure 4:

Mean scores obtained for the PBS

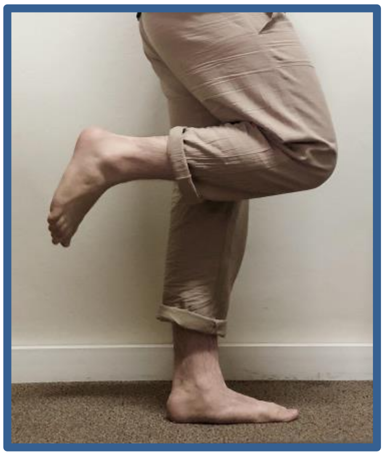


In item 3, when tasked with transferring one way to a chair with armrests and one way towards a chair without armrests, the majority of the DS group required verbal cueing after the initial instruction (which lowered the scores), whereas the control group could complete the item following the first verbal instruction. Item 8, standing unsupported with one foot in front of the other in a heel-to-toe position, is recognised clinically as a sharpened Romberg with eyes open. The majority of the DS group needed assistance to take the initial step and place their foot in front of the other after being given the verbal instruction and the researcher demonstrating the task. If the stance could be achieved, DS participants were unable to maintain the position for an appropriate duration (mean 13.42s, SD 12.27, range 0 to 30s) without losing balance and taking a corrective step. In contrast, the control group was able to maintain the position for significantly longer (mean 28.26 , SD 4.83, range 13 to 30s) (Table 3). During item 8, despite reassurances to the contrary, multiple DS participants expressed fear of falling, using phrases like “careful” or “I am going to fall”.

When asked to perform item 9, standing on one leg (SLS) for as long as possible, the instruction was given verbally and demonstrated by the researcher. Participants were instructed to keep their preferred leg in the flamingo (Figure 5) position with their hands on their hips and were allowed a practice trial and second attempt.

Figure 5:

Researcher demonstrating the Flamingo SLS



While all DS participants attempted the task, some (n=3; 12.5%) were unable to hold their leg in the air and immediately lowered it. For item 14, reaching forward with an outstretched arm (similar to functional reach tests) while standing, participants in the DS group generally struggled with the instructions, even when demonstrated by the researcher. The distances reached by the DS group (mean 12.92cm, SD 7.54, range 0 to 24.5cm) were considerably less than those of the control group (mean 30.04cm, SD 6.15, range 16 to 42cm). Statistical analysis indicated that all differences between the groups were significant (all p-values < 0.001), with the control group scoring significantly higher on all items of the PBS (Table 3).

Table 3:

Summary of the PBS items in which the DS group differed significantly from the control group

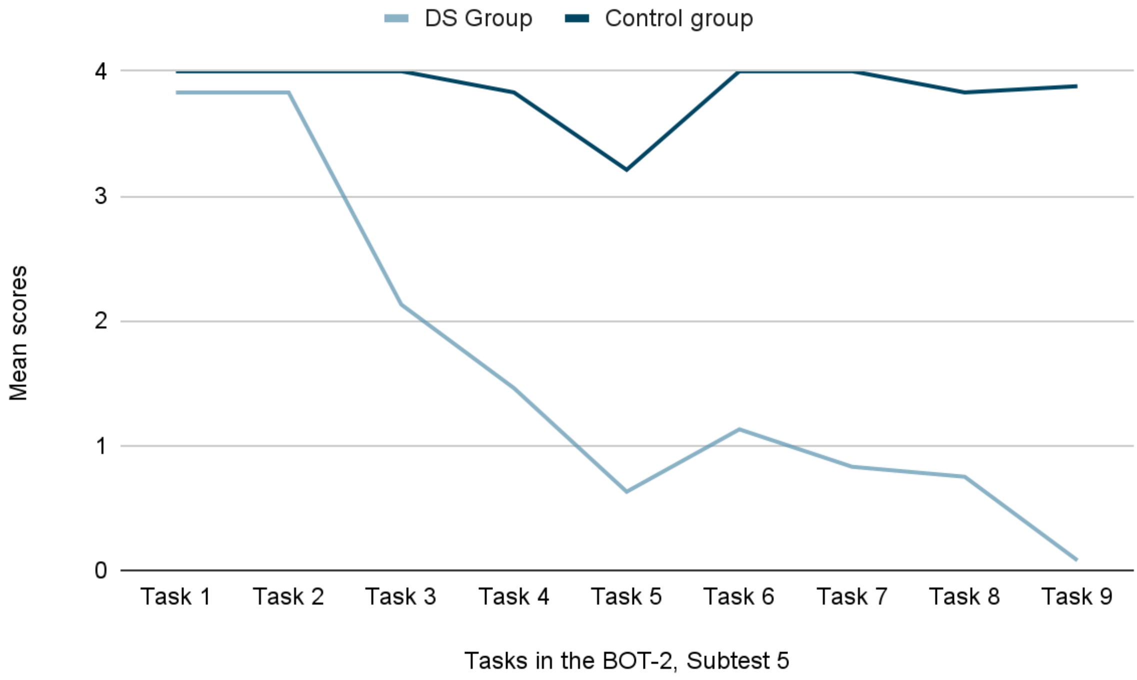
Item number	Item description	DS group mean score (SD)	Control Group mean score (SD)	*t*	*p*	*d*	Distance reached (cm) or duration stood (s) (SD) - DS Group	Distance reached (cm) or duration stood (s) (SD) - Control group
3.	Transferring one way to a chair with armrests and one way towards a chair without armrests.	2 (0.59)	4 (0)	14.36	< 0.001	4.15		
8.	Standing unsupported with one foot in front of the other, heel-to-toe.	1 (1.18)	3.53 (1.27)	7.24	< 0.001	2.09	13.42 s (12.27)	28.26 s (4.83)
9.	Standing on one leg for as long as possible.(Scoring, not timing)	1.63 (1.24)	3.84 (0.57)	7.74	< 0.001	2.23		
14.	Reaching forward with outstretched arms while standing (Scoring, not length of reach)	2.25 (1.22)	3.78 (0.42)	5.84	< 0.001	1.69	12.92cm (7.54)	30.04cm (6.15)

Bruininks-Oseretsky Test of Motor Proficiency, Second edition (BOT-2), Subtest 5: Balance

In this assessment, the control group achieved significantly superior scores for all the tasks, as with the PBS (Figure 6). The DS group performed progressively worse as the tasks progressed in complexity, with tasks 1 and 2 (standing on a firm surface with eyes open and eyes closed and feet apart respectively) yielding similar scores to that of the control group.

Figure 6:

Mean scores obtained for the BOT-2, Subtest 5



For task 5, participants were asked to stand on a straight line with one leg in the flamingo position and their hands on their hips, with their eyes closed (thus, a more challenging task than the SLS in the PBS where fixation is permitted). This task proved to be challenging for both groups, as reflected by decreased scores in both the DS and control groups. However, the control group still achieved higher scores compared to the DS group (Table 4).

Table 4:

Summary of the scoring and timing of all items in the BOT-2, (Subtest 5) requiring standing on one leg

Item number	Item description	Max score that could be obtained	DS group mean score (SD)	Time (s) (SD) (trial 1 & 2)	Control Group mean score (SD)	Time (s) (SD) (trial 1 & 2)
4.	Standing on one leg on a straight line with eyes open	4	1.46 (1.28)	2.59 (2.86)	3.83 (0.64)	9.05 (2.57)
				3.19 (3.26)		9.63 (1.58)
5.	Standing on one leg on a straight line with eyes closed		0.63 (0.71)	0.95 (1.2)	3.21 (1.02)	5.58 (3.33)
				1.08 (1.7)		7.51 (3.13)
8.	Standing on one leg on a balance beam with eyes open		0.75 (1.11)	1.67 (2.60)	3.83 (0.56)	8.92 (2.47)
				0.86 (1.58)		9.38 (2.11)
9.	Standing on one leg on a straight line with eyes closed	5	0.08 (0.28)	0.15 (0.56)	3.88 (1.45)	6.04 (3.35)
				0.06 (0.29)		7.73 (3.19)

Notably, the control group also performed better in task 9, where they were asked to stand on one leg on a balance beam (Figure 7) with eyes open. It is important to note that the maximum score criteria for task 9 differs (total of 5 points can be achieved in comparison to 4 on the other tasks).

Figure 7:

Model standing on a balance beam

(Shutterstock, 2025)

In general, the control group maintained a SLS for significantly longer periods across all task conditions compared to the DS group, with consistently high scores and extended times across both trials (Table 5). The DS group, while showing better performance in conditions where their vision was not restricted, demonstrated limited improvements between trials, suggesting minimal evidence of a learning or practice effect. For example, in Item 4 (SLS with eyes open), the DS group increased their time from 2.59 s (s) in trial 1 to 3.19 s in trial 2, but the difference was not significant when compared to the control group, whose times also increased from 9.05 to 9.63 sec. These minute increases in time was even more pronounced in item 5 (SLS with eyes closed), where the DS group showed only a slight increase from 0.95 s in trial 1 to 1.08 s in trial 2, compared to the larger improvement seen in the control group (5.58 to 7.51 s). These results suggest that while both groups exhibited slight improvements across trials, the DS group’s limited progress may indicate intrinsic balance and motor control challenges that reduce their capacity to benefit from repeated exposure to the tasks. Furthermore, the consistently low mean scores across all vision-denied conditions (e.g., item 9) reinforce the significant impact of sensory limitations on balance performance in the DS group.

Table 5:

Comparison of mean scores, time, and effect sizes for BOT-2 Subtest 5 items requiring standing on one leg

Item number	Group Mean score			Time (s) (SD) (trial 1 & 2)		
	t	***p***	***d***	***t***	***p***	***d***
4.	8.11	< 0.001	2.34	8.24	< 0.001	2.38
				8.70	< 0.001	2.51
5.	10.15	< 0.001	2.93	6.38	< 0.001	1.84
				8.85	< 0.001	2.56
8.	12.10	< 0.001	3.49	9.90	< 0.001	2.86
				15.85	< 0.001	4.58
9.	12.54	< 0.001	3.62	8.48	< 0.001	2.45
				11.73	< 0.001	3.39

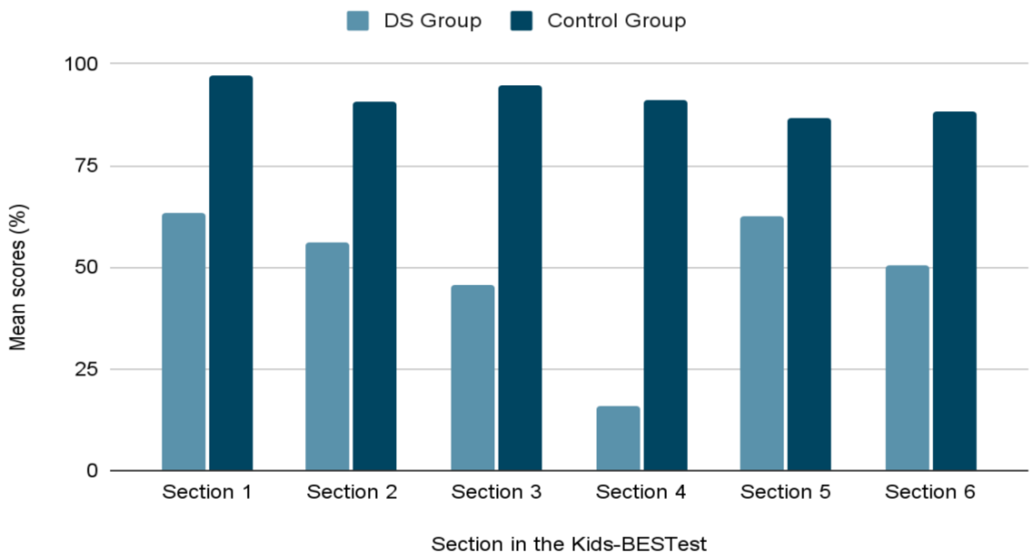
During task 3 the DS participants could walk forward, but could not keep their feet on a straight line while walking for more than a mean of 2.54 steps (SD 1.96, range 0 to 6), which improved slightly with a second trial (mean 3.04 steps, SD 2.29, range 0 to 6). Poorer scores were however obtained when tasked with walking heel-to-toe on a line (task 6) (mean 1.13 points, SD 1.42, range 0 to 4). The DS group showed overall caution when completing tasks on a balance beam (tasks 7-9) with one third of them (n=8; 33.33%) preferring to complete the tasks with touch assistance and fewer refusing (n=3; 12.5%) to attempt the tasks at all.

Children’s-Balance Evaluations Systems Test (Kids-BESTest)

The scores obtained for the Kids-BESTest revealed superior percentage scores in the control group compared to the DS group across all sections of the assessment. The statistical values are discussed in the appropriate sections accompanied by Table 6,Table 7, Table 8 & Table 9. The tasks are grouped into 6 sub-sections viz., Biomechanical Constraints (1), Stability Limits (2), Transitions - Anticipatory Postural Adjustment (3), Reactive Postural Responses (4), Sensory Orientation (5) and Stability in Gait (6). The DS group had the poorest scores in Sections 3 (Transitions - Anticipatory Postural Adjustment) and 4 (Reactive Postural Responses), while the best performance was observed in Sections 1 (Biomechanical Constraints) and 5 (Sensory Orientation) (Figure 8).

Figure 8:

Mean scores obtained for the Kids-BESTest



In Section 1, which examines the base of support (feet) and posture, 17 (70.83%) participants in the DS group exhibited pes planus[7] and/or splayed feet, and three (12.5%)

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[7] Refer to glossary

showed abnormalities in one foot. For posture and centre of mass alignment (item 2), 19 (79.17%) participants demonstrated abnormal antero-posterior (AP) and/or medio-lateral (ML) alignment.

In Section 3 (Transitions), the DS group performed similarly to the control group on Items 9 and 13, with mean scores almost identical between the groups (Table 6). The poorest performance in the DS group was observed on Item 11, which required participants to stand on one leg in the flamingo stance with hands on hips. The DS group generally struggled more with this task, maintaining the stance for shorter periods compared to the control group, though no significant difference in stance time was found between the left and right legs for either group. For Item 12, which required alternating steps to touch a step, the DS group took significantly longer and scored lower than the control group.

Table 6:

Summary of the scores and timing of items in Section 3 of the Kids-BESTest

Item Number	Item description (sub-test)	DS group mean score (SD)	Timing (s) (SD)	Control group mean score (SD)	Timing (s) (SD)
9.	Sit to stand	2.92 (0.28)		3 (0)	
10.	Rise to toes	1.46 (0.93)		2.67 (0.48)	
11a.	Stand on one leg (left)	0.54 (0.78)	2.86 (4.61)	2.71 (0.55)	19.15 (2.97)
11b.	Stand on one leg (Right)	0.46 (0.59)	2.6 (4.39)	2.83 (0.38)	19.22 (2.66)
12.	Alternate stair touch	1.63 (0.71)	15.81 (2.92)	3 (0)	8 (0.87)
13.	Standing arm raise	2.33 (1.05)		2.88 (0.34)	

Legend: The maximum possible score that could be obtained is 3 points

The timing comparison revealed a significant difference with a t-value of -2.97 (p = 0.005), indicating that the DS group had more difficulty completing the task. The effect size for this difference was large (d = 0.857), further emphasizing the magnitude of the discrepancy between the groups. This suggests that the balance task was more challenging for children with DS (Table 7). Effect sizes, calculated using Cohen’s d, provide a measure of the magnitude of differences between groups, where values of 0.2, 0.5, and 0.8 are interpreted as small, medium, and large effects, respectively.

For Section 4 (Reactive Postural Responses), which involves compensatory stepping corrections in response to front, back, and side perturbations, the DS group displayed difficulty following the task instructions, whether given verbally or through demonstration. This led to incomplete performance and thus lower scores, however there were no refusals.

In Section 5 (Sensory Orientation), the participants completed the modified Clinical Test of Sensory Integration of Balance (mCTSIB) (Item 19). Performance declined in both groups as the tasks became more challenging, such as standing on a foam surface or with eyes closed. There was no significant difference between the groups for Item 19a (standing eyes open on a firm surface), which correlates with the same task in the PBS, but significant differences were observed for Items 19c and 19d, where the DS group exhibited more pronounced difficulties as more sensory cues were removed/altered (Table 8).

Finally, in the Timed Up & Go (TUG) tasks (Items 26 and 27), the DS group had more difficulty with the dual task component. While the control group counted backward as per the description of the item, the DS group was asked to sing “Happy Birthday” due to difficulties with counting. Eight participants (33.33%) in the DS group were unable to complete Item 27 (TUG with dual task), even with the adjusted dual task. The DS group took longer on average to complete the TUG tasks compared to the control group, with significant differences noted in Item 26 (TUG simple) (Table 9). The control group performed better in task 26 (TUG simple), achieving significantly superior scores.

Table 7:

Comparison of group mean scores, timing, and effect sizes for items in Section 3 of the Kids-BESTest

Item Number	Item description (sub-test)	Group mean score			Timing		
		t	*p*	*d*	*t*	*p*	*d*
9.	Sit to stand	1.74	0.089	0.501			
10.	Rise to toes	5.57	< 0.001	1.608			
11a.	Stand on one leg (left)	11.89	< 0.001	3.431	14.55	< 0.001	4.200
11b.	Stand on one leg (Right)	16.61	< 0.001	4.794	15.86	< 0.001	4.579
12.	Alternate stair touch	9.67	< 0.001	2.793	-2.97	0.005	0.857
13.	Standing arm raise	2.41	0.020	0.695			

Table 8:

Mean scores obtained in item 19, the mCTSIB

Item number	Item description	DS group mean score (SD)	Control Group mean score (SD)	*t*	*p*	*d*	Maximum time that could be achieved (s)	Duration Stood (s) (SD) - DS Group	Duration Stood (s) (SD) - Control Group
19a.	Standing eyes open on a firm surface	3 (0)	3 (0)	-	-	-	30 s	30 s (0)	30 s (0)
19b.	Standing eyes closed on a firm surface	2.67 (0.48)	2.88 (0.33)	1.61	0.115	0.463		30 s (0)	30 s (0)
19c.	Standing eyes open on a foam surface	2.08 (0.58)	2.82 (0.39)	5.75	< 0.001	1.660		28.75 s (6.12)	30 s (0)
19d.	Standing eyes closed on a foam surface	1.5 (0.88)	2.09 (0.29)	3.43	0.001	0.991		22.55 s (12.1)	30 s (0)

Legend: The maximum possible score that could be obtained is 3 point

Table 9:

Mean scores and timing for the TUG tasks in the Kids-BESTest

Item number	Item description	DS group mean score (SD)	DS group mean time (s) (SD)	Control group mean score (SD)	Control group mean time (s) (SD)	Group mean score			Timing		
						t	*p*	*d*	*t*	*p*	*d*
26.	TUG simple	2.13 (0.99)	12.92 (4.62)	3 (0)	7.64 (1.06)	4.79	< 0.001	1.382	-5.45	< 0.001	1.573
27.	TUG with dual task	1 (1.02)[8]	13.51 (2.93)	1.75 (0.99)	11.26 (3.67)	2.58	0.013	0.746	-2.12	0.040	0.672

Legend: The maximum possible score that could be obtained is 3 points

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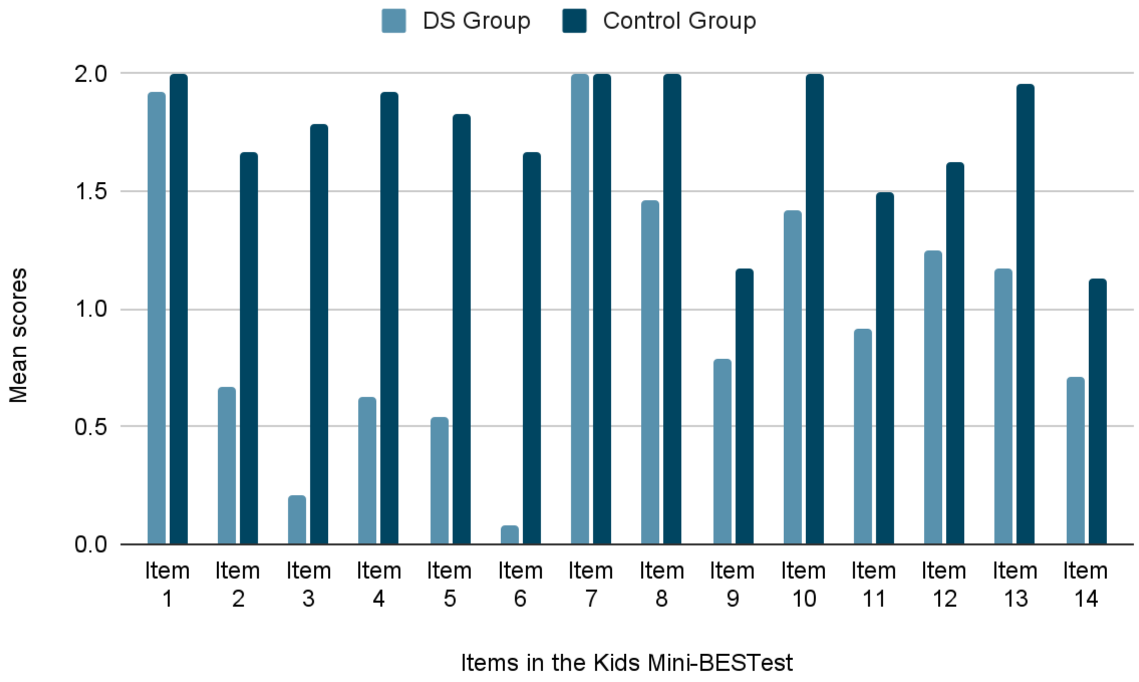
[8] n=16

Children's-Balance Evaluations Systems Test shortened version (Kids Mini-BESTest)

The Kids Mini-BESTest, an abbreviated version of the full Kids-BESTest, was designed to assess specific domains of dynamic balance in a shorter time-frame. The scores for this assessment were extracted from the results of the full Kids-BESTest (Figure 9). This was done to avoid participant fatigue and to make use of time more efficient.

Figure 9:

Mean scores obtained for the Kids Mini-BESTest



Consistent with the findings for the full version, the control group outperformed the DS group across most items, with statistically significant differences observed for item 7 (Stance (feet together); Eyes open, firm surface), item 9 (Incline - Eyes closed), item 12 (Walk with pivot turns), and item 14 (TUG with dual task). In item 1 (Sit to stand) both groups achieved similar high scores (Table 10).

Table 10:

Comparison of mean scores, timing, standard deviations, and effect sizes for items in the Kids Mini-BESTest: DS vs. Control Group

Item number	Item description	DS group mean score (SD)	Control Group mean score (SD)	*t*	*p*	*d*
1	Sit to stand	1.90 (0.29)	2 (0)	1.74	0.089	0.50
2	Rise to toes	0.69 (0.29)	1.67 (0.48)	5.39	<0.001	1.56
3 (Left)	Stand on one leg	0.23 (0.47)	1.75 (0.44)	11.60	<0.001	3.35
3 (Right)	Stand on one leg	0.17 (0.38)	1.83 (0.38)	15.71	<0.001	4.38
4	Compensatory stepping correction - Forward	0.63 (0.82)	1.92 (0.28)	7.26	<0.001	2.10
5	Compensatory stepping correction - Backward	0.56 (0.68)	1.83 (0.38)	7.98	<0.001	2.30
6 (Left)	Compensatory stepping correction - Lateral	0.04 (0.20)	1.67 (0.48)	15.22	<0.001	4.39
6 (Right)	Compensatory stepping correction -	0.13 (0.34)	1.67 (0.48)	12.84	<0.001	3.71

	Lateral					
7	Stance (feet together); Eyes open, firm surface	2 (0)	2 (0)	-	-	-
8	Stance (feet together); Eyes closed, foam surface	1.44 (0.83)	2 (0)	3.34	0.002	0.96
9	Incline - Eyes closed	0.81 (0.44)	1.17 (0.48)	2.67	0.011	0.77
10	Change in gait speed	1.38 (0.76)	2 (0)	4.05	<0.001	1.17
11	Walk with head turns - Horizontal	0.94 (0.70)	1.50 (0.51)	3.19	0.003	0.92
12	Walk with pivot turns	1.25 (0.53)	1.63 (0.49)	2.53	0.015	0.73
13	Step over obstacles	1.17 (0.57)	1.96 (0.20)	6.46	<0.001	1.87
14	TUG with dual task	0.69 (0.69)	1.13 (0.61)	2.33	0.024	0.67

Legend: The maximum possible score that could be obtained is 2 points

Items 2 through 6, which include “Rise to toes” and “Compensatory stepping corrections” (forward, backward, and lateral), recorded the lowest mean scores for the DS group, highlighting challenges in tasks requiring reactive postural control. In contrast, the control group achieved significantly higher scores in these items ($p < 0.001$), reflecting their superior postural stability and balance responses. Both groups scored well on Items 1 (Sit to stand) and 7 (Stance: feet together; eyes open, firm surface), indicating that these tasks were less demanding and accessible to both groups. Conversely, Items 9 (Incline - eyes closed) and 14 (TUG with dual task) were challenging for both groups, as evidenced by lower mean scores.

Clinimetric Properties of Selected Tests

This section evaluates the clinimetric properties of the four balance outcome measures used in this study, viz., the PBS, BOT-2 (Subtest 5), Kids-BESTest, and Kids Mini-BESTest. Constructs of inter-rater and test-retest reliability, criterion validity, known-groups validity, floor and ceiling effects, and internal consistency are explored (Table 11). All measures demonstrated good inter-rater reliability, with varying strengths in test-retest reliability ranging from moderate to very strong. Strong criterion validity was evident across most measures, with the BOT-2 showing moderate associations. Known-groups validity was excellent for the Kids-BESTest and Kids Mini-BESTest and good to excellent for the PBS and BOT-2, reflecting their ability to differentiate between children with DS and typically developing peers. Floor and ceiling effects varied, with some measures showing challenges in specific subgroups. Finally, internal consistency was excellent for the Kids-BESTest and Kids Mini-BESTest, supporting their robustness in evaluating balance. The clinimetric properties of these tests will be discussed in detail in the following subsections.

Table 11:

Summary of the results of the clinimetric aspects assessed in this study

Construct measured	Outcome measure			
	PBS	BOT-2, Subtest 5	Kids-BESTest	Kids Mini-BESTest
Inter-rater reliability	Good reliability	Good reliability	Good reliability	Good reliability
Test-Retest reliability	Moderate to strong	Very strong	Strong	Strong
Criterion validity	Strong	Moderate	Strong	Strong
Known-Groups Validity	Good	Excellent	Excellent	Excellent
Floor-Ceiling effect	Ceiling effects observed in the control group. The DS group showed possible floor effects for item 3, but not consistently across other items	Ceiling effects are present in the control group, with potential floor effects in the DS group items requiring a narrow base of support	The control group shows possible ceiling effects in some items (numbers 3, 5, 6, 9. 12, 22 and 26) while the DS group demonstrates floor effects in section 4	Ceiling effects are evident in several items (numbers 1 and 7) in both groups, with additional floor effects in items 3 and 6 for the DS group
Internal Consistency	Good	Good	Excellent	Excellent

Reliability

Inter-Rater Reliability

Inter-rater reliability was evaluated for all outcome measures using the Intraclass Correlation Coefficient (ICC), a commonly used statistic for assessing the degree of agreement or consistency between raters. Strong inter-rater reliability was observed overall, with the best reliability calculated for the BOT-2, Subtest 5 (ICC = 0.889) and the Kids-BESTest (ICC = 0.887), both categorised as "good" based on established thresholds. In contrast, the Kids Mini-BESTest (ICC = 0.714) and the PBS (ICC = 0.735) demonstrated "moderate" reliability (Table 12). These findings highlight variability in rater consistency across measures, particularly for the PBS and Kids Mini-BESTest, which may require closer examination of scoring procedures to improve reliability. Although the Kids Mini-BESTest's results were derived from the Kids BESTest, the difference observed in the inter-rater reliability is due to the fact that certain items with better inter-rater reliability were excluded from the Kids Mini-BESTest.

Table 12:

Inter-rater reliability for each outcome measure used in the DS group

Outcome measure	ICC	Degree of reliability
PBS	0.735	Moderate
BOT-2, Subtest 5	0.889	Good
Kids-BESTest	0.887	Good
Kids Mini-BESTest	0.714	Moderate

Test-Retest Reliability

The BOT-2, Subtest 5 demonstrated very strong test-retest reliability, as indicated by the Pearson's correlation coefficient of 0.917 ($p = 0.001$), suggesting a highly consistent performance over time in the DS group (Table 13). The Kids-BESTest and Kids Mini-BESTest also displayed strong test-retest reliability with Pearson's correlation coefficients of 0.736 ($p = 0.037$) and 0.758 ($p = 0.029$), respectively. In contrast, the PBS yielded a moderate to strong correlation (0.606, $p = 0.111$), which was the lowest among the outcome measures used. These correlation coefficients were calculated using Pearson's r to assess the degree of reliability for each outcome measure, with values closer to 1 indicating stronger correlations.

Table 13:

Test-retest reliability of each outcome measure in the DS group

Outcome measure	Pearson's correlation coefficient (SD)	Degree of correlation	*p*
PBS	0.606	Moderate to Strong	0.111
BOT-2, Subtest 5	0.917	Very strong	0.001
Kids-BESTest	0.736	Strong	0.037
Kids Mini-BESTest	0.758	Strong	0.029

Validity

Criterion Validity

The criterion validity of the balance outcome measures was evaluated by examining their associations with the TUG test (score and timing) in children with DS and typically developing control children, as presented in Table 14 and Table 15, respectively.

For the DS group, regression analyses revealed significant associations between the TUG test and all four balance tests. The Kids-BESTest demonstrated strong criterion validity, explaining 53.6% of the variance in TUG performance, with a significant positive model coefficient. Similarly, the Kids Mini-BESTest accounted for 55.5% of the variance in TUG scores, showing a significant relationship. The BOT-2 Subtest 5 showed moderate explanatory power with a significant positive coefficient. The PBS also demonstrated strong criterion validity, explaining 49.4% of the variance in TUG scores, with a significant model coefficient .

For TUG timing in the DS group, similar patterns were observed. The Kids-BESTest and Kids Mini-BESTest were the strongest predictors of TUG timing, explaining 52% and 50.6% of the variance, respectively, with significant negative coefficients. The BOT-2 Subtest 5 accounted for 30.7% of the variance with a significant negative association . The PBS explained 49.2% of the variance in TUG timing with a significant negative coefficient.

Table 14:

Regressions: DS Group

	Model fit			Model coefficients			
	R^2	F	p	Estimate	SE	t	p
TUG Score							
Kids-BESTest	0.536	25.4	< 0.001	13.7	2.72	5.04	< 0.001
Kids Mini-BESTest	0.555	27.5	< 0.001	3.52	0.37	5.24	< 0.001
BOT-2, Subtest 5	0.335	11.1	0.003	3.99	1.20	3.33	0.003
PBS	0.494	21.5	< 0.001	5.91	1.28	4.64	< 0.001
TUG Timing							
Kids-BESTest	0.520	23.8	< 0.001	-2.80	0.58	-4.88	< 0.001
Kids Mini-BESTest	0.506	22.5	< 0.001	-0.70	0.15	-4.75	< 0.001
BOT-2, Subtest 5	0.307	9.77	0.005	-0.79	0.25	-3.13	0.005
PBS	0.492	21.3	< 0.001	-1.22	0.27	-4.62	< 0.001

In contrast, the regression analyses for the control group, presented in Table 15, showed no significant associations between the TUG test and any of the balance measures. These findings highlight the strong criterion validity of the balance outcome measures when applied to children with DS, particularly the Kids-BESTest and Kids Mini-BESTest, which exhibited the highest R2 values. The lack of significant associations in the control group suggests that these tools may be less sensitive to detecting balance differences in typically developing children, potentially reflecting a ceiling effect or limited variability in this population.

Table 15:

Regressions: Control Group

	Model fit			Model coefficients			
	R^2	F	p	Estimate	SE	t	p
TUG Timing							
Kids-BESTest	0.002	0.05	0.827	0.166	0.75	0.22	0.827
Kids Mini-BESTest	0.034	0.78	0.388	0.391	0.44	0.88	0.388
BOT-2, subtest 5	0.015	0.34	0.566	-0.328	0.56	-0.58	0.566
PBS	< 0.001	< 0.01	0.976	0.01	0.34	0.03	0.976

Known-Groups Validity

The known-groups validity was evaluated for the PBS, the BOT-2, Subtest 5, the Kids-BESTest, and the Kids Mini-BESTest by comparing performance between children with DS and typically developing children.

Across all measures, the group of typically developing children consistently outperformed the group of children with DS, confirming the suspected differences in balance function between these populations. Statistical analyses demonstrated significant differences in the mean scores between the groups for each test (all $p < 0.001$), with large effect sizes indicating robust known-groups validity. The effect sizes observed in this study ranged from 1.84 to 3.94, underscoring the substantial differences in balance performance between the groups.

The PBS (maximum possible score = 56 points, converted to a percentage) showed significant group differences, with a mean score of 78.35 (SD 14.25) in the group of children with DS compared to 98 (SD 3) in the group of typically developing children ($t = 6.39$, $p < 0.001$, $d = 1.84$). The group of typically developing children achieved consistently high scores across all PBS items, with a mean score of 3 or higher (out of 4) for each item.

Conversely, the group of children with DS showed significantly poorer performance on items requiring advanced balance control, such as standing heel-to-toe (Item 8), standing on one leg (Item 9), and reaching forward while standing (functional reach) (Item 14).

The BOT-2, Subtest 5 (maximum possible score = 37 points, converted to a percentage), which assesses balance through tasks of increasing complexity, showed the largest mean difference between groups (54.28 points). The group of children with DS had a mean score of 39.64 (SD 17.87), while the group of typically developing children scored 93.41 (SD 7.26) ($t = 13.65$, $p < 0.001$, $d = 3.94$). Performance gaps widened as task complexity increased. For example, in Task 5 (standing on a line with one leg in flamingo position and eyes closed), the group of children with DS struggled significantly, achieving a mean score of 0.63 (SD 0.71) compared to 3.21 (SD 1.02) in the group of typically developing children ($t = 10.15$, $p < 0.001$, $d = 2.93$).

The Kids-BESTest (maximum possible score= 108 points, converted to a percentage) demonstrated strong known-groups validity, with the group of children with DS achieving a mean score of 54.19% (SD 16.69) compared to 98.61% (SD 4.44) in the group of typically developing children ($t = 10.74$, $p < 0.001$, $d = 3.10$). The largest deficits in the group of children with DS were observed in Sections 3 (Transitions - Anticipatory Postural Adjustments) and 4 (Reactive Postural Responses), tasks requiring dynamic balance and rapid motor responses. For example, in Item 11 (standing on one leg), the group of children with DS achieved a mean score of 0.54 (SD 0.78) for the left leg and 0.46 (SD 0.59) for the right leg, compared to 2.71 (SD 0.55) and 2.83 (SD 0.38), respectively, in the group of typically developing children.

The Kids Mini-BESTest (maximum possible score= 28 points, converted to a percentage) also revealed substantial differences, with mean scores of 43.88% (SD 14.5) for the group of children with DS and 86.55% (SD 7.83) for the group of typically developing children (t = 13.27, p < 0.001, d = 3.83). Significant deficits were observed in items involving sensory orientation and reactive balance.

The results demonstrate strong known-groups validity for all four measures, as each test effectively differentiated between children with DS and typically developing children. The large effect sizes and statistically significant differences across all tests confirm the ability of these measures to assess balance function in groups with varying levels of balance ability. This supports their use as reliable tools for evaluating balance in clinical and research settings involving children with DS.

Score Distribution and Internal Consistency

Floor & Ceiling Effects

In the PBS, the control group consistently achieved scores close to 4 across all items, suggesting a ceiling effect as their scores are near the maximum. The DS group's results vary more as item 3 (Transferring from one chair to another) specifically has a mean score of 2, which is much lower than the other items which suggests a possible floor effect. Whereas, the remaining items have relatively higher scores (around 3.79 - 4), indicating no clear floor effect.

Ceiling effects can also be seen in the scores obtained for the control group when doing the BOT-2 test, specifically in tasks 1 (standing with feet apart on a line with eyes open), 2 (standing with feet apart on a line with eyes closed), 3 (walking forward on a straight line), 6 (walking forward heel-to-toe on a straight line) and 7 (walking forward heel-to-toe on a balance beam). In the DS group, possible floor effects were seen in items 5 through 9 which mostly include items that participants had to complete on a narrow base of support, including single leg stance and activities done on a balance beam.

The results of the Kids-BESTest, however, showed more variability. While the control group generally scored higher, none of the combined sections achieved perfect scores. It is possible that a ceiling effect influenced the results, particularly for the control group.

Specifically, items such as 3 (ankle strength and range) and 5 (sit on floor and stand up) in Section 1 (Biomechanical constraints), Item 6 (sitting verticality and lateral lean) in Section 2 (Stability limits), Items 9 (sit to stand) and 12 (alternate stair touch) in Section 3 (Transitions – anticipatory postural adjustments), and Items 22 (change in gait speed) and 26 (Timed Up and Go) in Section 6 (Stability in gait) showed signs of this. Both groups also displayed potential ceiling effects in Section 5 (Sensory orientation), particularly for Item 19, the mCTSIB, in the condition with eyes open on a firm surface.

The DS group, however, performed poorly in Section 4 (Reactive postural responses), suggesting the presence of a floor effect in that section. In the Kids Mini-BESTest, clear ceiling effects were observed for the control group in items 1 (Base of support), 7 (Functional reach forward), 8 (Functional reach lateral), and 10 (Rise to toes). Possible ceiling effects were also noted for items 4 (Hip/trunk lateral strength) and 13 (Standing arm raise) for the control group. For the DS group, potential ceiling effects were identified in Items 1 (Base of support) and 7 (Functional reach forward), while Items 3 (Ankle strength and range) and 6 (Sitting verticality and lateral lean) showed possible floor effects.

Internal Consistency

The PBS and BOT-2, Subtest 5 yielded similar scores when subjected to Cronbach's alpha, indicating good internal consistency (Table 16). The Kids-BESTest and Kids Mini-BESTest yielded the same result when subjected to Cronbach's alpha, suggestive of excellent internal consistency.

Table 16:

Internal consistency for outcome measures

Outcome measure	Cronbach's alpha	Level of consistency
PBS	0.873	Good
BOT-2, Subtest 5	0.867	Good
Kids-BESTest	0.971	Excellent
Kids Mini-BESTest	0.930	Excellent

Clinical Utility: Practical Applicability

The practical applicability of the PBS, BOT-2 Subtest 5, Kids-BESTest, and Kids Mini-BESTest was evaluated based on their accessibility[9], acceptability[10], and time efficiency (Table 17).

Table 17:

Practical applicability of balance outcome measures: accessibility, acceptability, and time efficiency

Construct measured	outcome measure			
	PBS	**BOT-2, Subtest 5**	**Kids-BESTest**	**Kids Mini-BESTest**
Accessibility	Most accessible	Least accessibility	Moderate accessibility	Most accessible
Acceptability	Good acceptability	Moderate acceptability	Moderate acceptability	Good acceptability
Time efficiency	Good time efficiency	Good time efficiency	Poor time efficiency	Estimated good time efficiency

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[9] Refer to glossary

[10] Refer to glossary

These factors are crucial for determining the feasibility of implementing the outcome measures in clinical and educational settings, and are particularly relevant in resource constrained settings, as discussed in the literature review. Accessibility varied across measures, with the PBS and Kids Mini-BESTest being the most accessible and the BOT-2, subtest 5 the least accessible. Acceptability ratings were generally positive, with the PBS and Kids Mini-BESTest demonstrating good acceptability, while the BOT-2 Subtest 5 and Kids-BESTest were moderately acceptable. The acceptability of the balance outcome measures was evaluated by considering participants' willingness and ability to engage with the tasks. Time efficiency emerged as a key differentiator, with both the PBS and BOT-2 Subtest 5 showing good efficiency, the Kids-BESTest being the least time-efficient, and the Kids Mini-BESTest estimated to offer good time efficiency. These findings highlight the importance of optimising practicality and comprehensiveness when selecting appropriate tools for assessing balance in children with DS. The practical applicability of the outcome measures in this study will be discussed in detail in the following subsections.

Accessibility

The cost of equipment required for each outcome measure varied and was calculated according to the equipment needed as per Table 1. As clinical utility was being assessed, commentary was added throughout to aid in contextualisation. The most expensive assessment tool in terms of equipment costs was the Kids-BESTest, while the BOT-2 Subtest 5 had the lowest equipment cost (Table 18). The BOT-2 however needs to be purchased before use and the pricing to purchase the entire assessment totals to roughly $898.00 which, when converted using the current exchange rate (correct as on 6 January 2025 (South African Reserve Bank, 2025)) totals to about R16 684.11. The PBS and Kids Mini-BESTest had similar equipment costs, with the latter being slightly more expensive. The other assessments used are freely available for use. These variations in cost highlight the financial barriers that could influence the accessibility of these tools, particularly for institutions with limited budgets.

Table 18:

Equipment costs for each outcome measure

Outcome measure	Equipment costs
PBS	R2 235.58 ($119.84)
BOT-2, Subtest 5	R1 114.00 ($59.72) (R17 798.11 ($954.09) with the assessment purchase cost included)
Kids-BESTest	R3 894.58 ($208.77)
Kids Mini-BESTest	R2 784.00 ($149.24)

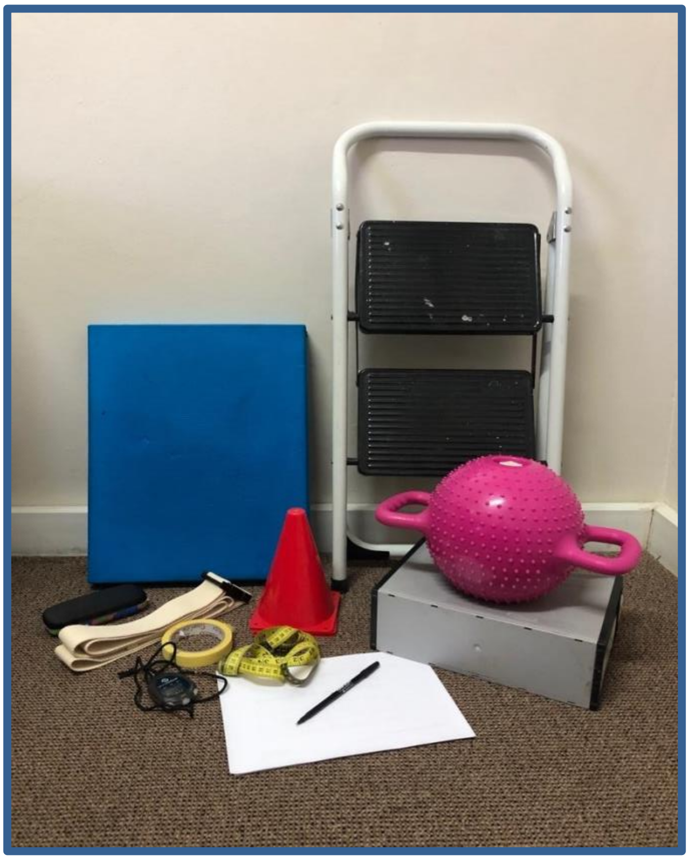
Legend: R = South African Rand; $ = United States (US) Dollar

In terms of availability, the necessary equipment for all outcome measures was sourced online through major retailers, such as Takealot.com or Amazon, which delivers to most locations within South Africa (SA).

The cost of equipment for this study was covered by the researcher, alleviating financial barriers for the participating schools. This underscores the need for external funding or institutional support to ensure equitable access to these assessment tools across diverse settings in SA. However, given that valuable and clinically relevant information was shown from this array of tests (discussed further in the next Chapter), the costs are not deemed to be excessive in that the equipment can be used repeatedly and is mobile enough to be transported between sites (Figure 10).

Figure 10:

Small equipment used



Acceptability

Of the 27 participants with DS who were recruited, one child (10 year old male) discontinued participation after attempting a few tasks. These tasks were at the beginning of the scales concerned and therefore the easiest. The remaining participants in the DS group demonstrated an overall willingness to complete the balance activities and expressed no refusal to participate. This willingness indicates that the majority of the DS participants found the activities acceptable, though individual variations in task engagement did occur.

All participants in both the control and DS groups wore gait belts during the assessments to ensure safety throughout the activities. While no stumbles, falls, trips, or other safety concerns were observed, the absence of refusals and the general compliance with wearing the gait belts further support the acceptability of the procedures used in this study. Self-correction strategies were however apparent, thus potential falls (‘near misses’[11]) were not accounted for. Additionally, no participants from the control group expressed concerns about the activities, and only two children from the DS group voiced mild apprehension. One of these participants used the word “careful” when assisted in stepping into a tandem stance, while another expressed fear of falling during balance-challenging activities, particularly those that involved vision restriction or required a narrow base of support.

Despite the minor concerns expressed by some participants, there was no widespread refusal to engage in the activities, suggesting that the assessment tasks were generally acceptable to the participants. Informal parent feedback also reinforced this conclusion, as no parents from either group raised concerns about the safety or appropriateness of the activities.

However, certain tasks proved more challenging for the DS group. The balance beam tasks were particularly difficult, with many participants requiring physical assistance (including touch assistance) to obtain and maintain the positions throughout. In some cases, participants resorted to placing one foot on the beam (BOT-2, Subtest 5, task 7: Walking forward heel-to-toe on a balance beam) and the other on the floor for additional stability, rather than completing the task as instructed. Most tasks were completed more effectively when demonstrated by a teacher or researcher, indicating the need for additional support for comprehension and execution. Modeling the tasks did however take longer than giving purely instruction, which potentially influenced the administration time. Shorter assessments were also completed more effectively, due to the limited concentration present in the DS group, as well as younger children in the control group.

Additional challenges arose during the standing on an incline assessment from the Kids-BESTest and Kids Mini-BESTest, where many DS participants required touch

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[11] Refer to glossary

assistance to find their balance before proceeding with the blindfolded portion of the task. Similarly, functional reach tasks in both the PBS and Kids-BESTest proved difficult to assess in the DS group, as participants struggled to comprehend the task instructions, even after demonstrations. During the standing arm raise task in the Kids-BESTest, one participant from the DS group mistakenly identified the purple adjustable kettlebell as a steering wheel and pretended to steer a taxi while completing the task, which affected the accuracy of the assessment. In the reactive postural responses section of the Kids-BESTest, many DS participants struggled to follow the instructions, resulting in lower scores despite the task being demonstrated. Fear of the unknown assessment and person (researcher) could have also potentially contributed to the difficulty following instructions.

In the TUG test with a dual task, the control group completed the task correctly as instructed, by either counting backwards by twos or listing random numbers while walking. However, the DS group responded better to a modification of the task, where they sang “Happy Birthday” in their preferred language while performing the walking portion, suggesting that an adapted approach was more acceptable for this group. The alternate stair touch assessment in the Kids-BESTest revealed further variations within the DS group. Some children required touch assistance, while another felt the task was unsafe and chose to lie down, placing both feet on the stair.

The testing environment also contributed to the task’s acceptability. The physiotherapy room at the school featured large mirrors along one wall, which distracted many DS participants, as they became focused on their own reflections rather than the task at hand. To mitigate this, assessments were conducted away from the mirrors, and distracting physiotherapy equipment was removed from the room to help maintain participants’ focus.

Overall, while most tasks were feasible, the DS group required additional assistance and adaptations to complete the activities optimally. These simple modifications, including task demonstrations, touch assistance, and adaptations to the testing environment, helped improve the acceptability of the balance assessments for participants with DS.

Time Efficiency

Each outcome measure was timed to determine the time efficiency of each (Table 19) This was only done in the DS group and not in the control group. The outcome measure that took the most time to complete was the Kids-BESTest, which correlates with the greater number of items that the outcome measure comprises. The BOT-2, Subtest 5 was completed in the shortest time frame, which was similar to that of the PBS compared to the Kids-BESTest. It should however be noted that because the score for the Kids Mini-BESTest was derived from that obtained in the full version of the Kids-BESTest, time efficiency could not be calculated for the particular outcome measure.

Table 19:

Time efficiency calculated for each outcome measure in the DS group

Outcome measure	Mean time taken (min)	Standard deviation (SD)	Range
PBS	8.77	1.65	6.17 to 12.07
BOT-2, Subtest 5	6.45	1.79	3.17 to 9.93
Kids-BESTest	21.52	4.20	16.25 to 34

The Kids-BESTest, consisting of 36 items, required an average time of 21.52 minutes to complete, with a standard deviation of 4.20 minutes and a range of 16.25 to 34 minutes. This equates to an average of approximately 0.60 minutes (36 s) per item. Extrapolating this average to the shorter Kids Mini-BESTest, which includes 16 items, the estimated time to complete this version would be approximately 9.6 minutes. This aligns with the expectation that reducing the number of test items significantly decreases administration time, potentially improving the feasibility of the Kids Mini-BESTest for clinical and research settings while retaining the assessment’s core objectives.

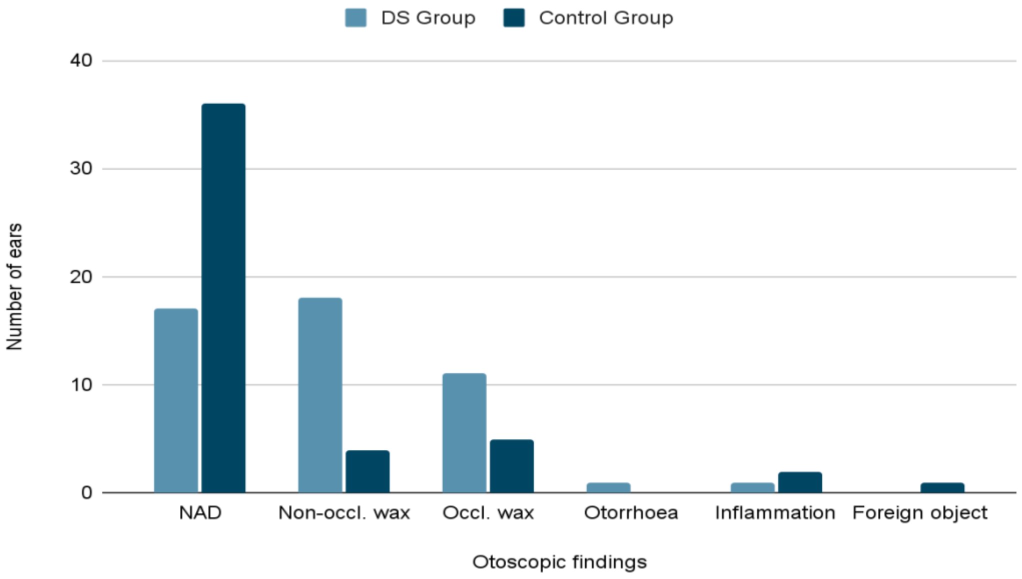
Risk Factors and Health Variables

Otologic Considerations

The otoscopy results indicate that the majority (75%) of the control group presented with no abnormalities, whereas the DS group presented with both occluding (22.92%) and non-occluding (37.5%) cerumen in the majority of the cases (Figure 11). It should be noted that the results presented in Figure 11 and Figure 12 are the results obtained per ear tested and not per participant, as some participants presented with different results in both ears. One participant in the DS group presented with unilateral otorrhoea, whereas another participant presented with unilateral inflammation. Within the control group, one participant presented with a foreign object in one ear, whereas another participant presented with inflammation of both ears. Children with either otologic abnormalities, abnormalities in BMI, or abnormalities in both were referred for further assessment and management with appropriate medical professionals.

Figure 11:

Otoscopy results of the groups compared



Legend: *NAD* = No abnormalities detected; *Occl.* = Occluding

Children with normal otoscopic findings (no abnormality detected - NAD) in both groups combined demonstrated significantly higher balance scores on the Kids Mini-BESTest ($p = 0.002$) and BOT-2 Subtest 5 ($p < 0.001$) compared to those with occluding or non-occluding cerumen (change throughout) (Table 20).

Table 20:

Comparison of balance assessment scores across otoscopy results for both groups combined

Outcome measure	Otoscopic results	n	Mean	SD	SE	F	p
Kids-BESTest	NAD	53	83.9	25.40	3.49	3.82	0.025
	Occluding cerumen	16	75.7	21.58	5.39		
	Non-occluding cerumen	22	67.8	19.08	4.07		
Kids Mini-BESTest	NAD	53	23.1	8.01	1.10	6.53	0.002
	Occluding cerumen	16	19.6	7.42	1.86		
	Non-Occluding cerumen	22	16.5	5.58	1.19		
BOT-2, Subtest 5	NAD	53	28.6	11.10	1.53	9.88	<0.001
	Occluding cerumen	16	21.7	11.14	2.79		
	Non-Occluding cerumen	22	17.3	7.89	1.68		
PBS	NAD	53	50.5	9.79	1.35	1.45	0.241
	Occluding cerumen	16	49.5	5.10	1.28		
	Non-occluding cerumen	22	47	3.56	0.76		

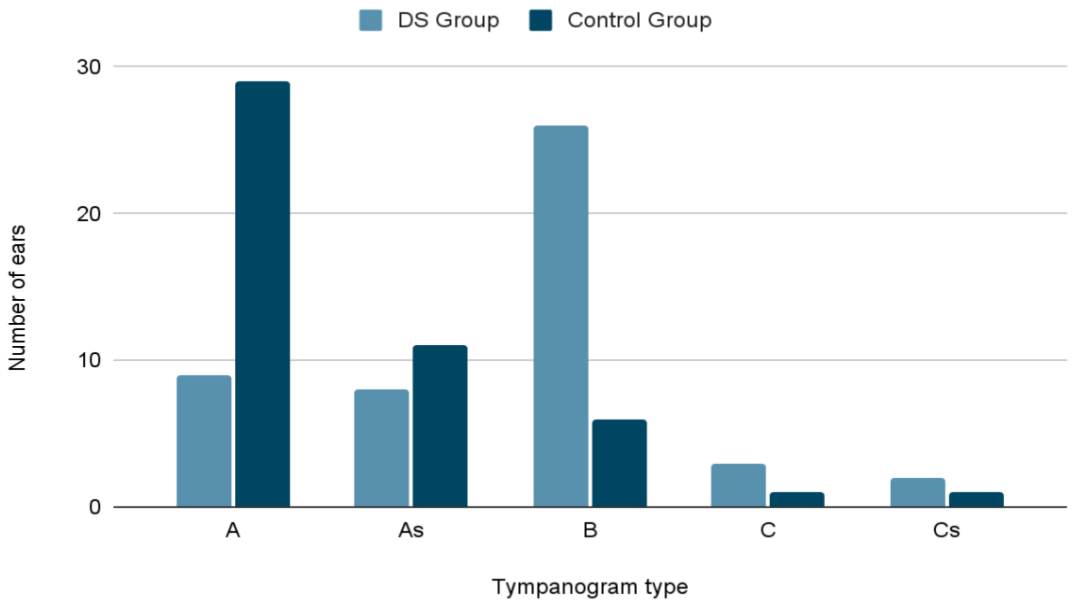
Legend: *NAD* = No abnormalities detected; *SD* = Standard deviation; *SE* = Standard error.

For the Kids Mini-BESTest, children with NAD achieved a mean score of 23.1, compared to 19.6 for children with occluding cerumen and 16.5 for those with non-occluding cerumen. Similarly, for BOT-2 Subtest 5, children with NAD scored a mean of 28.6, higher than those with occluding cerumen or non-occluding cerumen. While the Kids-BESTest also revealed a significant group ($p = 0.002$) difference, post hoc comparisons highlighted more pronounced effects for the Mini-BESTest and BOT-2 Subtest 5. The PBS did not show significant ($p = 0.241$) differences across otoscopy groups. These findings suggest that cerumen may influence performance on specific balance assessments, particularly those requiring dynamic balance and motor coordination.

The majority (60.42%) of the control group presented with type A tympanograms, indicating normal ear canal volume, static compliance and middle ear pressure (Figure 12). The DS group yielded type B tympanograms as the majority (54.17%) result. Type C and Cs tympanograms made up the minority of tympanometry results for both groups, being less in this control group (C: 2.08%; Cs: 2.08%) compared to the DS group (C: 6.35%; Cs: 4.17%). With regards to type As tympanograms a similar amount was obtained within both groups, the DS group presented with a total of 8 (16.67%) and the control group with a total of 11 (22.92%). Type B, C, Cs and As tympanograms all suggest abnormal middle ear function in their own right.

Figure 12:

Distribution of tympanogram types between groups



Analysis of the data revealed significant differences in balance scores across tympanogram types for the Kids-BESTest (p = 0.002), Kids Mini-BESTest (p < 0.001), and BOT-2, Subtest 5 (p < 0.001), but not for the PBS (p = 0.176). Participants classified as tympanogram Type B had significantly (p ≤ 0.002) lower scores on these measures compared to those classified as tympanogram Types A or As (Table 21). Specifically, for the Kids-BESTest, children with Type B tympanograms had a mean score of 68.1 (SD = 19.87), which was significantly (p = 0.002) lower than the scores for children with Type A and Type As. Similarly, for the Kids Mini-BESTest, participants with type B tympanograms had a mean score of 17.2 (SD = 6.03), compared to 23.8 (SD = 7.72) for Type A and 21.9 (SD = 8.20) for Type As (p < 0.001). For the BOT-2, Subtest 5, children with Type B had a mean score of 19.1 (SD = 8.73), which was significantly (p < 0.001) lower than the scores for Type A (M = 29.8, SD = 11.05) and Type As.

Table 21:

Comparison of balance assessment scores across tympanometry results

Outcome measure	Tympanogram type	N	Mean	SD	SE	F	p
Kids-BESTest	A	38	87.1	24.18	3.92	6.52	0.002
	As	19	81.1	24.47	5.61		
	B	35	68.1	19.87	3.36		
Kids Mini-BESTest	A	38	23.8	7.72	1.25	7.89	<0.001
	As	19	21.9	8.20	1.88		
	B	35	17.2	6.03	1.02		
BOT-2, Subtest 5	A	38	29.8	11.05	1.79	9.93	<0.001
	As	19	25.4	11.02	2.53		
	B	35	19.1	8.73	1.48		
PBS	A	38	50.9	9.74	1.58	1.77	0.176
	As	19	50.2	8.58	1.97		
	B	35	47.6	4.34	0.73		

Legend: *SD* = Standard deviation; *SE* = Standard error.

No significant differences were found across tympanogram types for the PBS (F = 1.77, p = 0.176), although Type B children exhibited slightly lower scores (M = 47.6, SD = 4.34) compared to Type A (M = 50.9, SD = 9.74) and Type As (M = 50.2, SD = 8.58). These findings highlight that middle ear status, as indicated by tympanometry, may influence balance performance, particularly on dynamic and functional measures like the Kids-BESTest, Kids Mini-BESTest, and BOT-2, Subtest 5.

Distortion product otoacoustic emissions (DPOAE) screening results indicate that the majority (95.83%) of the control group presented with “pass” results. Only one participant, who presented with bilateral cerumen occlusion, (4.17%) also presented with a “refer” result bilaterally. The DS group presented with more varied results, as the majority (60.42%) of the participants presented with a "refer" result in either one or both ears. One participant (4.17%) in the DS group did not give assent to the DPOAE screening being done. Slightly over one third (35.42%) of the results in the DS group were "pass" results.

The results of the analysis indicated significant differences in balance scores based on DPOAE screening results across all balance subtests when the participants are grouped in either "pass" or "refer" results (Table 22). Participants who passed the DPOAE screening scored significantly ($p \leq 0.002$) higher on all measures compared to those who received a refer result. Specifically, children with pass results had a mean score of 87.2 (SD = 20.13) on the Kids-BESTest, while those with refer results scored significantly ($p < 0.001$) lower with a mean of 66.1 (SD = 20.23), with a large effect size. Similarly, on the Kids Mini-BESTest, participants who passed the DPOAE screening had a mean score of 23.8 (SD = 6.86), significantly higher ($p < 0.001$) than those with refer results (mean = 16.4, SD = 6.26), with a large effect size. For the BOT-2 Subtest 5, the pass group scored a mean of 28.7 (SD = 10.18), whereas the refer group scored significantly ($p < 0.001$) lower (mean = 18.8, SD = 8.94), with a large effect size. Lastly, for the PBS, participants who passed the DPOAE screening had a mean score of 51.6 (SD = 6.23), while those with refer results had a mean of 47.3 (SD = 6.28), with a moderate effect size. These findings suggest that poorer DPOAEs (refer results) are associated with significantly ($p \leq 0.002$) lower balance performance across all tests.

Table 22:

Comparison of balance assessment scores across DPOAE screening results for both DS and control groups combined

Outcome measure	DPOAE Screening result	N	Mean	SD	SE	t	p	d
Kids-BESTest	Pass	61	87.2	20.13	2.58	4.84	<0.001	1.05
	Refer	33	66.1	20.23	3.52			
Kids Mini-BESTest	Pass	61	23.8	6.86	0.88	5.12	<0.001	1.11
	Refer	33	16.4	6.26	1.09			
BOT-2, Subtest 5	Pass	61	28.7	10.18	1.30	4.68	<0.001	1.01
	Refer	33	18.8	8.94	1.56			
PBS	Pass	61	51.6	6.23	0.80	3.25	0.002	0.73
	Refer	33	47.3	6.28	1.09			

Legend: *SD* = Standard deviation; *SE* = Standard error.

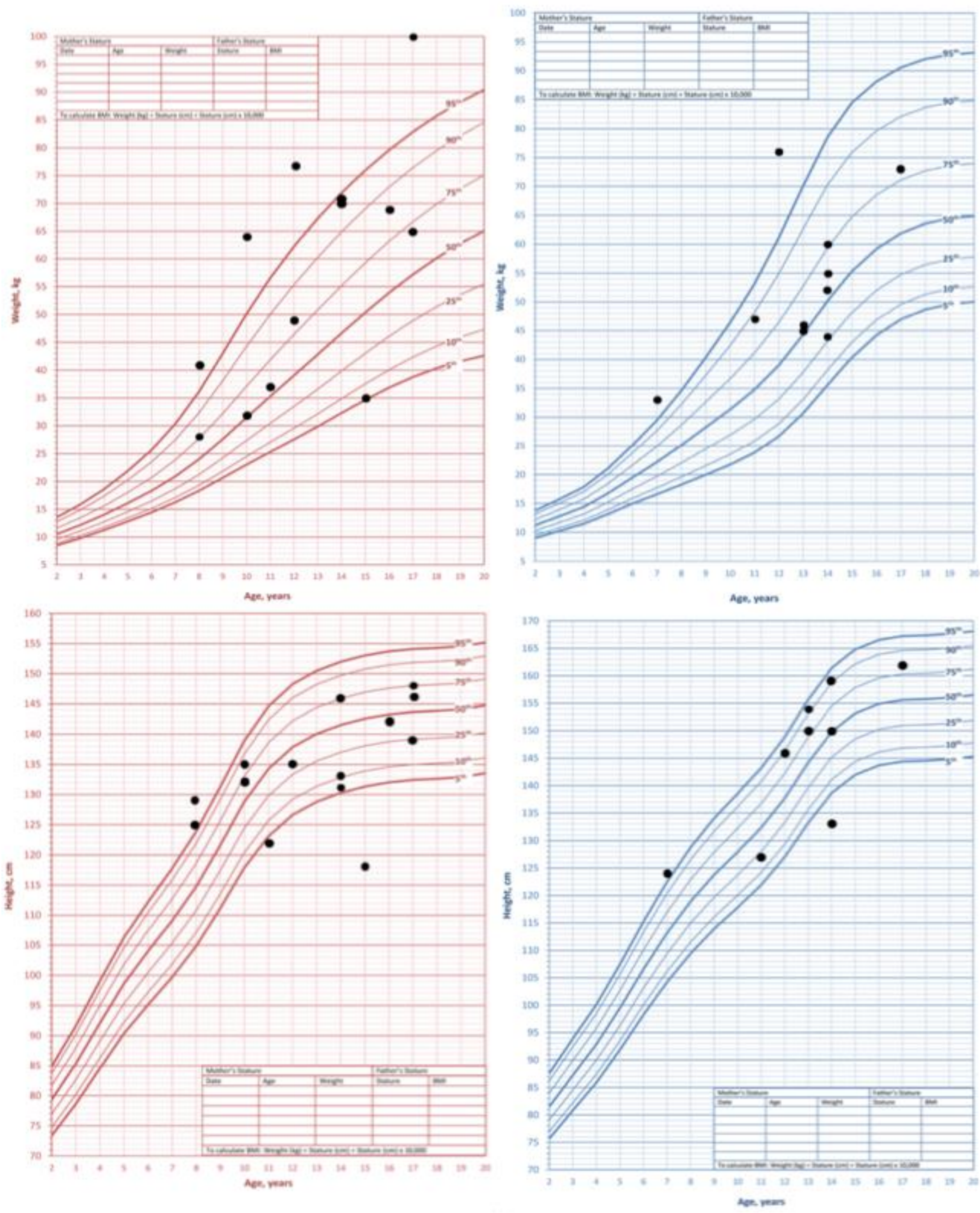
The relationship between otoscopy, tympanometry, and DPOAE screening results highlights distinct patterns of otologic health in the DS group compared to the control group. In the DS group, otoscopic findings revealed a higher prevalence of cerumen-related issues, which corresponded with the higher frequency of Type B tympanograms and more frequent "refer" results on the DPOAE screening. In contrast, the control group showed minimal otoscopic abnormalities, which aligned with the majority of Type A tympanograms and a high proportion of "pass" results on the DPOAE screening. The correlation between otoscopic findings, tympanometry results, and DPOAE outcomes suggests that the DS group experiences more frequent ear-related issues compared to the control group, who exhibited healthier ear function overall. This inter-dependence emphasizes the importance of assessing all three factors when evaluating ear and hearing health in these populations.

Body Mass Index (BMI)

The weight and height of each participant was plotted on growth charts developed by Zemel et al. (2015) for children with DS in the United States of America (USA), adopted by the Centers for Disease Control and Prevention (CDC) (Figure 13). Growth charts like these have not been developed for children with DS in a South African context, thus the growth charts by Zemel et al. (2015) were used, although they may not be totally representative of the South African population. The top graphs in Figure 13 represent the weight of the participants and the bottom graphs represent their height. Further the red (left) graphs represent the female participants and the blue (right) graphs represent the male participants. With regards to weight in the DS group, the majority of both male and female participants fall between the 50th and 95th percentile, whereas six participants fall above the 95th percentile of which four are female and two are male and only two participants fall between the 5th and 50th percentile. In terms of height of the DS group, similar results were obtained in the male participants with the majority of participants falling between the 50th and 95th percentile, one falling between the 5th and 50th percentile, one falling above the 95th percentile and one falling below the 5th percentile. The female participants show more variation in terms of height with half of the participants falling above the 50th percentile and the other half falling below it. Five participants fall between the 50th and 95th percentile while another five fall between the 5th and 50th percentile. Further only two female participants fall above the 95th percentile in terms of height and another two fall below the 5th percentile of whom one was male and the other female.

Figure 13:

Growth charts for children with DS (Zemel et al., 2015)



Legend: *kg* = kilogram; *cm* = centimetre

The mean height for male and female participants in the control group is equal, while the male participants in the DS group were taller on average than the female participants

(Table 23). On average the DS participants were shorter than the control group's participants. In terms of weight, female DS participants were heavier on average than the male participants, whereas the opposite is true for the control group. On average the control group was heavier compared to the DS group. Although the control group was taller and heavier on average than the DS group, the control group presented with overall lower BMI results on average. The control group's average BMI results are classified as healthy for both male and female, as well as for the group as a whole. The total BMI average for the DS group is classified as overweight, which is also the case for the average of the male participants in this group. The average BMI for the female participants in the DS group is classified as obese.

Table 23:

Height, weight and BMI averages for the represented groups

Construct measured	DS Group			Control Group		
	Male (SD)	Female (SD)	Total (SD)	Male (SD)	Female (SD)	Total (SD)
Height (m)	1.46 (0.13)	1.34 (0.09)	1.39 (0.12)	1.56 (0.16)	1.56 (0.1)	1.56 (0.13)
Weight (kg)	53.04 (13.24)	59.07 (28.50)	56.87 (22.74)	60.71 (28.69)	57.1 (18.88)	59.02 (24.27)
BMI	25.17 (6.04)	31.67 (11.77)	28.98 (9.95)	23.87 (8.39)	22.98 (5.8)	23.46 (7.19)

Legend: *m* = meter; *kg* = kilogram

The analysis revealed that higher BMI was significantly associated with lower performance across all balance outcome measures, as shown by both simple and partial correlation analyses. Pearson's correlation coefficients indicated moderate negative associations between BMI and balance scores (Table 24). When controlling for group (DS group versus typically developing controls), the negative correlations remained significant but slightly attenuated, suggesting that BMI independently influences balance performance beyond group differences. Partial correlations showed moderate negative relationships between BMI and Kids-BESTest , Kids Mini-BESTest, BOT-2 Subtest 5, and PBS. These findings highlight BMI as a significant factor affecting balance function in children, with implications for targeting obesity in interventions aimed at improving balance outcomes.

Table 24:

Correlations between BMI and balance assessment scores, including partial correlations controlling for group

Outcome measures used	BMI			
	Correlation Matrix		Partial correlation controlling for group	
	Pearson's r	p-value	Pearson's r	p-value
Kids-BESTest	-0.43	0.002	-0.34	0.018
Kids Mini-BESTest	-0.44	0.002	-0.40	0.006
BOT-2, Subtest 5	-0.43	0.002	-0.38	0.008
PBS	-0.49	<0.001	-0.41	0.005

Analysis revealed that children with a higher BMI exhibited significantly lower performance on Kids BESTest Item 19c (standing on a foam surface with eyes open) and significantly longer timing for Item 26 (TUG), even after controlling for group membership (Table 25). Correlation analysis indicated a strong negative relationship between BMI and standing on a foam surface with eyes open scores and a strong positive relationship with TUG timing. These relationships remained significant when controlling for group, with partial correlations for standing on a foam surface with eyes open and for TUG timing. No significant associations were observed for standing on a firm surface with eyes open, standing on a firm surface with eyes closed, standing on a foam surface with eyes closed, or TUG with dual task timing, either in the correlation or partial correlation analyses. These results underscore the influence of BMI on specific aspects of balance and mobility.

Table 25:

Relationship between BMI and mCTSIB & TUG Items, including partial correlations controlling for group

Outcome measures used		**BMI**			
		Correlation Matrix		**Partial correlation controlling for group**	
		Pearson's r	**p-value**	**Pearson's r**	**p-value**
mCTSIB conditions	**Standing eyes open on a firm surface**	-	1	-	1
	Standing eyes closed on a firm surface	-0.35	0.03	-0.26	0.073
	Standing eyes open on a foam surface	-0.49	<0.001	-0.41	0.005
	Standing eyes closed on a foam surface	-0.35	0.015	-0.25	0.091
TUG conditions	**Timed Get up & Go (TUG) simple timing**	0.61	<0.001	0.56	<0.001
	Timed Get up & Go (TUG) with dual task timing	0.21	0.189	0.15	0.361

Other potential factors that should be considered

During data collection, several potential risk factors were identified that could influence the balance test results in children with DS. Visual acuity was one such factor, as some participants had visual impairments that were corrected with glasses, while others were suspected to have visual issues but had not been formally diagnosed. This lack of assessment and correction could have influenced their ability to perform balance tasks effectively, potentially impacting their performance on the various balance measures.

Cognitive function levels were also observed to affect testing. Although cognitive function was not directly assessed in this study, it became evident that participants who were assumed to have lower cognitive function were more difficult to test than those with assumed higher cognitive function. These children appeared to have more difficulty understanding the tasks or following instructions, which may have led to inconsistencies in their performance on the balance tests.

The language of instruction also emerged as a potential influencing factor. The medium of instruction at the schools was English. Most of the children spoke Afrikaans or English (the researcher is fluent in both), but some were more proficient in isiXhosa, and one participant's home language was Swahili. Children whose first language was not Afrikaans or English struggled more to follow instructions, especially when tasks were only explained verbally in the child's preferred language (English or Afrikaans). This language barrier could have affected their ability to perform the balance tasks accurately, and it may explain some of the variability in test results, particularly for those children who were less proficient in the language of instruction.

Additionally, verbal communication abilities were influenced by a combination of language proficiency and cognitive function. Children with lower cognitive function or limited language proficiency appeared to have greater difficulty communicating during the assessment, which may have impacted their ability to fully engage with the tasks and provide accurate responses.

Vestibular function is another important factor that may have influenced test performance. Although not directly assessed in this study, vestibular dysfunction is common in individuals with DS and is known to impact postural control. In the absence of objective vestibular assessment tools, it is possible that undetected vestibular deficits contributed to balance variability across participants.

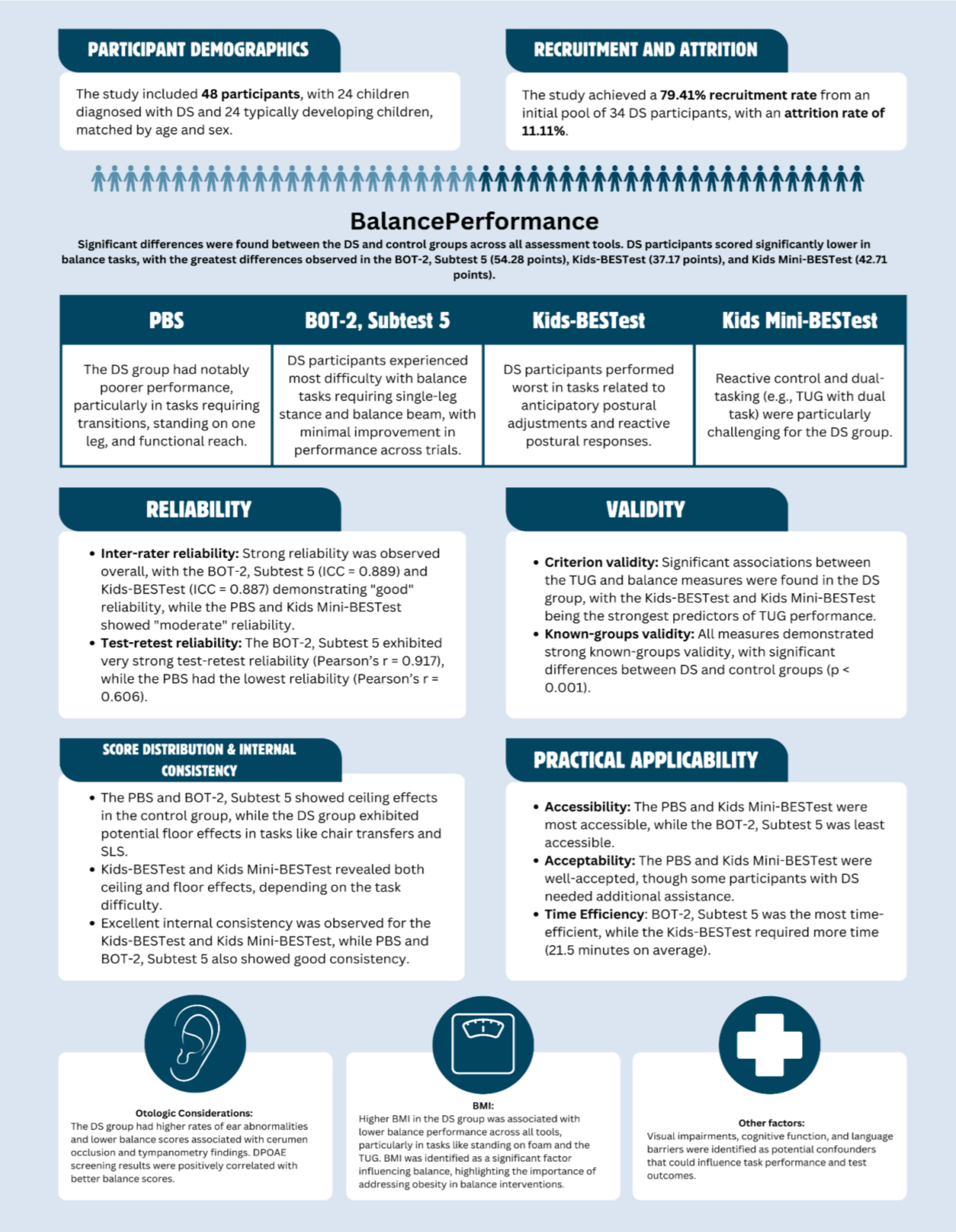
Contextual factors such as the time of day and testing environment were also noted. All assessments were conducted during school hours (08:00–13:00), with younger or more challenging participants typically assessed earlier in the morning. The presence of the school’s speech therapist and/or physiotherapist during testing may have helped some children feel more at ease, but for others, it could have introduced distractions. Testing took place in the school’s physiotherapy room, which was familiar to some children, but the impact of the testing location on the results remains uncertain and warrants further consideration.

Summary of Key Findings

The key findings are presented as an infographic in Figure 14.

Figure 14:

Infographic of key findings



PARTICIPANT DEMOGRAPHICS

The study included **48 participants**, with 24 children diagnosed with DS and 24 typically developing children, matched by age and sex.

RECRUITMENT AND ATTRITION

The study achieved a **79.41% recruitment rate** from an initial pool of 34 DS participants, with an **attrition rate of 11.11%**.

BalancePerformance

Significant differences were found between the DS and control groups across all assessment tools. DS participants scored significantly lower in balance tasks, with the greatest differences observed in the BOT-2, Subtest 5 (54.28 points), Kids-BESTest (37.17 points), and Kids Mini-BESTest (42.71 points).

PBS	BOT-2, Subtest 5	Kids-BESTest	Kids Mini-BESTest
The DS group had notably poorer performance, particularly in tasks requiring transitions, standing on one leg, and functional reach.	DS participants experienced most difficulty with balance tasks requiring single-leg stance and balance beam, with minimal improvement in performance across trials.	DS participants performed worst in tasks related to anticipatory postural adjustments and reactive postural responses.	Reactive control and dual-tasking (e.g., TUG with dual task) were particularly challenging for the DS group.

RELIABILITY

- **Inter-rater reliability:** Strong reliability was observed overall, with the BOT-2, Subtest 5 (ICC = 0.889) and Kids-BESTest (ICC = 0.887) demonstrating "good" reliability, while the PBS and Kids Mini-BESTest showed "moderate" reliability.
- **Test-retest reliability:** The BOT-2, Subtest 5 exhibited very strong test-retest reliability (Pearson's r = 0.917), while the PBS had the lowest reliability (Pearson's r = 0.606).

VALIDITY

- **Criterion validity:** Significant associations between the TUG and balance measures were found in the DS group, with the Kids-BESTest and Kids Mini-BESTest being the strongest predictors of TUG performance.
- **Known-groups validity:** All measures demonstrated strong known-groups validity, with significant differences between DS and control groups ($p < 0.001$).

SCORE DISTRIBUTION & INTERNAL CONSISTENCY

- The PBS and BOT-2, Subtest 5 showed ceiling effects in the control group, while the DS group exhibited potential floor effects in tasks like chair transfers and SLS.
- Kids-BESTest and Kids Mini-BESTest revealed both ceiling and floor effects, depending on the task difficulty.
- Excellent internal consistency was observed for the Kids-BESTest and Kids Mini-BESTest, while PBS and BOT-2, Subtest 5 also showed good consistency.

PRACTICAL APPLICABILITY

- **Accessibility:** The PBS and Kids Mini-BESTest were most accessible, while the BOT-2, Subtest 5 was least accessible.
- **Acceptability:** The PBS and Kids Mini-BESTest were well-accepted, though some participants with DS needed additional assistance.
- **Time Efficiency**: BOT-2, Subtest 5 was the most time-efficient, while the Kids-BESTest required more time (21.5 minutes on average).

Otologic Considerations:
The DS group had higher rates of ear abnormalities and lower balance scores associated with cerumen occlusion and tympanometry findings. DPOAE screening results were positively correlated with better balance scores.

BMI:
Higher BMI in the DS group was associated with lower balance performance across all tools, particularly in tasks like standing on foam and the TUG. BMI was identified as a significant factor influencing balance, highlighting the importance of addressing obesity in balance interventions.

Other factors:
Visual impairments, cognitive function, and language barriers were identified as potential confounders that could influence task performance and test outcomes.

Chapter 4: Discussion

This chapter discusses the findings, beginning with an overview of key results and their interpretation in the context of existing literature. The performance as well as the clinimetric properties of the assessment tools were critically examined to determine their feasibility and utility for both clinical and educational settings. The discussion further addresses the influence of risk factors and health variables on balance outcomes, highlighting otologic considerations and body mass index (BMI) as key contributors. The strengths and limitations of the study are outlined, alongside recommendations for future research and the practical implications of the findings for inclusive education and clinical practice. This structured approach offers a comprehensive synthesis of the study's contributions and potential impact.

Performance overview of outcome measures

Pediatric Balance Scale (PBS)

The results of the PBS revealed significant differences between the Down Syndrome (DS) and control groups. The total PBS score for the DS group (78.35%, standard deviation (SD) = 14.25) was significantly lower than the control group (98%, SD = 3), with a large effect size (d = 1.84). The findings align with existing literature accentuating balance challenges in individuals with DS due to motor and postural control deficits (Leite et al., 2018). Consistent with previous findings, the PBS demonstrated sensitivity in identifying specific areas of balance impairment, such as tasks involving narrow bases of support, postural adjustments, and functional reach (Franjoine et al., 2003; Galli et al., 2015).

Performance in items 3 (Transferring from one chair to another), 8 (Standing unsupported with one foot in front of the other (Sharpened Romberg)), 9 (Standing on one leg), and 14 (Reaching forward with outstretched arm while standing) illustrated these deficits. For instance, tasks requiring precision, such as heel-to-toe stance (Item 8) and standing on one leg (Item 9), yielded significantly lower scores in the DS group, suggesting reduced stability under narrow base conditions and difficulty maintaining challenging postures. Similarly, the functional reach task (Item 14) revealed limited forward reach in the DS group, consistent with reduced postural control and potential fear of falling, as reflected in participants' verbal expressions of concern during testing. Additionally, the ability to transfer from one chair to another (Item 3) demonstrated considerable challenges, highlighting transitioning’s critical role in functional mobility and relevance of such tasks in daily living. Evidence from prior research emphasises that difficulty with such sit-to-stand activities is associated with an increased risk of falling, given its reliance on lower limb strength, balance, and postural control (Pozaic, Lindemann, Grebe & Stork 2016). However, the challenges faced with instructions during item 3 could be due to cognition, as a lot of the DS participants needed verbal cueing to be able to optimally complete the task. The increased risk of falling underscores the importance of assessing this item, as impaired performance could serve as an indicator of fall risk in this population. These findings are consistent with earlier research indicating that postural instability in children with DS may stem from delayed sensory integration and motor control maturation (Chen, Yeh & Howe, 2015). The PBS's ability to detect these deficits, even in tasks requiring minimal equipment and straightforward instructions, highlights its clinical utility for assessing and monitoring balance in this population. The average age of participants in this study (13.3 years) falls within the period where putative maturation of the vestibular system takes place (Urbančič, Battelino & Vozel, 2023). Given the known developmental delays that individuals with DS face, maturation of the vestibular system may be delayed.

Malak et al. (2015) further support the relevance of the PBS in assessing balance in children with DS. They reported median PBS scores of 50 points (min 34, max 56) among children aged four years and older (Malak et al., 2015) compared to the rounded mean of 44 points in the current study. Malak and colleagues (2015) highlighted significant correlations between PBS scores and advanced motor functions measured by the Gross Motor Function

Measure-88 (GMFM-88) (e.g., walking, running, and jumping), reinforcing the critical role of balance in motor development.

The PBS showed an intra-class correlation coefficient (ICC) of 0.735, suggesting moderate to strong reliability. However, this is significantly lower than the reported ICCs of 0.98–0.99 in typically developing children (Franjoine et al., 2003) and that of the Turkish version (0.915) (Erden et al., 2020). Factors such as cognitive and language challenges, which influence consistency in scoring, likely contributed to this discrepancy, along with variability in motor responses and attention levels may have further affected reliability (Erden et al., 2020).

A test-retest reliability of r = 0.606 was obtained, reflecting a moderate to strong correlation. This is lower than the ICC values of 0.96 - 0.99 reported in typically developing children (Franjoine et al., 2003) and for the Turkish version (0.927) (Erden et al., 2020). Such discrepancies may stem from variability in participant performance due to attention, motivation, or fatigue, which are factors commonly observed in children with DS (Erden et al., 2020). The variability in task performance underscores the importance of considering these influences when using the PBS, particularly when tracking progress in vestibular rehabilitation therapy.

The results of the present study demonstrate that the PBS has moderate criterion validity when applied to children with DS. Significant associations with TUG (Timed Up & Go) scores were observed, explaining 49.4% of the variance in TUG performance ($R^2 = 0.494$). While this is lower than the variance explained by the full Children's-Balance Evaluations Systems Test (Kids-BESTest) and its shortened version (Kids Mini-BESTest), it supports the utility of the PBS as a clinical tool for assessing balance in this population. Previous research has further reinforced criterion validity, indicating strong correlations between the PBS and other balance measures, such as the BOT-2 and Functional Reach Test (Franjoine et al., 2003; Erden et al., 2020). However, its moderate predictive power suggests that it may be best suited as a supplementary measure rather than a primary tool in comprehensive balance assessments.

The PBS effectively distinguished between the two groups, with children with DS achieving a mean score of 78.35% (SD = 14.25) compared to 98% (SD = 3) in typically developing children at all ages. Items requiring advanced postural control, such as standing heel-to-toe (Item 8) and standing on one leg (Item 9), revealed the largest discrepancies, underscoring the difficulty of tasks involving stability in the DS group. This result corroborates earlier findings that the PBS has robust known-groups validity in identifying motor impairments (Franjoine et al., 2003).

The control group presented with ceiling effects, where scores were consistently near the maximum across several items. This suggests the PBS may be less sensitive in distinguishing between high-functioning children, particularly those with typical development (Franjoine et al., 2010). In contrast, the DS group demonstrated possible floor effects, particularly in item 3 (Transferring from one chair to another), where scores were significantly lower. These floor effects suggest difficulties children with DS face in performing tasks that require dynamic balance (Franjoine et al., 2010). The PBS's design, with its limited number of tasks, may not adequately capture the broad spectrum of balance performance, especially for children at the lower end of the balance spectrum.

Good internal consistency was demonstrated with a Cronbach’s alpha of 0.873. This result is consistent with the literature, which reports high internal consistency reliability for the PBS across various populations (Cronbach’s alpha ≥ 0.80). Franjoine et al. (2003) emphasised the robustness of the PBS, highlighting its sensitivity to balance impairments in children with motor difficulties. The strong internal consistency in this study further confirms the tool's suitability for assessing balance in children with DS, aligning with its established reliability across diverse paediatric groups.

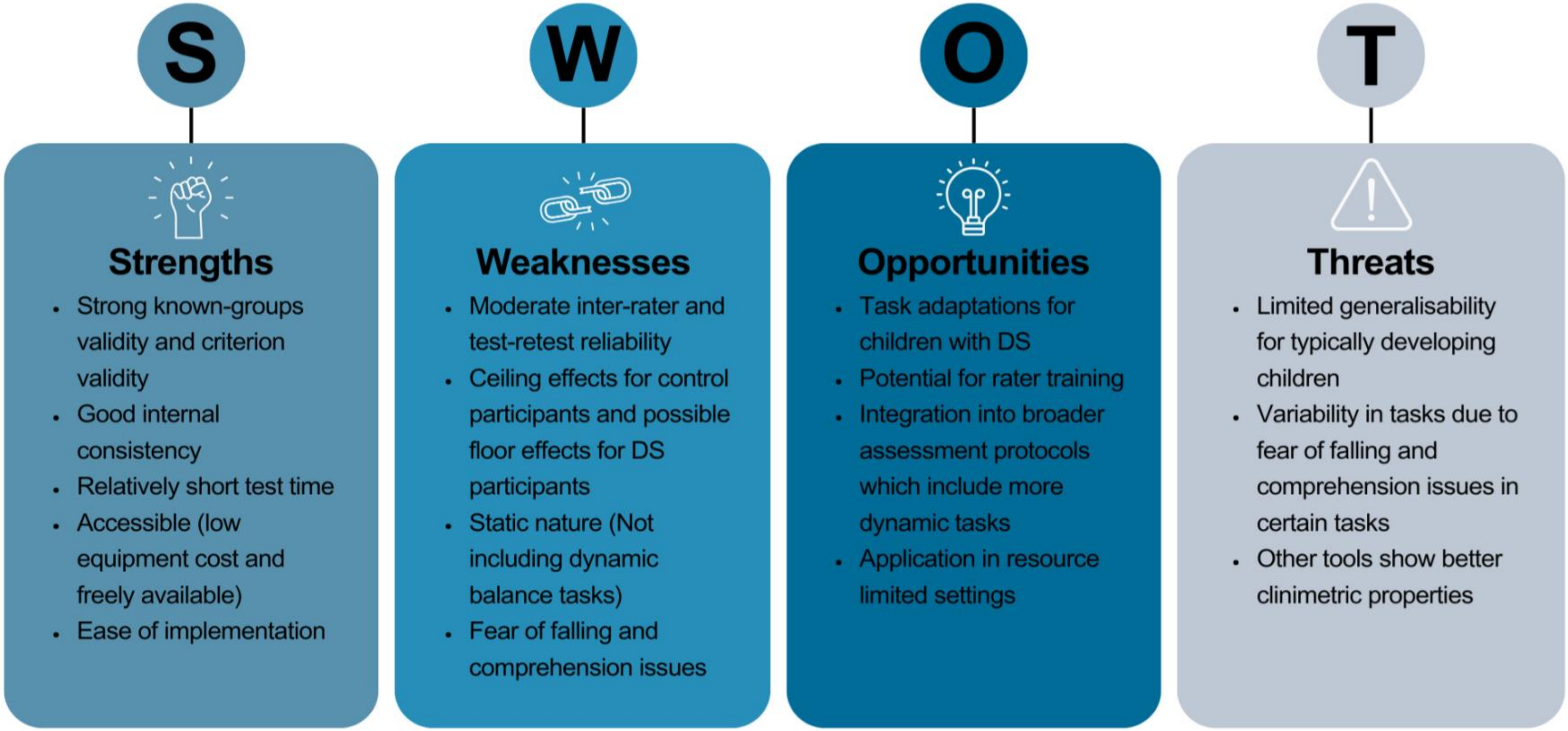
The PBS stands out as one of the most accessible tools in this study due to its minimal equipment requirements and affordability. This aligns with findings in the literature that highlight its practicality, particularly in resource-limited settings (Franjoine et al., 2003). The PBS's ease of use and compatibility with locally available materials enhance its feasibility in remote and rural areas. These attributes underscore its potential as a preferred tool in low-resource settings, especially where infrastructure and funding are inadequate.

Excellent time efficiency was demonstrated for the PBS, with a mean administration time of 8.77 minutes, significantly shorter than the approximately 15 minutes reported in the literature (Franjoine et al., 2003). This efficiency, combined with the PBS's simplicity and lack of reliance on specialised equipment, makes it particularly practical for resource-limited settings. Its short duration is advantageous for children with DS, who may have limited attention spans or stamina, ensuring that the assessment remains feasible in clinical and research contexts while maintaining its reliability.

The PBS demonstrated utility as an accessible and cost-effective tool for assessing balance in children and adolescents with DS. Its strengths include strong known-groups and criterion validity, good internal consistency, and a relatively short administration time, making it practical for clinical and educational settings (Figure 15). However, moderate reliability, the presence of floor effects in DS participants, and ceiling effects in typically developing children limit its broader applicability. Performance challenges on advanced tasks and psychological factors, such as fear of falling, further underscore the need for adaptations to improve engagement and reliability. These findings suggest that while the PBS has significant potential for use with children with DS, modifications to task difficulty, clearer instructions, and enhanced rater training are recommended to optimise its effectiveness and address its identified weaknesses.

Figure 15:

SWOT[12] analysis of the PBS



Strengths

- Strong known-groups validity and criterion validity
- Good internal consistency
- Relatively short test time
- Accessible (low equipment cost and freely available)
- Ease of implementation

Weaknesses

- Moderate inter-rater and test-retest reliability
- Ceiling effects for control participants and possible floor effects for DS participants
- Static nature (Not including dynamic balance tasks)
- Fear of falling and comprehension issues

Opportunities

- Task adaptations for children with DS
- Potential for rater training
- Integration into broader assessment protocols which include more dynamic tasks
- Application in resource limited settings

Threats

- Limited generalisability for typically developing children
- Variability in tasks due to fear of falling and comprehension issues in certain tasks
- Other tools show better clinimetric properties

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[12] Refer to glossary

As shown in Figure 15, despite its strengths, the PBS has limitations, such as exclusion of dynamic locomotion tasks, which are crucial for comprehensive balance assessment (Johnson et al., 2023). Nevertheless, the scale's accessibility and ease of administration make it a valuable tool in clinical, school, and research settings, particularly for guiding interventions and tracking developmental progress.

Bruininks-Oseretsky Test of Motor Proficiency, Second edition (BOT-2), Subtest 5: Balance

The results of the BOT-2, Subtest 5: Balance revealed significant differences between the performance of children with DS and typically developing children. The typically developing group achieved markedly higher scores (mean = 93.41%, SD = 7.26) compared to the group with DS (mean = 39.64%, SD = 17.87). This difference was statistically significant ($t = 13.65$, $p < 0.001$), with a large effect size ($d = 3.94$). These findings are consistent with prior research that indicates that balance deficits are possibly attributable to hypotonia, joint hypermobility, and delayed motor development (Malak et al., 2013; Jung et al., 2017).

The disparity in performance was evident across most tasks within the subtest. Tasks involving simpler postural demands, such as standing on a firm surface with eyes open and closed (Tasks 1 and 2), yielded scores for the DS group that were closer to those of their typically developing peers. Clinicians will recognise these tasks as the standard Romberg, which continues to be used as a clinical test despite its poor sensitivity, as previously suggested in the literature. It is interesting that despite large differences between the two groups of participants in other tests, the performance was very similar for the Romberg, upholding concerns about its ability to assess balance. The Romberg test has low sensitivity to vestibular lesions, specifically compared to caloric irrigation, thus it lacks sensitivity to optimally diagnose vestibular lesions (Moghadasi-Boroujeni & Adel-Ghahraman, 2021). However, as task complexity increased, such as standing on a straight line with one leg in the flamingo position (Task 5) or standing on one leg on a balance beam with eyes open (Task 8), the performance of the group with DS declined significantly. The challenge of maintaining single-leg stances (SLS) for extended periods, particularly under conditions of reduced visual input, aligns with known difficulties in sensory integration and postural stability in the DS population (Nocera et al., 2021).

The findings regarding task 5, (described above) merit further discussion. While this task was challenging for both groups, the typically developing children still performed better. This task demands a high degree of proprioceptive input and motor control, both of which are often impaired in individuals with DS (Malak et al., 2013). However, the influence of intellectual developmental delay (IDD) on task performance must also be considered. Participants with DS may have difficulty assessing the risk of falling during tasks, which could heighten anxiety or fear of falling, in turn influencing balance performance (Pikora et al., 2014). Recent evidence suggests that emotions such as fear and anxiety can alter balance control strategies in children (Hill et al., 2024; Pikora et al., 2014). Children with movement disorders, including DS, may exhibit maladaptive postural strategies characterised by reduced frequency and increased amplitude of centre of pressure movement, further compounding their challenges in balance tasks. For example, task 9 (standing on one leg on a balance beam with eyes closed) resulted in extremely low scores for the DS group, reinforcing the impact of sensory limitations on their balance abilities.

The minimal improvement observed across trials in the DS group provides further insight into their motor learning capabilities. For instance, in task 4 (standing on one leg with eyes open), the DS group increased their time only slightly from 2.59 s in trial 1 to 3.19 s in trial 2. This limited progress suggests intrinsic challenges in motor planning and adaptation, consistent with previous literature that reports reduced practice effects in children with DS (Aslan, 2016; Abdullah et al., 2022).

The BOT-2 Subtest 5 exhibited the highest inter-rater reliability in this study, with an ICC of 0.889, aligning with ICCs >0.90 in typically developing children (Deitz et al., 2007). Its structured format and clear scoring criteria make it robust for assessing children with DS, whose cooperation and understanding may vary.

In this study, the BOT-2, Subtest 5 demonstrated the highest test-retest reliability, with $r = 0.917$, reflecting very strong correlation and aligning closely with reliability coefficients ($r \geq 0.80$) reported in typically developing children (Deitz et al., 2007). Its structured format and clearly defined scoring criteria likely contribute to its robustness, making it a reliable choice for assessing balance in children with DS over time.

Moderate criterion validity was demonstrated in the current study, explaining 33.5% of the variance in TUG performance ($R^2 = 0.335$). Although its predictive power was lower than that of the Kids-BESTest and Kids Mini-BESTest, it still showed significant associations with TUG scores, indicating its utility for evaluating balance in children with DS. The BOT-2 has been validated in previous research, with moderate to strong correlations with other motor assessments, such as the Movement Assessment Battery for Children (Deitz et al., 2007). These findings suggest that the BOT-2, subtest 5 can provide valuable insights into balance performance, particularly when used in conjunction with other assessment tools.

With children with DS scoring 39.64% (SD = 17.87) compared to 93.41% (SD = 7.26) in typically developing children, the BOT-2, Subtest 5 showed the largest mean difference between groups. Performance gaps widened as task complexity increased, consistent with the tool's design to assess progressive balance challenges. Prior literature supports the BOT-2’s construct and criterion validity in identifying motor deficits in populations with developmental delays, IDD (Deitz et al., 2007).

The BOT-2, Subtest 5 also displayed ceiling effects in the control group, where participants achieved near-perfect scores on several tasks. However, floor effects were evident in items 5 through 9, which involved more challenging tasks such as SLS and balance beam activities. These tasks proved difficult for children in the DS group, whose balance deficits were most apparent in these specific activities. The difficulty identified reflects the previously described limitations of the BOT-2, Subtest 5 in assessing dynamic postural control and its reduced sensitivity to subtle improvements in balance (Deitz et al., 2007).

Good internal consistency (Cronbach’s alpha = 0.867) was observed in this study for the BOT-2, Subtest 5. This finding is consistent with the overall reliability of the BOT-2 reported by Deitz et al. (2007), who documented Cronbach’s alpha values exceeding 0.80 across most subtests. The result affirms that Subtest 5 provides a reliable measure of balance within the DS population, though the focus on static balance may limit its scope in capturing dynamic postural control.

The streamlined format and focus on balance-specific items ensured that the BOT-2, Subtest 5 was time-efficient. Its short administration time makes it an appealing option for assessing children with DS, especially those with lower cognitive functioning or limited endurance. Previous studies have noted that the BOT-2 combines efficiency with reliability and validity, making it suitable for use in both clinical and educational environments (Deitz et al., 2007). This balance between brevity and clinimetric robustness highlights the BOT-2 as a practical choice for routine screenings.

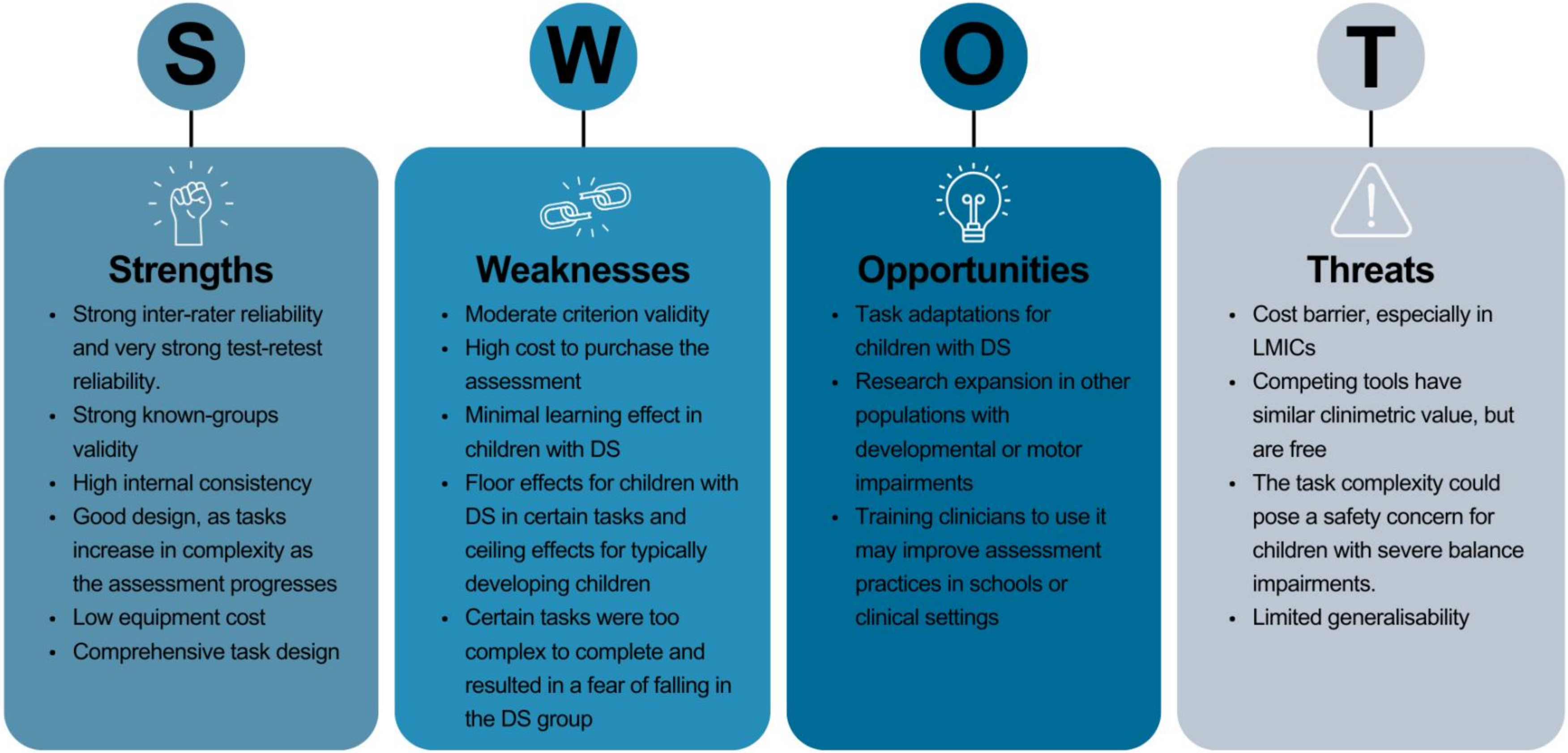
While the BOT-2, Subtest 5 boasts the lowest equipment cost among the tools evaluated, the price of the assessment itself presents a significant challenge for accessibility. The cost of purchasing the BOT-2 package in its entirety often makes it prohibitive for underfunded institutions, despite its efficiency and reliability (Deitz et al., 2007). This limitation underscores the need for more flexible purchasing options, such as standalone subtests, which could make the BOT-2, Subtest 5 more accessible to institutions with limited budgets. Furthermore, the reliance on imported materials adds to its financial burden, making it less feasible for widespread implementation in resource-constrained settings.

The BOT-2, Subtest 5: Balance, proved to be a reliable and valid tool for assessing balance deficits in children and adolescents with DS. Its strong inter-rater and test-retest reliability, alongside its ability to distinguish between DS participants and typically developing peers, underscores its clinical relevance (Figure 16). However, challenges such as the high cost, floor effects for DS participants, and ceiling effects for typically developing children limit its accessibility and generalisability, particularly in resource-constrained settings. Additionally, the complexity of certain tasks posed difficulties for the DS group, highlighting the need for task adaptations and enhanced evaluator training to improve its usability and safety. While the BOT-2, Subtest 5, offers significant potential for targeted assessments, these findings indicate that careful consideration of its limitations is necessary when implementing it in diverse populations or clinical contexts.

These results underscore the need for careful consideration when applying the BOT-2 balance subtest in populations with DS. While the typically developing children exhibited consistent performance across trials and conditions, the group with DS showed significant variability, particularly under vision-denied conditions. The findings align with Nocera et al. (2021), who noted inconsistent reliability of balance tasks in individuals with DS and suggested that certain tasks may require modification or further validation to enhance their applicability. This variability in performance raises questions about the BOT-2's sensitivity to detect subtle differences or improvements within this population, particularly following targeted interventions aimed at enhancing balance and motor coordination.

Figure 16:

SWOT analysis of the BOT-2, Subtest 5



Strengths

- Strong inter-rater reliability and very strong test-retest reliability.
- Strong known-groups validity
- High internal consistency
- Good design, as tasks increase in complexity as the assessment progresses
- Low equipment cost
- Comprehensive task design

Weaknesses

- Moderate criterion validity
- High cost to purchase the assessment
- Minimal learning effect in children with DS
- Floor effects for children with DS in certain tasks and ceiling effects for typically developing children
- Certain tasks were too complex to complete and resulted in a fear of falling in the DS group

Opportunities

- Task adaptations for children with DS
- Research expansion in other populations with developmental or motor impairments
- Training clinicians to use it may improve assessment practices in schools or clinical settings

Threats

- Cost barrier, especially in LMICs
- Competing tools have similar clinimetric value, but are free
- The task complexity could pose a safety concern for children with severe balance impairments.
- Limited generalisability

Children's-Balance Evaluations Systems Test (Kids-BESTest)

The Kids-BESTest provides a comprehensive assessment of balance, incorporating multiple components of postural control. In this study the control group presented superior performance compared to the DS group across all sections of the Kids-BESTest. These differences in performance reflect the challenges in balance function present in children with DS. These findings are consistent with previous research highlighting impairments in postural control, dynamic balance, and sensory integration among individuals with DS (Rutka & Pałac, 2020; Dewar et al., 2017).

Section 1 (Biomechanical Constraints) revealed notable issues in foot posture and centre of mass (COM) alignment among the DS group. The prevalence of pes planus or splayed feet in 70.83% of participants and the presence of abnormal antero-posterior (AP) and/or medio-lateral (ML) alignment in 79.17% support the hypothesis that biomechanical abnormalities contribute significantly to balance deficits in this population. These findings are consistent with previous literature indicating that structural differences like patellar instability, hip instability, spinal abnormalities, and foot deformities adversely affect balance in general within both children and adults (Dewar et al., 2017; Rako et al., 2021).

In Section 3 (Transitions), the DS group exhibited difficulty with anticipatory postural adjustments. Tasks requiring SLS highlighted substantial challenges, with the DS group maintaining the flamingo stance for shorter durations than the control group and had difficulty adopting the pose in general. However, no significant differences were observed between the left and right legs, suggesting likely more global balance deficits rather than asymmetry. These findings are supported by Leite et al. (2018), who noted that SLS tasks are particularly challenging for children with DS due to reduced postural stability and coordination. The significant delays and lower scores in the alternate stair touch task underscore difficulties in dynamic balance and motor planning, corroborating studies by

Bruininks and Bruininks (2005). The large effect size (d = 0.857) further emphasises the severity of these impairments.

Section 4 (Reactive Postural Responses) revealed difficulties in executing compensatory stepping corrections in response to perturbations of balance. The DS group's challenges in following verbal or demonstrated instructions suggest that cognitive and attentional factors also play a role in balance performance. This aligns with Rutka and Pałac's (2020) observations of limited cooperation and attention span in children with DS, which can complicate the administration of complex balance tasks.

In Section 5 (Sensory Orientation), significant differences were observed between groups as sensory cues were progressively reduced. While both groups performed well on simpler tasks (e.g., standing on a firm surface with eyes open), the DS group's performance declined significantly under more challenging conditions (e.g., standing on a foam surface with eyes closed). These results highlight sensory integration deficits in children with DS, particularly in processing vestibular and somatosensory inputs. Shumway-Cook and Horak (1986) and Christy, Payne, Azuero & Formby (2014) similarly reported that children with balance impairments struggle with tasks involving altered sensory conditions. The effect sizes for these tasks, especially in conditions with limited sensory inputs (e.g., d = 1.660 for Item 19c), further underscore the pronounced deficits in the DS group.

TUG tasks (Items 26 and 27) demonstrated the DS group's difficulties with functional mobility, particularly in dual-task conditions. The adjusted dual-task requirement for the DS group (singing “Happy Birthday” instead of counting backward) did not eliminate performance disparities, with a third of participants unable to complete the task. This inability to walk and talk directly links to fall risk, as Raffegeau, Haddad, Huber & Rietdyk (2018) found. The significant differences in completion times and scores (e.g., $t = -5.45$, $p < 0.001$ for Item 26 timing (TUG simple)) align with findings by Beerse, Lelko & Wu (2019) ($t = 4.82$,

$p < 0.001$), who identified prolonged phase durations and slower movement velocities in children with DS during TUG tasks.

The inability to perform a TUG dual task translates directly to everyday activities, where simultaneous motor and cognitive demands are common. For example, going shopping with another person may require walking while engaging in conversation or navigating a trolley while browsing items. Zukowski et al. (2021) indicated that dual-tasking impacts gait and cognitive performance in real-world environments, particularly among populations with mobility challenges. The study found that stride velocity during dual-task walking was significantly reduced compared to single-task walking, emphasising the additional cognitive and motor demands placed on individuals. For children with DS, similar dual-task challenges could exacerbate difficulties in adapting to dynamic and complex environments, further compromising balance and increasing the risk of falls or reduced participation in activities requiring multitasking.

Strong inter-rater reliability was demonstrated for the Kids-BESTest, with an ICC of 0.887, slightly below the excellent ICC of 0.96 reported for typically developing children (Dewar et al., 2017). Rutka and Pałac (2020) also reported high inter-rater reliability for this tool in children with DS, with domain-specific ICCs ranging from 0.22 (Biomechanical Constraints) to 0.98 (Reactive Postural Response). While Rutka and Palac's (2020) findings support the test's sensitivity to postural control disorders, the challenges of administering the test to children with DS, such as the need for prompts and modifications, may account for variability between raters.

A test-retest reliability of $r = 0.736$ was achieved, indicating strong consistency. This is lower than the ICC of 0.93 reported for typically developing children (Dewar et al., 2017). Findings from Rutka & Pałac (2020) confirm the robust intra-rater reliability of the Kids-BESTest in children with DS, with ICCs ranging from 0.95 to 0.97 across domains. However, domain-specific variability was noted, with ICC values ranging from 0.53 (Biomechanical

Constraints) to 0.97 (Stability Limits). The current study's slightly reduced reliability may reflect challenges in understanding and executing test instructions among children with DS, supporting recommendations for combining real-time scoring with video reviews for enhanced accuracy (Rutka & Pałac, 2020).

The Kids-BESTest emerged as one of the strongest predictors of balance performance in children with DS. It explained 53.6% of the variance in TUG scores ($R^2 = 0.536$), with a significant positive model coefficient. This high explanatory power aligns with prior studies that have demonstrated the Kids-BESTest's strong criterion-related validity, particularly in detecting postural control and stability deficits (Dewar et al., 2021). The Kids-BESTest's ability to capture comprehensive aspects of balance, including sensory integration and functional task performance, makes it an effective tool for assessing balance impairments in clinical populations.

The Kids-BESTest clearly distinguished between DS participants and typically developing participants, especially in tasks requiring postural adjustments. The DS group scored a mean of 54.19% (SD = 16.69) compared to 98.61% (SD = 4.44) in typically developing children. These results echo findings by Rutka and Pałac (2020), who reported that the Kids-BESTest is highly sensitive to postural control deficits in children with DS, particularly in domains such as stability limits and reactive balance.

Varied performance was observed across groups in the Kids-BESTest. The control group showed ceiling effects in several items, suggesting that the outcome measure may not fully capture subtle differences in balance among children with typical development (Dewar et al., 2021). However, this test effectively detected significant difficulties within the DS group, particularly in sections that required postural control adjustments.

The Kids-BESTest showed excellent internal consistency, with a Cronbach's alpha of 0.971. This result aligns with previous findings by Dewar et al. (2017), who reported strong internal reliability metrics for the Kids-BESTest in typically developing children. Its comprehensive framework, evaluating multiple domains of balance, likely contributes to its high reliability, ensuring consistent measurement. This consistency underscores its effectiveness in assessing complex balance impairments in children with DS.

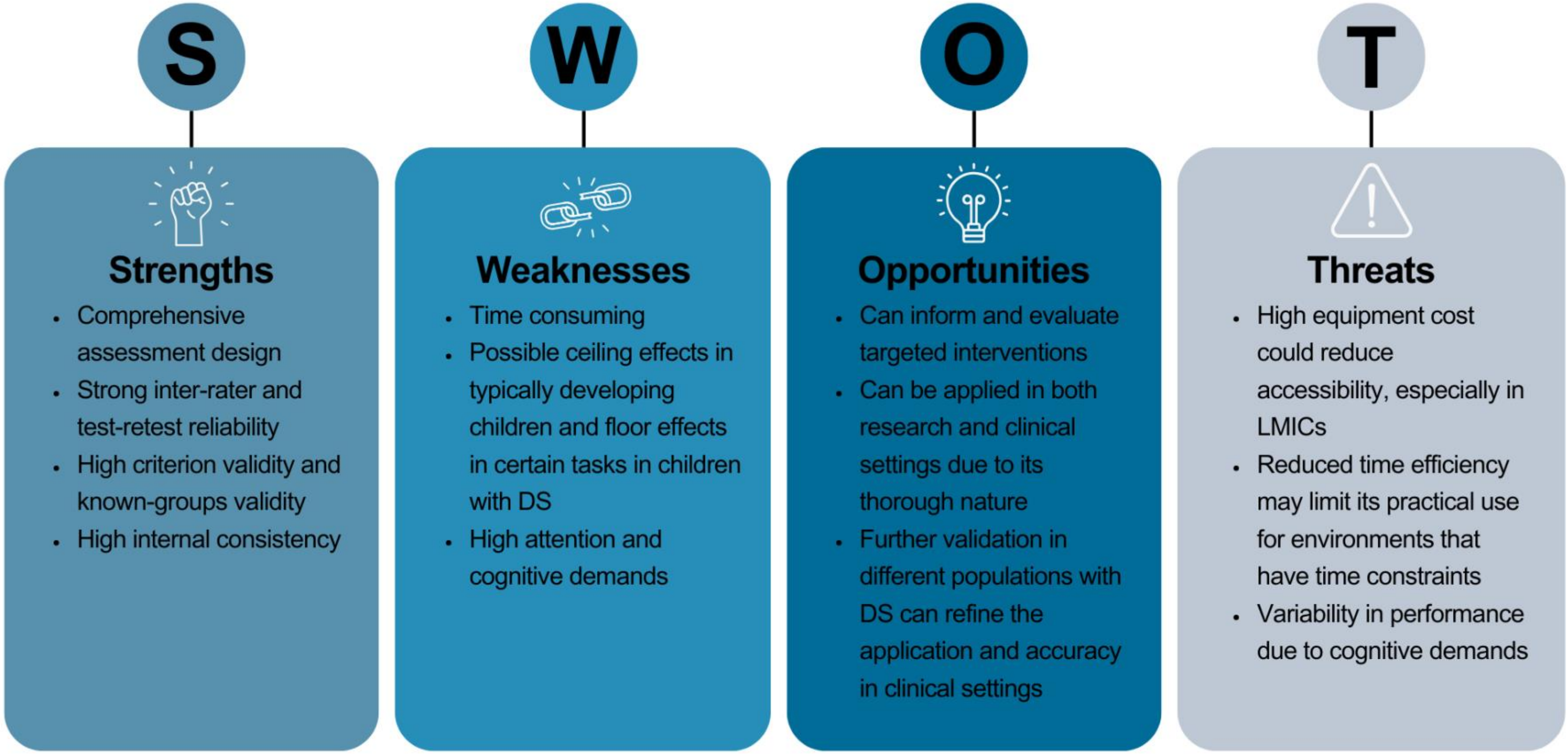
The high equipment cost of the Kids-BESTest, can be a significant financial obstacle for many institutions, making it less accessible. This aligns with findings by Dewar et al. (2017), who noted the test’s expense as a limitation in low-resource contexts. While the comprehensiveness of the Kids-BESTest justifies its cost in well-resourced settings, it remains inaccessible for most underfunded schools and clinics in South Africa.

The Kids-BESTest was the least time-efficient of the four measures. Its longer administration time reflects its detailed assessment of multiple balance domains, which, although valuable, may present challenges in contexts where time is limited. These findings align with Dewar et al. (2017), who noted the potential limitations of the Kids-BESTest for younger children or those with reduced attention spans. Despite these challenges, the detailed insights the test provides can justify the additional time in settings requiring a thorough balance profile, such as specialised clinics or research studies.

The Kids-BESTest demonstrated its value as a comprehensive and reliable tool for assessing balance in children and adolescents with DS. Its ability to evaluate multiple domains of balance and effectively differentiate between DS and typically developing groups highlights its clinical relevance (Figure 17). However, limitations such as the test’s time-consuming nature, high equipment cost, and the presence of floor and ceiling effects underscore challenges in its practical application, particularly in resource-limited or time-constrained settings. The complexity of some tasks and the cognitive demands of the test further emphasised the need for adaptations to improve accessibility and usability for children with DS. Despite these challenges, the Kids-BESTest holds promise for identifying specific balance impairments, informing targeted interventions, and contributing to the advancement of balance assessment in both research and clinical contexts.

Figure 17:

SWOT analysis of the Kids-BESTest



S

Strengths

- Comprehensive assessment design
- Strong inter-rater and test-retest reliability
- High criterion validity and known-groups validity
- High internal consistency

W

Weaknesses

- Time consuming
- Possible ceiling effects in typically developing children and floor effects in certain tasks in children with DS
- High attention and cognitive demands

O

Opportunities

- Can inform and evaluate targeted interventions
- Can be applied in both research and clinical settings due to its thorough nature
- Further validation in different populations with DS can refine the application and accuracy in clinical settings

T

Threats

- High equipment cost could reduce accessibility, especially in LMICs
- Reduced time efficiency may limit its practical use for environments that have time constraints
- Variability in performance due to cognitive demands

Overall, the performance of the DS group across the Kids-BESTest highlights pervasive balance impairments attributable to biomechanical, sensory, and cognitive factors. The comprehensive nature of the Kids-BESTest, which integrates static and dynamic tasks as well as sensory and functional components, underscores its utility in identifying specific deficits in children with DS.

Children's-Balance Evaluations Systems Test shortened version (Kids Mini-BESTest)

The Kids Mini-BESTest, a condensed version of the full Kids-BESTest, was designed to assess specific domains of static and dynamic balance in a more time-efficient manner. The results of this study indicate that the typically developing children outperformed the children with DS across most of the test items, aligning with previous findings in the literature (Rutka & Pałac, 2020). Statistically significant differences were observed in several items, particularly those assessing reactive postural control and dynamic balance, such as "Rise to toes," "Compensatory stepping corrections," and "Stand on one leg." These results suggest that children with DS exhibit greater difficulty in tasks that demand rapid postural adjustments and balance responses, a finding consistent with other studies of balance function in children with developmental disabilities (Leite et al., 2018; Dewar et al., 2017).

Notably, the items with the largest effect sizes, such as "Stand on one leg" and "Compensatory stepping correction" (both forward and lateral), demonstrated considerable disparities between the two groups. These tasks require high levels of balance control and coordination, both of which are typically impaired in children with DS due to deficits in strength, postural stability, and motor planning (Rutka & Pałac, 2020). The significant differences in these tasks underline the challenges faced by children with DS in maintaining balance when reacting to perturbations which might easily happen in childhood.

Interestingly, both groups performed similarly well on the "Sit to stand" and "Stance feet together, eyes open, firm surface" tasks. These tasks involve less dynamic balance control and permit visual cues, so are generally less challenging, which may explain the higher scores observed across both groups. The high scores on these items could reflect the relative ease with which children with DS are able to perform more stable and less complex movements. This is in contrast to the more dynamic tasks, where they face more pronounced difficulties.

The items that proved challenging for both groups were "Incline - eyes closed" and "TUG with dual task." These tasks involve elements of sensory integration (e.g., vestibular and somatosensory inputs) and multi-tasking, which may increase the cognitive load and further challenge balance control (Shumway-Cook & Horak, 1986). The lower scores on these tasks for both groups may indicate that they are more sensitive to the effects of sensory and cognitive demands, which aligns with the findings from other studies (Christy et al., 2014; Itzkowitz et al., 2016). The children with DS, in particular, may struggle more with tasks that require rapid sensory processing and multi-tasking due to their underlying neurological and motor deficits.

The Kids Mini-BESTest had the lowest inter-rater reliability in this study, with an ICC of 0.714. This aligns with the challenges noted by Rutka and Pałac (2020), who observed intra-rater ICCs of 0.87–0.99 across domains, but variability in Sensory Orientation (ICC = 0.4). While the shorter format of the Kids Mini-BESTest is more feasible for children with attention difficulties, its adjusted items may result in lower scoring precision. Rutka and Pałac (2020) also recommended combining real-time scoring with video review to improve reliability which was not done in this research. Use of video would be a feasible option in research settings, but not necessarily in clinical settings. However, the almost universal use of smartphones, which have built in video capacity, could well be useful. Inexperienced examiners could share videos with experts, allowing support in under-resourced context. The South African Protection of Personal Information Act (POPIA) should however be considered in events where videos are shared among clinicians, as the act stipulates that the person who is the subject of a video needs to consent to both being filmed and for the video to be shared (POPIA, 2013).

A test-retest reliability of r = 0.758 was observed, classified as strong. This aligns with the ICC range of 0.87 - 0.99 reported by Rutka and Pałac (2020) for intra-rater reliability in the DS population. The adjusted and simplified format of the Kids Mini-BESTest likely contributes to its feasibility for younger or less attentive participants but may reduce the sensitivity to subtle postural control issues compared to the full Kids-BESTest.

The Kids Mini-BESTest demonstrated the highest criterion validity among the four measures in the study, explaining 55.5% of the variance in TUG performance ($R^2 = 0.555$). This finding supports its role as a highly effective tool for detecting balance impairments in children with DS. The Kids Mini-BESTest's focus on dynamic balance and functional stability likely contributes to its strong associations with TUG scores. Its criterion validity has also been supported in other clinical populations, such as children with cerebral palsy (Dewar et al., 2021). The current study's results further highlight the utility of the Kids Mini-BESTest as a sensitive and specific measure for identifying balance deficits in paediatric populations with motor impairments. The Kids Mini-BESTest also demonstrated strong known-groups validity, differentiating between the groups. However, its simpler structure and fewer items may reduce sensitivity compared to the full Kids-BESTest.

The Kids Mini-BESTest exhibited ceiling effects in the control group and floor effects in the DS group for tasks like sensory orientation and anticipatory postural control. These results align with Rutka and Pałac (2020), who found that both the Kids-BESTest and Kids Mini-BESTest could assess postural control and balance disorders effectively in children with DS. However, attention and cooperation issues in children with more severe intellectual disabilities could complicate test administration.

Excellent internal consistency was demonstrated in this study, with a Cronbach's alpha of 0.930. These findings are consistent with Dewar et al. (2021), who reported excellent test-retest reliability and internal consistency for the tool, particularly in clinical populations. The Kids Mini-BESTest's shorter format and focus on key domains of balance may contribute to its practicality and strong reliability in a specialised population like children with DS, thus making it an excellent screening tool to use.

Similar to the PBS, the Kids Mini-BESTest demonstrated high accessibility due to its relatively low equipment cost and streamlined administration. Its affordability makes it a viable option for underfunded institutions while maintaining its validity and reliability as a measure of balance (Dewar et al., 2017). Additionally, the shorter time required to administer the Mini-BESTest enhances its practicality for use in children with DS, who may have limited attention spans or stamina.

A level of time efficiency similar to the BOT-2 Subtest 5 was exhibited, making the Kids Mini-BESTest a practical alternative to the longer Kids-BESTest. Its shorter administration time is particularly advantageous for children with DS, who may have limited mobility or attention spans. The Kids Mini-BESTest effectively balances brevity with a robust assessment of dynamic balance, reinforcing its utility in both clinical and research settings. Its efficiency and practicality position it as a strong option for use in routine assessments or time-sensitive environments.

The Kids Mini-BESTest demonstrated promising potential as a dynamic balance assessment tool for children with DS, offering strong criterion validity, good internal consistency, cost effectiveness and time efficiency (Figure 18). Its ability to differentiate balance performance between children with DS and typically developing children supports its clinical and research utility. However, moderate inter-rater reliability, ceiling effects in typically developing children, and challenges with highly dynamic tasks in children with DS highlight areas for refinement. The findings emphasised the need for further validation, particularly in addressing scoring variability and exploring the influence of otological conditions on balance performance. Despite these limitations, the Kids Mini-BESTest provides a practical and accessible alternative to more comprehensive assessments, particularly in resource-constrained settings, with opportunities for broader clinical application and targeted interventions.

The Kids Mini-BESTest balances practicality and performance, demonstrating strong criterion validity, good internal consistency, and the ability to address dynamic balance tasks essential for assessing functional impairments in children with DS. Its time efficiency and affordability make it particularly advantageous for use in resource-constrained environments. The Kids Mini-BESTest also serves as a practical preliminary diagnostic tool, allowing clinicians and researchers to quickly identify balance deficits and determine the need for further assessment. For a more detailed diagnostic evaluation, the Kids-BESTest can be used subsequently to the Kids Mini-BESTest, offering a deeper understanding of specific balance impairments and aiding in the identification and monitoring of areas for targeted intervention. Despite some limitations, such as moderate inter-rater reliability and challenges with certain dynamic tasks, the Kids Mini-BESTest stands out as a practical, versatile, and clinically relevant tool for use in children and adolescents with DS.

Figure 18:

SWOT analysis of the Kids Mini-BESTest

Strengths

- Strong test-retest reliability
- Strong criterion validity and known-groups validity
- Good time efficiency
- Excellent internal consistency
- Low cost

Weaknesses

- Moderate inter-rater reliability
- Challenges in some dynamic tasks like the compensatory stepping corrections
- Possible ceiling effects in typically developing children and floor effects in DS children
- Time efficiency was not directly measured

Opportunities

- Can be applied in both research and clinical settings due to its validity and internal consistency
- Further examination of scoring procedures could improve inter-rater reliability
- Use in lower-resourced clinical settings
- Can be used in future studies that examine the impact of otological considerations on balance

Threats

- Limited sensitivity in typically developing children
- Ceiling effects in typically developing children and floor effects in children with DS
- Inconsistent inter-rater reliability

Practical applicability within the South African context

The varying equipment costs of balance assessment tools present a challenge in resource-constrained settings. The purchasing and sharing of equipment among multiple facilities could potentially offer a practical solution in under-resourced areas. The reliance of many rural hospitals and clinics on non-governmental organisations (NGOs), non-profit organisations (NPOs), government initiatives or corporate social responsibility (CSR) programmes for equipment funding (Zihindula, John, Gumede & Gavin, 2019) underscores systemic under-resourcing within the healthcare and education sectors. Limited funding, inadequate infrastructure, and systemic inequities further exacerbate barriers to healthcare access for individuals with disabilities, including those with DS (Walton & Engelbrecht, 2022; Mahlaule et al., 2024). Financial support from external organisations or government subsidies could be pivotal in making these tools more accessible.

South Africa’s unequal distribution of healthcare resources, especially between public and private sectors, is a persistent barrier to accessing balance assessment tools (Naidoo, 2012). The public health sector, which serves 84% of the population, is often under-resourced, limiting the availability of specialised diagnostic and therapeutic tools in rural and underserved areas (Maphumulo & Bhengu, 2019). Additionally, offering subtests as standalone purchases could benefit audiologists and other professionals who do not require the complete assessment package.

Procurement of equipment through online platforms such as Takealot.com or local retail stores like Mr. Price Sport and Makro is a feasible option in urban areas, it is less accessible in remote regions. Infrastructural challenges, including unreliable internet connectivity, power outages, and limited access to courier services in areas like the Eastern Cape (EC) and KwaZulu-Natal (KZN), hinder institutions in rural settings from acquiring essential tools. Decentralising procurement processes, establishing regional equipment banks, or leveraging partnerships with local businesses and courier services could mitigate these challenges. Historical inequities rooted in apartheid continue to marginalise under-resourced areas, further limiting access to necessary tools (Walton & Engelbrecht, 2022).

The development of cost-effective, locally manufactured tools is critical in reducing dependence on imported equipment. While tools like the PBS and Kids Mini-BESTest offer viable options for low-resource settings, the development of local alternatives would require extensive research to ensure their reliability and validity, potentially adding to costs. Policymakers should prioritise such initiatives to ensure long-term sustainability in the South African context.

As noted by Maphumulo and Bhengu (2019), healthcare reform initiatives such as the National Health Insurance (NHI) policy aim to improve access to healthcare services, but significant challenges persist, including infrastructure deficits and staff shortages. Political will and strategic leadership are critical to addressing these issues, as highlighted by Louw et al. (2023). Developing normative data for South African populations, along with culturally and linguistically appropriate training materials, could enhance the applicability of balance assessments across diverse settings.

The extrapolation of specific balance-related tasks from the PBS, BOT-2, and Kids-BESTest offers an opportunity to create a highly specific and sensitive assessment instrument for special populations, such as children with DS and potentially those with deafness. Items like standing on one leg (PBS items 9, BOT-2 tasks 4 and 5, and Kids-BESTest item 11), which consistently challenge the DS group, highlight their difficulty with static and dynamic postural control. Similarly, tasks like transferring between chairs (PBS item 3) or alternating stair touches (Kids-BESTest item 12) further emphasised challenges in motor planning and anticipatory postural adjustments. Tasks evaluating functional reach (PBS item 14) or sensory reliance (e.g., BOT-2 and Kids-BESTest tasks with eyes closed) also reveal critical gaps in balance strategies, particularly under altered sensory conditions. Incorporating these specific tasks into a composite instrument could yield a tool tailored to detect subtle balance deficits and track improvements, even in populations with significant motor and sensory impairments. This instrument could be particularly beneficial in evaluating the interplay between sensory modalities, motor control, and adaptive strategies in children with complex needs.

Language barriers and cognitive limitations often impact the accessibility and effectiveness of balance assessments. Many children with DS lack access to assessments in their home language or struggle with task instructions. The development of culturally appropriate, multilingual training materials and test facilitators is essential to overcome these barriers.

While this study eliminated financial barriers by covering equipment costs for participating schools, this approach is not sustainable for broader implementation. Institutions must adopt systemic solutions to ensure equitable access to balance assessments. Simplified, low-tech tests requiring minimal training and equipment may offer feasible alternatives for low-resource settings (Seedat et al., 2018). Efforts to improve accessibility must also include logistical support, such as improving infrastructure in rural areas and addressing systemic inequities in resource distribution.

Improving the accessibility of balance assessments and rehabilitation aligns with the broader social inclusion and quality of life of individuals with DS. Promoting independence, participation in meaningful activities and social engagement for individuals with DS is integral and deserves stronger advocacy (Faragher, Cooke and Lloyd, 2024). Improved balance function through the access to adequate balance assessments and rehabilitation has the potential to enable greater participation in sports, dance and other physical activities that allow self-expression and a greater sense of identity in people with DS (Faragher et al., 2024). Reducing the risk of falls, that could potentially result in injury, through improvement of postural control and overall stability further promotes increased confidence in navigating daily activities.

To ensure practical applicability within the South African context, balance assessment tools must be accessible, cost-effective, and validated for diverse populations. Addressing financial and logistical barriers, fostering local tool development, and incorporating culturally relevant adaptations are crucial steps toward improving health outcomes for children with DS. By prioritising funding, infrastructure improvements, and collaboration among stakeholders, SA can move closer to equitable access to essential healthcare services.

Fall Risk

Sub-sections of some of the outcome measures (like the TUG) are frequently used to establish fall risk (Barry et al., 2014). Therefore, it is reasonable to extrapolate these results in the context of fall risk. This study highlights the multifaceted nature of fall risks in children with DS, particularly in relation to balance and mobility impairments. The results demonstrate that balance outcome measures showed strong criterion validity in the DS group, especially when correlated with the TUG test, a widely used mobility measure (Itzkowitz et al., 2016). The Kids-BESTest and Kids Mini-BESTest, which exhibited the highest R^2 values, explained over 50% of the variance in TUG performance, indicating robust predictive capabilities. In contrast, the BOT-2 Subtest 5 and PBS showed moderate explanatory power, underscoring the importance of selecting comprehensive balance assessment tools for this population. From an audiological perspective, the concept of cross-checking findings using a test battery is practiced consistently and is crucial for confirming diagnostic outcomes. However, this approach may not be as commonly applied across other healthcare professions, where there may be a greater temptation to rely on a single measure. This highlights the importance of promoting the use of multiple complementary assessment tools, such as the combination of balance tests used in this study, to achieve a more holistic understanding of fall risks in children with DS.

Significant associations between balance assessments and the TUG test ($p \leq 0.005$) were observed in the DS group but not in the control group, suggesting that these measures are particularly sensitive to the unique mobility challenges faced by children with DS. The lack of significant associations in the control group likely reflects ceiling effects or reduced variability in typically developing children, consistent with previous studies (Itzkowitz et al., 2016). For children with DS, impaired motor coordination and balance, compounded by cognitive limitations, increase their susceptibility to falls (Bull et al., 2022; Jung et al., 2017). The strong criterion validity of the Kids-BESTest and Kids Mini-BESTest supports their reliability in identifying fall risks and mobility deficits in this population.

Tasks involving dual-tasking, such as the TUG with a secondary cognitive component, were particularly challenging for the DS group. Modifications like singing "Happy Birthday" instead of counting backwards improved task acceptability. Such adjustments have implications for interventions, for example, fall prevention programmes or vestibular rehabilitation therapy, to ensure that incorporating dual-tasking activities is done in an appropriate and supportive manner. Further modifications to include manual tasks (like TUG-Manual where a glass of water is carried) rather than cognitive tasks could still serve as dual tasking while improving participation and performance. Further research could establish if the TUG-Manual is capable of inducing the >10% slowing from TUG simple which is required for scoring in the BESTests. Such modifications may not only be useful for DS populations, but also children who are non-verbal due to deafness or autism, for example.

The acceptability section also highlighted that certain balance tasks, such as the balance beam and incline standing tasks, posed significant challenges. Many DS participants required touch assistance and some expressed apprehension about falling. Although near misses, but no actual falls were observed during testing, these difficulties reinforce the heightened fall risks faced by children with DS during balance-challenging daily activities.

BMI was identified as a significant factor influencing performance on specific balance and mobility tasks and is worth discussing in the context of fall risk. Higher BMI was strongly associated with poorer performance on Item 19c (standing eyes open on a foam surface) of the Kids-BESTest and longer times on TUG, Item 26. These findings align with literature indicating that increased BMI negatively impacts balance and mobility due to altered biomechanics and increased physical strain (Itzkowitz et al., 2016). This underscores the importance of addressing modifiable risk factors, such as obesity, in conjunction with balance impairments to reduce fall risks.

Poor scores in specific test items reflect activities commonly performed in school settings. For instance, PBS Item 3 (Transferring from one chair to another) and Kids-BESTest Item 12 (Alternate stair touch) assess skills essential for navigating the school environment. Poor performance in these tasks suggests increased fall risks during routine school activities, where falls are notably common. Benítez, Soriano & León (2010) found that falls accounted for 43.4% of all accidents recorded in school settings, emphasizing the need for targeted fall prevention strategies in educational contexts.

The heightened fall risk in children with DS is compounded by socio-economic factors. While South Africa is classified as an upper-middle-income country, systemic inequities in healthcare and education disproportionately affect children with disabilities, including those with DS (Walton & Engelbrecht, 2022; Mahlaule et al., 2024). Limited access to early intervention services, along with a lack of early childhood development (ECD) programmes even for typically developing children, along with no fall prevention education for caregivers and educators exacerbates the challenges faced by these children. Early and targeted interventions incorporating validated balance assessments, such as the Kids-BESTest and Kids Mini-BESTest, are critical to highlight focus areas for rehabilitation, in turn reducing fall risks. It should be remembered that falls during childhood are associated with marked morbidity and mortality, and data from developing countries exacerbate the likelihood of adverse consequences from falls (Patel et al., 2025). These tools provide reliable metrics for identifying balance deficits and offer insights that could inform tailored intervention programmes. Although customised intervention programmes are intensive in terms of costs and health care resources, understanding areas of deficit in DS children, suggested by the results of this study, could even inform a more general public health campaign addressing IDD and other special populations regarding fall risk.

The interplay between gait, balance, and fall risk in children with DS is influenced by developmental and environmental factors. Cognitive impairments, attention deficits, and reduced motor coordination collectively limit their ability to respond to sudden environmental changes, increasing susceptibility to falls during daily activities (Malak et al., 2013; Jung et al., 2017). Environmental distractions, such as large mirrors noted in this study's testing environment, can further hinder performance and arguably increase fall risks. Addressing these factors through adaptations to testing or learning environments is crucial.

Despite evidence suggesting that comprehensive balance assessments could enhance predictive accuracy for fall risks, their implementation remains limited in resource-constrained environments (Shi et al., 2018). This study underscores the need to integrate such assessments into routine care to bridge gaps and improve outcomes for children with DS.

This study explores the critical role of validated balance assessment tools in identifying fall risks among children with DS. The strong criterion validity of the Kids-BESTest and Kids Mini-BESTest supports their use in clinical and educational settings to inform targeted interventions. Addressing modifiable risk factors, such as obesity, alongside implementing evidence-based fall prevention strategies, is essential for reducing fall risks and improving the quality of life for children with DS.

Impact of risk factors and health variables

Otologic Considerations

The findings of this study highlight significant otologic differences between children with DS and their typically developing peers, as well as the impact of these differences on balance performance. These results align with broader literature emphasising the importance of middle and inner ear function in relation to balance and vestibular outcomes (Goiacchini et al., 2014; Carpenter & Campos, 2020).

Otoscopy revealed that the majority of the control group presented with no abnormalities (NAD) (75%), whereas the DS group exhibited a higher prevalence of cerumen impaction, with non-occluding (37.5%) and occluding cerumen (22.92%) accounting for the majority of cases. This finding is consistent with Clark et al. (2016), who noted that narrow ear canals, a common structural feature in DS, predispose individuals to cerumen impaction. Dudley (2024) further emphasises that cerumen impaction can hinder accurate auditory and vestibular assessments and is linked to instability and falls, particularly in vulnerable populations. Such impaction can contribute to conductive hearing loss (CHL), potentially affecting vestibular function and spatial orientation (Goiacchini et al., 2014).

The relationship between otoscopic findings and balance performance was particularly evident for dynamic balance measures such as the Kids Mini-BESTest and BOT-2 Subtest 5. Children with NAD achieved significantly higher scores on these measures compared to those with occluding or non-occluding cerumen. For example, children with NAD scored a mean of 23.1 out of a possible 28 on the Kids Mini-BESTest, compared to 16.5 for those with non-occluding cerumen. While the Kids-BESTest also revealed significant group differences, post hoc analyses indicated a stronger association for the Kids Mini-BESTest and BOT-2 Subtest 5. Conversely, the PBS did not show significant differences across otoscopy groups.

The tympanometry results further reinforced the connection between possibly abnormal middle ear function and balance performance. While the majority of the control group presented with Type A tympanograms (60.42%), indicative of normal ear canal volume, middle ear pressure and static compliance, the DS group predominantly yielded Type B tympanograms (54.17%). Type B tympanograms are often associated with middle ear effusion or cerumen impaction, both of which can contribute to CHL and vestibular disturbances (Golz et al., 1998; Horowitz et al., 2019).

Children with Type B tympanograms scored significantly lower on dynamic balance measures, such as the Kids-BESTest, Kids Mini-BESTest, and BOT-2 Subtest 5. For instance, children with Type B tympanograms achieved a mean score of 68.1 out of a possible 108 on the Kids-BESTest, compared to 87.1 for those with Type A tympanograms. These findings are consistent with prior research indicating that middle ear pathologies possibly have adverse effects balance performance (Golz et al., 1998; El Shennawy, 2015). It should be noted that in the current study cerumen removal was not administered, which could have potentially contributed to the prevalence of type B tympanograms obtained. Thus, the type B tympanograms obtained could not definitively be contributed to middle ear pathologies per se. Interestingly, no significant differences were found across tympanometry groups for the PBS. The differences in findings between outcome measures underscores the importance of incorporating both static and dynamic balance assessments when evaluating balance function in children with DS.

The distortion product otoacoustic emissions (DPOAE) screening results revealed further disparities between the DS and control groups. While 95.83% of the control group passed the OAE screening, the majority of the DS group (60.42%) yielded “refer” results in one or both ears. This finding aligns with the broader literature, which reports a high prevalence of hearing loss (HL) in children with DS due to conductive and sensorineural pathologies (Kaga, 2014; Agarwal Gupta & Kabra, 2014). Goiacchini et al. (2014) previously highlighted the link between cochlear dysfunction and vestibular deficits, supporting the current study’s findings. However, caution is suggested when interpreting these data. Similar to the prevalence of type B tympanometry results, participants’ ‘refer’ results obtained in the DPOAE screening could have partially been as a result of occluding cerumen and not the definite presence of HL.

Nevertheless, the results demonstrated a clear association between DPOAE outcomes and balance performance across all outcome measures. Participants who passed the DPOAE screening scored significantly higher on the Kids-BESTest, Kids Mini-BESTest, BOT-2 Subtest 5, and PBS compared to those with refer results. For example, children with “pass” results achieved a mean score of 87.2 on the Kids-BESTest, compared to 66.1 for those with “refer” results. The presence of refer results in the DS group may be attributed to middle ear pathologies, such as middle ear effusion (MEE) and cerumen impaction, both of which are prevalent in this population (Clark et al., 2016; Dudley, 2024).

The findings of this study have important audiological implications for the assessment and management of balance function in children with DS. Regular otologic assessments, including otoscopy, tympanometry, and DPOAE screening, are essential for identifying and managing conditions that may compromise auditory and vestibular function.

Without establishing cause/effect, the results from this study align with evidence suggesting that untreated ear pathologies contribute to instability and falls (Dudley, 2024; Goiacchini et al., 2014) and underscores the significant impact of otologic considerations on balance function in children with DS. In addition, these results highlight the need for multidisciplinary approaches that integrate audiological and vestibular assessments with balance interventions. The role of the audiologist is apparent and justified Addressing cerumen impaction, assisting with monitoring (treatment of) MEE or conductive hearing loss, and monitoring/managing cochlear function/loss may help optimize balance outcomes and reduce fall risk in children with DS. Possible middle ear pathologies, as evidenced by otoscopy and tympanometry, and possible cochlear dysfunction, as indicated by DPOAE screening, were associated with poorer balance performance, particularly on dynamic balance measures.

Body Mass Index (BMI)

The results of this study highlight a significant relationship between higher BMI and poorer balance performance in children with DS, which is consistent with findings from previous literature (Galli et al., 2015). In particular, BMI was negatively correlated with balance scores across all four assessment tools used in the study. These findings support the hypothesis that higher BMI adversely affects balance, which is particularly relevant when considering children with DS, a population that is at increased risk of obesity compared to typically developing children (Martínez-Espinosa et al., 2020).

The negative correlations between BMI and balance performance were moderate, indicating a substantial but not overwhelming influence of BMI on balance outcomes. The partial correlation analysis, controlling for group membership (DS versus typically developing controls), revealed that this relationship persisted even after accounting for group differences, suggesting that BMI independently affects balance performance beyond the effects of DS itself. This finding aligns with studies by Galli et al. (2015), who demonstrated that obesity in children with DS leads to slower walking speeds and altered gait patterns, both of which are linked to poorer balance outcomes.

Interestingly, specific items on the balance assessments revealed more pronounced effects of BMI on both static and dynamic balance. For example, the modified Clinical Test of Sensory Integration on Balance (mCTSIB) conditions, particularly standing on a foam surface with eyes open, showed strong negative correlations with BMI. This suggests that children with higher BMI may struggle more with maintaining balance under conditions that challenge proprioception and stability, such as when standing on an unstable surface. Similarly, the TUG test, which measures mobility and dynamic balance, showed a strong positive correlation with BMI, indicating that higher BMI is associated with longer times to complete the test, further supporting the idea that obesity negatively impacts balance and mobility.

These findings contribute to the growing body of evidence that obesity is a significant factor influencing balance in children with DS. However, the literature presents mixed results on this relationship. For instance, Leite et al. (2018) found no significant differences in balance function between obese and non-obese children with DS, which could be attributed to small sample sizes. Similarly, Itzkowitz et al. (2017) did not find significant differences in TUG scores across BMI categories in typically developing children but observed a positive correlation between BMI and TUG performance in younger age groups. These inconsistencies in the literature underscore the complexity of the relationship between BMI and balance, suggesting that factors such as age, socio-economic status, and regional context may influence the extent to which BMI affects balance. Tisano et al. (2022) found that obese children are not only more susceptible to orthopaedic pathologies, but have an increased likelihood of traumatic injuries, including fractures, which could potentially be exacerbated by fall and higher fall risk.

In conclusion, this study highlights that BMI is a significant factor potentially influencing balance in children with DS. The correlations observed between BMI and balance scores suggest that interventions targeting obesity may be important for improving balance outcomes in this population.

Other potential factors that should be considered

In addition to the primary variables assessed, several potential factors emerged during data collection that could influence balance function outcomes in children with DS. These factors include visual acuity, cognitive function, language and communication proficiency, and contextual testing variables. These considerations align with broader findings in the literature and underscore the multifaceted nature of balance assessment in this population.

Visual acuity was identified as a potential influencing factor. Some participants presented with diagnosed visual impairments corrected by glasses, while others were suspected to have unassessed visual issues. The lack of formal evaluation and corrective measures for certain children may have affected their ability to perform balance tasks effectively. This observation aligns with findings from Ebensen et al. (2017), who reported that sensory deficits, including vision problems, are common in individuals with DS and can significantly impact motor function and balance. Additionally, Pikora et al. (2014) found that 72.6% of participants with DS had vision-related conditions, which impaired their ability to gauge distances and navigate steps, further emphasising the role of visual feedback in maintaining postural control. Future research should ensure systematic screening and correction of visual impairments to minimise their impact on balance assessment outcomes.

Cognitive function appeared to influence the ease and consistency of testing. While formal cognitive assessments were not conducted, children presumed to have lower cognitive function exhibited greater difficulty understanding tasks and following instructions, leading to potential inconsistencies in their performance. The presumption of cognitive function was based on verbal reports from the teachers and therapists working with the children on a daily basis. This observation reflects findings by Startin et al. (2020), who noted that cognitive variability in DS is associated with health comorbidities and may directly affect task execution. Incorporating standardised cognitive and psychological assessments in future studies could help quantify the relationship between these factors and balance performance.

Language proficiency emerged as a critical factor during data collection. This finding is consistent with the broader literature, which highlights how communication challenges in DS can affect task engagement and accuracy (Ebensen et al., 2017). Moreover, verbal communication difficulties were amplified in children with presumed lower cognitive function or limited language proficiency, further complicating task execution. This also points to the need for verified translations of each outcome measure. Undiagnosed, untreated hearing loss could potentially also have posed a communication barrier in this study.

Language, hearing and visual acuity issues and environmental factors all highlight the complexity of balance assessments in children with DS. Acknowledging and addressing these variables in study designs is crucial for improving the reliability and validity of test outcomes. Future research should prioritise comprehensive evaluations of these factors to enhance the interpretability and applicability of findings in this population. By accounting for these considerations, researchers can better understand the multifaceted contributors to balance function in children with DS and develop more tailored assessment and intervention strategies.

Strengths and Limitations

Strengths

One of the key strengths of this study is its design as a clinimetric pilot study, which allows for a comprehensive evaluation of balance outcome measures in a clinical population. By focusing on children with DS and typically developing children, the study provides valuable insights into the reliability and validity of various balance assessment tools within this specific context. The small, yet carefully matched sample size (24 participants, with 14 females and 10 males, alongside a matched control group) ensures that the findings are robust while also being feasible in a resource-constrained setting such as South Africa. The study's design allows for detailed exploration of the tools' accessibility, acceptability, and practical application in real-world clinical settings, providing critical evidence for resource-limited countries where such assessments may not be routinely available.

A significant strength of the study lies in its evaluation of the relationship between fall risk, balance, and modifiable risk factors such as BMI and otologic health in children with

DS. By incorporating these factors into the analysis, the study contributes to a more nuanced understanding of the multifactorial nature of balance deficits in children with DS, which is often overlooked in the literature. The inclusion of both criterion validity and known-groups validity assessments strengthens the study’s findings by demonstrating the capacity of the assessment tools to differentiate between children with DS and typically developing children. The strong criterion validity, particularly with tools like the Kids-BESTest and Kids Mini-BESTest, ensures that these measures are both reliable and applicable for clinical use in this population, adding significant value to the clinical assessment landscape.

Finally, the study’s focus on inter-rater and test-retest reliability further enhances the robustness of its findings. By examining these properties across multiple balance assessment tools, the study provides critical insights into their consistency and reproducibility, which are essential for their clinical utility. The study also addresses real-world challenges, such as variability due to cognitive and behavioural factors in children with DS, and emphasizes the importance of tailored approaches to balance assessment. Furthermore, the research underlines key audiological and clinical implications, such as the need for training clinicians to administer and interpret these assessments effectively, particularly in low-resource settings where access to specialised training may be limited. Additionally, the research highlights the practical implications for clinicians in terms of selecting the most appropriate tools, factoring in time efficiency, safety, and the accessibility of these assessments in low-resource settings. This holistic approach ensures that the study’s findings are not only scientifically rigorous but also directly applicable to improving clinical practice and interventions for children with DS.

Limitations

This study provides valuable insights into the balance function of children with DS, yet there are several limitations to consider. One primary limitation is the small sample size, which was restricted to 24 participants, potentially affecting the generalisability of the findings. A larger, more diverse sample would enhance the ability to draw broader conclusions about the applicability of the assessment tools for children with DS, particularly in different cultural, socioeconomic, or healthcare contexts across age groups. Additionally, the control group of typically developing children exhibited ceiling effects, limiting the ability to differentiate between subtle balance differences. Ceiling effects may reduce the sensitivity of the tools in detecting less severe balance issues, which is critical for identifying early signs of motor impairments in children at different developmental stages.

Another limitation is the study's lack of focus on specific environmental and demographic factors. The research did not extensively explore how factors like home or school settings, socio-economic status and even the amount of physical activity, which can vary greatly among participants, might influence balance outcomes. The study also did not account for potential confounders such as cognitive abilities, language proficiency, or other health conditions that may affect balance, which could lead to incomplete or skewed interpretations of the results. Incorporating standardized assessments for cognitive function and language skills would strengthen the study's findings. Sensitivity and specificity could also not be assessed, due to the lack of instrumented outcome measures like posturography. However, the reader is now familiar with the challenges of South African healthcare, and such 'gold standard' equipment is simply not available in state facilities, let alone in a rural province such as the EC. Furthermore, the study did not include a direct assessment of vestibular function, which represents a notable limitation given the vestibular system's critical role in postural control and balance. This omission was due to both practical constraints and the lack of access to specialised vestibular testing equipment in the public healthcare context.

This study used aspects of the administered tests (e.g., TUG, extracted from the BESTests) to extrapolate and illuminate fall risk. While helpful, particularly when examined with additional factors like middle/inner ear status and BMI, no measures of fall events, either retrospective or prospective, were taken. In the DS population in particular, it would be interesting to know if reduced intellectual capacity resulted in ‘near misses’, as observed in the study, developed into defined falls in non-clinical situations. The researcher was closely guarding participants throughout and had an assistant, but real world settings with competing distractions for both the individual and their caretakers, might be very different. Children younger than the included participants might also yield different results.

Finally, while the study emphasized the feasibility of using low-tech balance tests, their time demands and complexity may limit their utility in busy clinical settings or for children with more severe cognitive or physical impairments. The need for task modifications to accommodate the developmental levels of DS participants may also affect the consistency of the results, making it difficult to compare across participants. Moreover, the study's focus on a specific geographical region in South Africa may limit its generalisability to other regions with different cultural and educational contexts.

Recommendations for Future Research

This clinimetric pilot study provided valuable insights into balance function assessments in children with DS and typically developing peers. However, future research is needed to address the limitations of this study and expand understanding of balance assessments and related interventions. Longitudinal studies could explore how (and indeed if) balance function evolves over time, particularly in response to targeted interventions such as balance training, obesity management, or treatment of otologic conditions. These studies would help establish causality and provide insights into the long-term efficacy of assessment tools and intervention strategies.

Future research should also investigate the broader contextual and environmental factors influencing balance performance and fall risks. This includes understanding the role of school and home environments, socioeconomic factors, and cultural influences. Expanding the demographic diversity of study populations will enhance the generalisability of findings and provide a clearer picture of regional and population-specific challenges. Additionally, caregiver and educator involvement could offer valuable perspectives on the feasibility and acceptability of implementing balance assessments and interventions.

Given the small sample size of this study, larger, more diverse samples are necessary to improve the reliability and validity of the findings. Future studies should also include more comprehensive exploration of interrelated factors such as cognitive function, attention, physical activity levels, and muscle tone. In addition, there is a need to assess the responsiveness of these balance assessment tools, focusing on their ability to detect clinically meaningful changes over time. Establishing metrics such as the Minimal Detectable Change (MDC) and the Minimal Clinically Important Difference (MCID) will provide valuable insights into their utility in monitoring progress and guiding therapeutic interventions. The impact of BMI, middle ear status, and other comorbidities on balance performance warrants further exploration. For instance, longitudinal research could examine whether changes in BMI or improved otologic health through medical interventions result in measurable improvements in balance. Studies on specific balance tasks, such as those in the mCTSIB or TUG, may reveal which aspects of balance are most influenced by these factors.

Finally, the development of locally relevant assessment tools and training materials is essential for enhancing accessibility and applicability in resource-limited settings. This could involve culturally and linguistically tailored adaptations to assessments and increased collaboration with local healthcare providers and educators. Expanding the research to other populations and settings will help validate the utility of balance assessment tools in diverse contexts and ensure they meet the needs of children with DS worldwide.

Conclusion

This study has provided valuable insights into the assessment of balance in children and adolescents with DS using four tools: the PBS, BOT-2 Subtest 5: Balance, Kids-

BESTest, and Kids Mini-BESTest. Each tool demonstrated unique strengths and limitations in this context, with varying levels of reliability, validity, accessibility, and practicality.

The PBS showed strong known-groups and criterion validity, good internal consistency, and practicality due to its accessibility and short test time. However, its static nature, moderate reliability, and susceptibility to floor and ceiling effects limit its use for comprehensive balance assessments in children with DS. The BOT-2 Subtest 5 exhibited robust reliability, strong validity, and an effective task progression design but was hindered by high costs, task complexity, and limited generalisability. The Kids-BESTest emerged as a comprehensive tool with strong clinimetric properties, but its time-consuming nature, high cognitive demands, and elevated costs reduced its feasibility in many clinical or educational environments. The Kids Mini-BESTest demonstrated strong criterion validity, good internal consistency, and time efficiency, offering an accessible and cost-effective solution for balance assessments in resource-constrained settings.

Among these tools, the Kids Mini-BESTest emerged as the most practical and clinically relevant option for assessing balance in children with DS. It strikes a balance between practicality and performance, with opportunities for integration into clinical and research settings to identify deficits and inform targeted interventions. Additionally, its dynamic balance tasks provided valuable insights into functional impairments.

The study also highlighted the significant influence of otologic factors and BMI on balance performance. Middle ear pathologies and cochlear dysfunction, as indicated by otoscopy, tympanometry, and DPOAE results, were associated with poorer dynamic balance performance. Regular otologic assessments and interdisciplinary interventions are essential to address these challenges. Similarly, higher BMI negatively impacted balance outcomes, underscoring the importance of addressing obesity in children with DS to optimise their functional abilities and reduce fall risks.

These findings support a multidisciplinary approach to balance assessment in children with DS, combining comprehensive otologic evaluations and weight management with balance assessments. The results also highlight the need for further research to refine task designs, enhance training for evaluators, and explore the longitudinal impact of otologic and weight-related factors on balance outcomes in this population. Ultimately, this study underscores the importance of tailored, evidence-based strategies to improve the assessment and subsequent management of balance in children and adolescents with DS, promoting better functional outcomes and quality of life.

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Appendices

Appendix A: Paediatric Balance Scale (PBS)

The PBS is a criterion-based assessment derived from the Berg Balance Scale (BBS) and consists of 14 items that evaluate practical balance within the scope of activities of daily living (ADL) (Franjoine et al., 2003). Its administration and scoring can be typically completed within 20 minutes, using equipment commonly available in clinics and schools. The items in this test battery include:

Instructions	**Equipment**	**Scoring**
1. Sitting to standing		
Child is asked to “Hold arms up and stand up”. The child is allowed to select the position of his/her arms. Special instruction: Items #1 and #2 may be tested simultaneously if, in the determination of the examiner, it will facilitate the best performance of the child.	A bench of appropriate height to allow the child’s feet to rest supported on the floor with the hips and knees maintained in 90 degrees of flexion	4 - Able to stand without using hands and stabilise 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 stabilise
		0 - Needs moderate or maximal assist to stand
2. Standing to sitting		
Child is asked to sit down slowly, without use of hands. The child is allowed to select the position of his/her arms. Special instruction: Items #1 and #2 may be tested simultaneously if, in the determination of the examiner, it will facilitate the best performance of the child.	A bench of appropriate height to allow the child’s feet to rest supported on the floor with the hips and knees maintained in 90 degrees of flexion	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		
Arrange chair(s) for a stand pivot transfer, touching at a forty-five degree angle. Ask the child to transfer one way toward a seat with armrests and one way toward a seat without armrests.	Two chairs, or one chair and one bench. One seating surface must have arm rests. One chair/bench should be of standard adult size and the other should be of an appropriate height to allow the child to comfortably sit with feet supported on the floor and ninety degrees of hip and knee flexion.	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 cueing 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		
The child is asked to stand for 30 s without holding on or moving his/her feet. A taped line or footprints may be placed on the floor to help the child maintain a stationary foot position. The child may be engaged in non-stressful conversation to maintain attention span for thirty s. Weight shifting and equilibrium responses in feet are acceptable; movement of the foot in space (off the support surface) indicates end of the timed trial.	A stop watch with a second hand and a thirty centimetre long masking tape line of two footprints placed shoulder width apart.	4 - Able to stand safely 30 s
		3 - Able to stand 30 second with supervision (spotting)
		2 - Able to stand 15 s unsupported
		1 - Needs several tries to stand 10 s unsupported
		0 - Unable to stand 10 s unassisted
5. Sitting with back unsupported and feet supported on the floor		
Please sit with arms folded on your chest for 30 s. Child may be engaged in non-stressful conversation to maintain attention span for thirty s. Time	A stop watch or watch with a second hand and a bench of appropriate height to allow the feet to rest supported on the floor	4 - Able to sit safely for 30 s
		3 - Able to sit 30 s under supervision (spotting) or may require definite use of

should be stopped if protective reactions are observed in the trunk or upper extremities.	with the hips and knees maintained in ninety degrees of flexion.	upper extremities to maintain sitting position.
		2 - Able to sit 15 s
		1 - Able to sit 10 s
		0 - Unable to sit 10 s without support
6. Standing unsupported with eyes closed		
The child is asked to stand still with feet shoulder width apart and close his/her eyes for ten s. Direction: “When I say close your eyes, I want you to stand still, close your eyes, and keep them closed until I say open”. If necessary, a blindfold may be used. Weight shifting and equilibrium responses in the feet are acceptable; movement of the foot in space (off the support surface) indicates end of timed trial. A taped line or footprints may be placed on the floor to help the child maintain a stationary foot position.	A stop watch with a second hand and a thirty centimetre long masking tape line of two footprints placed shoulder width apart, with a blindfold if needed.	4 - Able to stand safely 10 s
		3 - Able to stand 10 second with supervision (spotting)
		2 - Able to stand 3 s
		1 - Unable to keep eyes closed 3 s but stays steady
		0 - Needs help to keep from falling.
7. Standing unsupported with feet together		
The child is asked to place their feet together and stand still without holding on. The child may be engaged in non-stressful conversation to maintain attention span for thirty s. Weight shifting and equilibrium responses in the feet are acceptable; movement of the foot in space (off the support surface) indicates end of timed trial. A taped line or footprints may be placed on the floor to help the child maintain a stationary foot position.	A stop watch with a second hand and a thirty centimetre long masking tape line or two footprints placed together.	4 - Able to place feet together independently and stand 30 s safely
		3 - Able to place feet together independently and stand for 30 s with supervision (spotting)
		2 - Able to place feet together independently but unable to hold for 30 s
		1 - Needs help to attain position but able to stand 30 s with feet together

		0 - Needs help to attain position and/or unable to hold for 30 s
8. Standing unsupported one foot in front		
The child is asked to stand with one foot in front of the other, heel to toe. If the child cannot place feet in tandem position (directly in front), they should be asked to step forward far enough to allow the heel of one foot to be placed ahead of the toes of the stationary foot. A taped line or footprints may be placed on the floor to help the child maintain a stationary foot position. In addition to a visual demonstration, a single physical prompt (assistance with placement) may be given. The child may be engaged in non-stressful conversation to maintain attention span for thirty s. Weight shifting and equilibrium responses in the feet are acceptable; movement of the foot in space (off the support surface) and/or if upper extremities support is utilised indicates end of timed trial.	A stop watch with a second hand and a thirty centimetre long masking tape line or two footprints placed heel to toe.	4 - Able to place feet in tandem independently and stand 30 s safely
		3 - Able to place foot ahead of the other independently and stand for 30 s. Note: The length of the step must exceed the length of the stationary foot and the width of the stance should approximate the subject's normal stride width.
		2 - Able to take small step independently and hold for 30 s, or required assistance to place foot in front, but can stand for 30 s.
		1 - Needs help to step, but can hold 15 s
		0 - Loses balance while stepping or standing
9. Standing on one leg		
The child is asked to stand on one leg for as long as he/she is able to without holding on. If necessary the child can be instructed to maintain his/her arms (hands) on his/her hips (waist). A taped line or footprints may be placed on the floor to help the child maintain a stationary foot position. Weight shifting and equilibrium responses in the feet are acceptable. Timed trials are ended if the weight-bearing foot	A stop watch with a second hand and a thirty centimetre long masking tape line or two footprints placed heel to toe.	4 - Able to lift leg independently and hold for 10 s
		3 - Able to lift leg independently and hold 5 to 9 s
		2 - Able to lift leg independently and hold 3 to 4 s
		1 - Tries to lift leg; unable to hold 3 s but remains standing

moves in space (leaves the support surface), the up limb touches the opposite leg or the support surface and/or upper extremities are utilised for support.		0 - Unable to try or needs assist to prevent fall
10. Turn 360 degrees		
The child is asked to turn completely around in a full circle, Stop, and then turn a full circle in the other direction.	A stop watch with a second hand	4 - Able to turn 360 degrees safely in 4 s or less each way (total of less than eight s)
		3 - Able to turn 360 degrees safely in one direction only in 4 s or less completes turn in the other direction requires more than four s
		2 - Able to turn 360 degrees safely but slowly
		1 - Needs close supervision (spotting) or constant verbal cueing
		0 - Need assistance while turning
11. Turn to look behind left & right shoulders while standing still		
The child is asked to stand with his/her feet still, fixed in one place. “Follow this object as I move it. Keep watching it as I move it, but don’t move your feet”	A brightly coloured object of at least five centimetres in size, or flash cards, a 30 centimetre long masking tape line or two footprints placed shoulder width apart	4 - Looks behind/over each shoulder; weight shifts include trunk rotation
		3 - Looks behind/over one shoulder with trunk rotation; weight shift in the opposite direction is to the level of the shoulder; no trunk rotation
		2 - Turns head to look to level of shoulder; no trunk rotation
		1 - Needs supervision (spotting) when turning; the chin moves greater

		than half the distance to the shoulder
		0 - Needs assist to keep from losing balance or falling; movement of the chin is less than half the distance to the shoulder
12. Pick up object from the floor from a standing position		
The child is asked to pick up a chalkboard eraser placed approximately the length of his/her foot in front of his/her dominant foot. In children, where dominance is not clear, ask the child which hand the want to use and place the object in front of that foot.	A chalkboard eraser and a taped line or footprints	4 - Able to pick up an eraser safely and easily
		3 - Able to pick up eraser but needs supervision (spotting)
		2 - Unable to pick up eraser but reaches 3 to 5 centimetres from the eraser and keeps balance independently
		1 - Unable to pick up eraser; needs supervision (spotting) while attempting
		0 - Unable to try, needs assist to keep from losing balance or falling
13. Placing alternate foot on step stool while standing unsupported		
The child is asked to place each foot alternately on the step stool and to continue until foot has touched the step/stool four times	A stop watch with a second hand and a step/stool of ten centimetres in height	4 - Stands independently and safely and completes 8 steps in 20 s
		3 - Able to stand independently and complete 8 staps >20 s
		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
14. Reaching forward with outstretched arm while standing		
The child is asked to lift his/her arm up like this. “Stretch out your fingers, make a fist, and reach forward as far as you can without moving your feet”	A yardstick or ruler, a taped line or footprints and a level	4 - Can reach forward confidently >25 centimetres
		3 - Can reach forward >12 centimetres, safely
		2 - Can reach forward >5 centimetres, safely
		1 - Reaches forward but needs supervision (spotting)
		0 - Loses balance while trying, requires external support

Appendix B: Bruininks-Oseretsky Test of Motor Proficiency, Second edition (BOT-2), Subtest 5: Balance

The BOT-2 is the second edition of a widely used scale that is designed to assess fine- and gross motor skills of children and adolescents with neurodevelopmental disorders as well as typically developing children aged 4 through 21 years (Bruininks & Bruininks, 2005). The scale is divided into four motor area composites viz. *Fine Manual Control, Manual Coordination, Body Coordination* and *Strength and Agility* with a total of 53 items divided between 8 distinct subtests (Bruininks & Bruininks, 2005). Subtest 5 of this scale, entitled *Balance,* falls under the motor area of *Body Coordination* and contains 9 sub-items (Bruininks & Bruininks, 2005). The items in this test battery include:

Examiner Instructions	**Child Instructions**	**Scoring**
4. Body Coordination		
V. Balance		
Task 1. Standing with feet apart on a line - Eyes open		
Start keeping time with a stopwatch when the child is standing in position. If the child moves off the line or removes their hands from their hips before the 10 s is over, stop the timer. The time the test was done correctly should then be recorded for the child's record.	With your feet apart and your hands on your hips, stand on the line with your eyes open, until I say stop.	Maximum time: 10 s
Task 2. Standing with feet apart on a line - Eyes closed		
Start keeping time with a stopwatch when the child is standing in position. If the child moves off the line, removes their hands from their hips or opens their eyes before the 10 s is over, stop the timer. The time the test was done correctly should then be recorded for the child's record.	With your feet apart and your hands on your hips, stand on the line with your eyes closed, until I say stop.	Maximum time: 10 s

Task 3. Walking forward on a straight line		
If the child moves one or both feet completely off the line, or removes their hands from their hips before completing six steps, the test should be stopped. The number of correct steps should be recorded.	Take six steps on the line with your eyes open and your hands on your hips.	Maximum steps: 6
Task 4. Standing on one leg on a straight line - Eyes open		
Start keeping time with a stopwatch when the child is standing in position. If the child moves off the line, stumbles, drops their free leg below 45 degrees, touches the floor with their free leg or removes their hands from their hips before the 10 s is over, stop the timer. The time the test was done correctly should then be recorded for the child's record.	Stand on the line with one leg only, while keeping your hands on your hips and your eyes open.	Maximum time: 10 s
Task 5. Standing on one leg on a straight line - Eyes closed		
Start keeping time with a stopwatch when the child is standing in position. If the child moves off the line, stumbles, drops their free leg below 45 degrees, touches the floor with their free leg, removes their hands from their hips or opens their eyes before the 10 s is over, stop the timer. The time the test was done correctly should then be recorded for the child's record.	Stand on the line with one leg only, while keeping your hands on your hips and your eyes closed.	Maximum time: 10 s
Task 6. Walking forward heel-to-toe on a straight line		
If the child moves one or both feet off the line, removes their hands from their hips or the heel of	Take six heel-to-toe steps on the line with	Maximum steps: 6

the front foot is placed on the toe of the back foot or the toe of the back foot touches the heel of the front foot before completing six steps, the test should be stopped. The number of correct steps should be recorded.	your eyes open and your hands on your hips.	
Task 7. Walking forward heel-to-toe on a balance beam		
If the child moves one or both feet off the balance beam, removes their hands from their hips or the heel of the front foot is placed on the toe of the back foot or the toe of the back foot touches the heel of the front foot before completing six steps, the test should be stopped. The number of correct steps should be recorded.	Take six heel-to-toe steps on the balance beam with your eyes open and your hands on your hips.	Maximum steps: 6
Task 8. Standing on one leg on a balance beam - Eyes open		
Start keeping time with a stopwatch when the child is standing in position. If the child moves off the balance beam, stumbles, drops their free leg below 45 degrees, touches the floor with their free leg or removes their hands from their hips before the 10 s is over, stop the timer. The time the test was done correctly should then be recorded for the child's record.	Stand on the balance beam with one leg only, while keeping your hands on your hips and your eyes open.	Maximum time: 10 s
Task 9. Standing on one leg on a balance beam - Eyes closed		
Start keeping time with a stopwatch when the child is standing in position. If the child moves off the balance beam, stumbles, drops their free leg below 45 degrees, touches the floor with their free leg or removes their hands from their hips before the 10 s is over, stop the timer. The time the test was done correctly should then be recorded for the child's record.	Stand on the balance beam with one leg only, while keeping your hands on your hips and your eyes closed.	Maximum time: 10 s

(Bruininks & Bruininks, 2005)

Appendix C: The full version of Kids-Balance Evaluation Systems Test (Full Kids-BESTest)

The Full Kids-BESTest is a comprehensive test battery evaluating postural control and consists of 36 items identifying and classifying postural control deficits across six systems of postural control (Dewar et al., 2017). A maximum of 108 points can be achieved and domain specific results can also be calculated by scoring each item from 0 (worst performance) to 3 (best performance) (Dewar et al., 2017). For the purpose of this study, the full Kids BESTest was used during the assessment, but particular focus will be on the mCTSIB, standing on one leg and TUG items during the data analysis stage.

The items with their scoring are as follows:

Examiner Instructions	**Child Instructions**	**Scoring**
I. Biomechanical Constraints		
Item 1. Base of support		
Closely examine both feet to look for deformities or complaints of pain such as abnormal pronation/supination, abnormal or missing toes, pain from plantar fasciitis, bursitis, etc.	Stand up with bare feet and tell me if you currently have any pain in your feet or ankles or legs.	0 - Both feet have deformities AND pain.
		1 - Both feet have deformities OR pain.
		2 - One foot has deformities and/or pain.
		3 - Normal Both feet have a normal base of support with no deformities or pain.
Item 2. Center of Mass (COM) Alignment		
Look at the child from the side and imagine a vertical line through their center of body mass (COM) to their feet. (The COM is the imaginary point inside or outside the body about which the body would rotate if floating in outer-	Stand relaxed, looking straight ahead	0 - Abnormal antero-posterior (AP) AND medio-lateral (ML) COM alignment.
		1 - Abnormal AP OR ML COM alignment

space.) When standing erect, a vertical line through the COM to the support surface is aligned in front of the vertebrae at the umbilicus and passes about 2 cm in front of the lateral malleolus, centered between the two feet. Abnormal segmental postural alignment such as scoliosis or kyphosis or asymmetries may or may not affect COM alignment.		AND abnormal segmental postural alignment.
		2 - Abnormal AP OR ML COM alignment OR abnormal segmental postural alignment.
		3 - Normal AP and ML COM alignment and normal segmental postural alignment.
Item 3. Ankle strength & range		
Ask the child to rest their fingertips in your hands for support while they stand on their toes as high as possible and then stand on their heels. Watch for height of heel and toe lift.	Rest your fingers in my hands for support while you stand on your toes. Stay there for my count of three. Now stand on your heels by lifting up your toes. Stay again in that position for my count of three.	0 - Both flexors and extensors in both left and right ankles impaired (i.e. less than maximum height).
		1 - Impairment in two ankle groups (e.g.: bilateral flexors or both ankle flexors and extensors in 1 foot).
		2 - Impairment in either foot of either ankle flexors or extensors (i.e. less than maximum height).
		3 - Normal Able to stand on toes with maximal height and to stand on heels with the front of feet up.
Item 4. Hip/trunk lateral strength		
Ask the child to rest their fingertips in your hands while they lift their leg to the side off the floor and hold. Count for 10 s while their	Lightly rest your fingertips in my hands while you lift your leg out to the side, just off the floor and hold until I	0 - Severe Cannot abduct either hip to lift a foot off the floor for 10 s with trunk

foot is off the floor with a straight knee. If they must use moderate force on your hands to keep their trunk upright, score as without keeping the trunk vertical.	tell you to stop. It is important to try to keep your body up as tall as you can and your knee straight while you hold your leg out.	vertical or without vertical.
		1 - Moderate Abducts only one hip off the floor for 10 s with a vertical trunk.
		2 - Mild Abducts both hips to lift the foot off the floor for 10 s but without keeping the trunk vertical.
		3 - Normal Abducts both hips to lift the foot off the floor for 10 s while keeping the trunk vertical.
Item 5. Sit on the floor and stand up		
Start with the child standing near a sturdy chair (if required). The child can be considered to be sitting when both buttocks are on the floor. If the task takes more than 2 minutes to complete, with or without a chair, score 0. If the patient requires any physical assistance, score 0.	Are you able to sit on the floor and then stand up, in less than 2 minutes? If you need to use a chair to help you go onto the floor or to stand up, go ahead but your score will be affected. Let me know if you cannot sit on the floor or stand up without my help.	0 - Severe Cannot sit on the floor or stand up, even with a chair, or refuses.
		1 - Moderate Uses a chair to sit on the floor AND to stand up.
		2 - Mild Uses a chair to sit on the floor OR to stand up.
		3 -Normal Independently sits on the floor and stands up.
II. Stability limits		
Item 6a. Sitting vertically and lateral lean: Lean		
Child is sitting comfortably on a firm, level, armless surface (bench	Place this mask on your eyes. Place feet shoulder	0 - No lean or falls (exceeds limits).

or chair) with feet flat on the floor. The child should place an eye mask on. It is okay to lift ischium or feet when leaning. Watch to see if the child returns to vertical smoothly without over or undershooting. Score the worst performance to each side.	width apart. Cross your arms over your chest and sit up as tall as you can. I'll be asking you to lean to one side as far as you can. You'll keep your body up tall and lean sideways as far as you can without losing your balance OR using your hands. Return to your starting position when you've leaned as far as you can. It's okay to lift your buttocks and feet. Lean now. (REPEAT other side)	1 - Very little lean, or significant instability.
		2 - Moderate lean, subject's upper shoulder approaches body midline or some instability.
		3 - Maximum lean, subject moves upper shoulders beyond body midline, very stable.
Item 6b. Sitting vertically and lateral lean: Verticality		
Child is sitting comfortably on a firm, level, armless surface (bench or chair) with feet flat on the floor. The child should place an eye mask on. It is okay to lift ischium or feet when leaning. Watch to see if the child returns to vertical smoothly without over or undershooting. Score the worst performance to each side.	Place this mask on your eyes. Place feet shoulder width apart. Cross your arms over your chest and sit up as tall as you can. I'll be asking you to lean to one side as far as you can. You'll keep your body up tall and lean sideways as far as you can without losing your balance OR using your hands. Return to your starting position when you've leaned as far as you can. It's okay to lift your buttocks and feet. Lean now. (REPEAT other side)	0 - Falls with the eyes closed.
		1 - Failure to realign to vertical.
		2 - Significantly over-or under-shoots but eventually realigns to vertical.
		3 - Realigns to vertical with very small or no overshoot.
Item 7. Functional reach forward		
A large sheet of paper is taped to a wall. The child holds a pen in their closed hand closest to the wall. A mark is made on the paper in the starting position, by the examiner. The child reaches forward. A second mark is made by the examiner at the end position. The child may not lift heels, rotate the trunk, or protract the scapula excessively. The child must keep their arms parallel to	Stand normally. Please lift both arms straight in front of you, holding this pen in your hand closest to the wall. I will make a mark on the paper then you will reach forward as far as you can. Don't lift your heels. Don't touch the paper or the wall. Once you've reached, as far forward as you can, I will make a mark	0 - No measurable lean – or must be caught.
		1 - Poor < 16.5 cm (6.5 in).
		2 - Moderate 16.5 cm -32 cm (6.5 – 12.5 in).
		3 - Maximum to limits: >32 cm (12.5 in).

the floor and may use less involved arm. The horizontal distance between these two marks is then measured after two trials. Record best reach.	on the paper. Then return to a normal standing position. I will ask you to do this two times. Reach as far as you can.	
Item 8. Functional reach lateral		
A large sheet of paper is taped to a wall. The child holds a pen in their closed hand closest to the wall. A mark is made on the paper in the starting position, by the examiner. The child reaches forward. A second mark is made by the examiner at the end position. The child may not lift heels, rotate the trunk, or protract the scapula excessively. The child must keep their arms parallel to the floor and may use less involved arm. The horizontal distance between these two marks is then measured after two trials. Record best reach.	Stand normally. Please lift both arms straight in front of you, holding this pen in your hand closest to the wall. I will make a mark on the paper then you will reach forward as far as you can. Don't lift your heels. Don't touch the paper or the wall. Once you've reached, as far forward as you can, I will make a mark on the paper. Then return to a normal standing position. I will ask you to do this two times. Reach as far as you can.	0 - No measurable lean, or must be caught.
		1 - Poor: < 10 cm (4 in).
		2 - Moderate: 10- 25.5 cm (4-10 in).
		3 - Maximum to limit: > 25.5 cm (10 in).
III. Transitions - Anticipatory postural adjustments		
Item 9. Sit to stand		
Note the initiation of the movement, and the use of hands on the arms of the chair or their thighs or thrusts arms forward.	Cross arms across your chest. Try not to use your hands unless you must. Don't let your legs lean against the back of the chair when you stand. Please stand up now.	0 - Requires moderate or maximal assist to stand.
		1 - Comes to stand after several attempts or requires minimal assistance to stand or stabilize or requires touch of the back of leg or chair.
		2 - Comes to stand on the first attempt with the use of hands.
		3 - Normal: Comes to stand without the use of hands and stabilizes independently.

Item 10. Rise to toes		
Allow the patient to try it twice. Record the best score. (If you suspect that the subject is using less than their full height, ask them to rise up while holding the examiners' hands.) Make sure subjects look at a target 4 - 12 feet away.	Place your feet shoulder width apart. Place your hands on your hips. Try to rise as high as you can onto your toes. I'll count out loud for 3 s. Try to hold this pose for at least 3 s. Look straight ahead at the target on the wall. Rise now.	0 - Unable. 1 - Holds for less than 3 sec. 2 - Heels up, but not full range (smaller than when holding hands so no balance requirement - OR - slight instability & holds for 3 sec. 3 - Normal: Stable for 3s with good height.
Item 11. Stand on one leg		
Allow the patient two attempts and record the best. Record the s they can hold posture, up to a maximum of 25 sec. If their legs touch, cue them to keep them apart but keep timing. If excessive trunk movement, hyperextension of the stance knee, excessive hip flexion, hover lifted toe or knees touching persists throughout the first 20 s, despite cues score 2. Stop timing when the subject moves their hands off hips or puts a foot down. Assess trunk movement and other signs of instability in the first 20 s only.	Look straight ahead at the target on the wall. Keep your hands on your hips. Bend one leg behind you to 90°. Don't touch your raised leg on your other leg or take your hands off your hips. Stay standing on one leg as long as you can. Look straight ahead. Lift now. (REPEAT other side)	0 - Unable. 1 - Stands 2 - 10 sec. 2 - Trunk motion AND/OR other signs of instability, OR 10 - 20 sec. 3 - Normal: Stable for > 20 sec.
Item 12. Alternate Stair touching		
Use standard stair height of 15cm. Count the number of successful touches and the total time to complete the 8 touches. It's permissible for subjects to look at their feet. If they take their hands off their hips cue them to put them back on.	Place your hands on your hips. Touch the ball of each foot alternately on the top of the stair, you must keep your hands on your hips. Continue until each foot touches the stair four times (8 total taps). I'll be timing	0 - Completes < 8 steps, even with assistive device. 1 - Completes < 8 steps – without minimal assistance (i.e. assistive device) OR > 20 s for 8 steps.

	how quickly you can do this. Begin now	2 - Completes 8 steps (10-20 sec) AND/OR shows instability such as inconsistent foot placement, excessive trunk motion, hesitation or arhythmical.
		3 - Normal: Stands independently and safely and completes 8 steps in < 10 sec.
Item 13. Standing arm raise		
Use 1 kg weight. Have the child stand and lift weight with both hands to shoulder height. Subjects should perform this as fast as they can. Lower score by 1 category if weight must be less than 1 Kg (5lb) +/or lifts < 75°.	Lift this weight with both hands from a position in front of you to shoulder level. Please do this as fast as you can. Keep your elbows straight when you lift and hold. Hold for my count of 3. Begin now.	0 - Unable, or needs assistance for stability.
		1 - Steps to regain equilibrium/unable to move quickly without losing balance.
		2 - Visible sway.
		3 - Normal: Remains stable.
IV. Reactive Postural responses		
Item 14. In place response - Forward		
Stand in front of the child, place one hand on each shoulder and lightly push the child backward until their anterior ankle muscles contract, (and toes just start to extend) then suddenly release. Do not allow any pre- leaning by the child. Score only the best of 2 responses if the child is unprepared or you pushed too hard.	For the next few tests, I'm going to push against you to test your balance reaction. Stand in your normal posture with your feet shoulder width apart, arms at your sides. Do not allow my hands to push you backward. When I let go, keep your balance without taking a step.	0 - Would fall if not caught OR requires assist OR will not attempt.
		1 - Takes one step with imbalance or multiple steps to recover stability.
		2 - Recovers stability with arm or hip motion OR takes one small step.

		3 - Recovers stability with ankles, no added arms or hips motion.
Item 15. In place response - Backward		
Stand behind the child, place one hand on each scapula and isometrically hold against the patient's backward push, until heels are about to be lifted, not allowing trunk motion. Suddenly release. Do not allow any pre-leaning by the child. Score the best of 2 responses if the patient is unprepared, or you pushed too hard.	Stand with your feet shoulder width apart, arms at your sides. Do not allow my hands to push you forward. When I let go, keep your balance without taking a step.	0 - Would fall if not caught OR requires assistance OR will not attempt.
		1 - Takes multiple steps to recover stability.
		2 - Recovers stability with some arm or hip motion OR takes one small step.
		3 - Recovers stability at ankles, no added arm or hip motion.
Item 16. Compensatory stepping correction – Forward		
Stand in front, to the side of the child with one hand on each shoulder and ask them to push forward. (Make sure there is room for them to step forward). Require them to lean until their shoulders and hips are in front of their toes. Suddenly release your support when the subject is in place. The test must elicit a step. Be prepared to catch the child.	Stand with your feet shoulder width apart, arms at your sides. Lean forward against my hands beyond your forward limits. When I let go, do whatever is necessary, including taking a step, to avoid a fall.	0 - No step OR would fall if not caught, OR falls spontaneously.
		1 - Takes multiple steps to recover equilibrium, or needs minimum assistance to prevent a fall.
		2 - More than 1 step used to recover equilibrium, but recovers stability independently OR 1 step with imbalance.
		3 - Recovers independently with a single, large step (second realignment step is allowed).
Item 17. Compensatory stepping correction - Backward		

Stand in back and to the side of the child with one hand on each scapula and ask them to lean backward. (Make sure there is room for them to step backward.) Require them to lean until their shoulders and hips are in back of their heels. Release your support when the child is in place. Test must elicit a step.	Stand with your feet shoulder width apart, arms down at your sides. Lean backward against my hands beyond your backward limits. When I let go, do whatever is necessary, including taking a step, to avoid a fall. NOTE: Be prepared to catch the child.	0 - No step OR would fall if not caught, OR falls spontaneously. 1 - Takes several steps to recover equilibrium, or needs minimum assistance. 2 - More than 1 step used, but stable and recovers independently OR 1 step with imbalance. 3 - Recovers independently with a single, large step.
Item 18. Compensatory stepping correction - Lateral		
Stand in back and to the side of the child with one hand on each scapula and ask them to lean backward. (Make sure there is room for them to step backward.) Require them to lean until their shoulders and hips are in back of their heels. Release your support when the child is in place. Test must elicit a step.	Stand with your feet shoulder width apart, arms down at your sides. Lean backward against my hands beyond your backward limits. When I let go, do whatever is necessary, including taking a step, to avoid a fall. NOTE: Be prepared to catch the child.	0 - Falls, or cannot step. 1 - Steps, but needs to be assisted to prevent a fall. 2 - Several steps used, but recovers independently. 3 - Recovers independently with 1 step of normal length/width (crossover or lateral OK).
V. Sensory Orientation		
Item 19. Sensory integration for balance (Modified CTSIB)		
Do the tests in order. Record the time the child was able to stand in each condition to a maximum of 30 s. Repeat condition if not able to stand for 30 s and record both trials (average for category). Use	For the next 4 assessments, you'll either be standing on this foam or on the normal ground, with your eyes open or with this eye mask	0 - Unable 1 - < 30 sec 2 - 30 s unstable

medium density Temper® foam, 10 cm thick. Assist the child in stepping onto foam. Have the child step off the foam between trials. Include leaning or hip strategy during a trial as “instability.”	in place. Place your hands on your hips. Place your feet together until almost touching. Look straight ahead. Each time, stay as stable as possible until I say stop.	3 - 30 s stable
Item 20. Incline eyes close		
Aid the child onto the ramp. Once the child closes their eyes, begin timing. Repeat condition if not able to stand for 30 s and average both trials/ Note if sway is greater than when standing on level surface with eyes closed (Item 15B) or if poor alignment to vertical. Assist includes use of a walking aide or light touch any time during the trial. during a trial as “instability.”	Please stand on the incline ramp with your toes toward the top. Place your feet shoulder width apart. Place your hands on your hips. I will start timing when you close your eyes.	0 - Unable to stand >10 s OR will not attempt independent stand.
		1 - Requires touch assist OR stands without assist for 10 - 20 sec.
		2 - Stands 30 s independently with greater sway than in item 19b OR aligns with surface.
		3 - Stands independently, steady without excessive sway, holds 30 sec, and aligns with gravity.
VI. Stability in gait		
Item 21. Gait on a level surface		
Place two markers 20 feet (6 meters) apart and visible to the patient on a level walkway. Use a stopwatch to time gait duration. Have the child start with their toes on the mark. Start timing with the stopwatch when the first foot leaves the ground and stop timing when both feet stop beyond the next mark.	Walk at your normal speed from here past the next mark and stop.	0 - Severe: Cannot walk 20 feet without assistance, or severe gait deviations OR severe imbalance.
		1 - Moderate: Walks 20 feet, evidence of imbalance (wide - base, lateral trunk motion, step path inconsistent) - at any preferred speed.

		2 - Mild: Walks 20 feet, slower speed (>5.5 sec), no evidence of imbalance.
		3 - Normal: Walks 20 feet, good speed (5.5 sec), no evidence of imbalance.
Item 22. Change in speed		
Allow the child to take 2-3 steps at their normal speed, and then say “fast”, after 2-3 fast steps, say “slow”. Allow 2-3 slow steps before they stop walking.	Begin walking at your normal speed, when I tell you “fast” walk as fast as you can. When I say “slow”, walk very slowly.	0 - Severe: Unable to achieve significant change in speed AND signs of imbalance.
		1 - Moderate: Changes walking speed but with signs of imbalance.
		2 - Mild: Unable to change walking speed without imbalance.
		3 - Normal: Significantly changes walking speed without imbalance.
Item 23. Walk with head turns - Horizontal		
Ask the child to turn their head and hold it so they are looking over their shoulder until you tell them to look over the opposite shoulder every 2-3 steps. If the child has cervical restrictions allow combined head and trunk movements (enbloc).	Begin walking at your normal speed, when I say “right”, turn your head and look to the right. When I say “left” turn your head and look to the left. Try to keep yourself walking in a straight line.	0 - Severe: Performs head turns with reduced speed AND imbalance AND /OR will not move head within available range while walking.
		1 - Moderate: Performs head turns with imbalance.
		2 - Mild: Performs head turns smoothly with reduction in gait speed.

		3 - Normal: Performs head turns with no change in gait speed and good balance.
Item 24. Walk with pivot turns		
Demonstrate a pivot turn. Once the child is walking at normal speed, say “turn and stop.” Count the steps from turn until the child is stable. Instability is indicated by wide stance width, extra stepping or trunk and arm motion.	Begin walking at your normal speed. When I tell you to “turn and stop”, turn as quickly as you can to face the opposite direction and stop. After the turn, your feet should be close together.	0 - Severe: Cannot turn with feet close at any speed and significant imbalance.
		1 - Moderate: Turns with feet close at any speed with mild signs of imbalance.
		2 - Mild: Turns with feet close SLOW (>4 steps) with good balance.
		3 - Normal: Turns with feet close, FAST (<3 steps) with good balance.
Item 25. Step over obstacles		
Place an object (mid shin height) 3m away from where the child will begin walking. Use a stopwatch to time gait duration to calculate average velocity by dividing the number of s into 6m. Look for hesitation, short steps, excessive trunk flexion/extension and touch on the obstacle.	Begin walking at your normal speed. When you come to the object, step over it, not around it and keep walking.	0 - Severe: Cannot step over the object AND slows down with imbalance OR cannot perform with assistance.
		1 - Moderate: Steps over the object with imbalance or touches the object.
		2 - Mild: Steps over the object at mid shin height but slows down, with good balance.

		3 - Normal: Able to step over the object at mid shin height without changing speed and with good balance.
Item 26. Timed “Up & Go”		
Have the child sit with their back against the chair. Time the child from the time you say “go” until they return to sitting in a chair. Stop timing when the child’s buttocks hit the chair bottom. The chair should be firm with arms to push from if necessary. TOOLS: TAPE ON FLOOR 3 METERS FROM THE FRONT OF THE CHAIR LEGS.	“When I say go, stand up, walk to the line, turn around, walk back to the starting line, and sit back down on the chair. Walk, don’t run. 1, 2, 3, GO.” (Itzkowitz et al., 2016)	0 - Severe: Slow (>11 sec) AND imbalance. 1 - Moderate: Fast (<11 sec) with imbalance. 2 - Mild: Slow (>11 sec) with good balance. 3 - Normal: Fast (<11 sec) with good balance.
Item 27. Timed “Up & Go” with dual task		
Before beginning, practice with the child how to count backward from a number between 90 and 100 by 2s, to make sure they can do the cognitive task. Then ask them to count backwards from a different number and after a few numbers say GO for the GET UP AND GO TASK. Time the child from when you say “go” until they return to sitting. Stop timing when the child’s buttocks touch the chair bottom. The chair should be firm with arms to push from if necessary.	a) Count backwards by 2’s starting at 100 OR b) List random numbers and when I say “GO,”stand up from the chair, walk, don't run across the tape on the floor, turn around, and come back to sit in the chair but continue listing numbers. For the purpose of this study, the participants will be asked to recite a nursery rhyme or sing a song.	0 - Severe: Can’t count backward while walking or stops walking while talking. 1 - Moderate: Affects on BOTH the cognitive task AND slow walking (>10%) in dual task. 2 - Mild: Noticeable slowing, hesitation or errors in counting backwards OR slow walking (10%) in dual task. 3 - Normal: No noticeable change between sitting and standing in the rate or accuracy of backwards counting and no

		change in gait speed.

(Dewar et al., 2017)

Appendix D: The shortened Kids-Balance Evaluation Systems Test (mini Kids-BESTest)

The Mini-Kids-BESTest is a short form of the full Kids-BESTest that is completed in 10-15 minutes, with a subset of 14 items derived from the full Kids-BESTest (Dewar et al., 2017). A maximum of 28 points can be achieved and domain specific results can also be calculated by scoring each item from 0 (worst performance) to 2 (best performance) (Dewar et al., 2017).

The items with their scoring are as follows:

Examiner Instructions	Child Instructions	Scoring
I. Transitions - Anticipatory postural adjustments		
Item 1. Sit to stand		
Note the initiation of the movement, and the use of hands on the arms of the chair or their thighs or thrusts arms forward.	Cross arms across your chest. Try not to use your hands unless you must. Don't let your legs lean against the back of the chair when you stand. Please stand up now.	0 - Requires moderate or maximal assist to stand.
		1 - Comes to stand on the first attempt with the use of hands.
		2 - Normal: Comes to stand without the use of hands and stabilizes independently.
Item 2. Rise to toes		
Allow the patient to try it twice. Record the best score. (If you suspect that the subject is using less than their full height, ask them to rise up while holding the examiners' hands.) Make sure subjects look at a target 1.2m - 3.6m away.	Place your feet shoulder width apart. Place your hands on your hips. Try to rise as high as you can onto your toes. I'll count out loud for 3 s. Try to hold this pose for at least 3 s. Look straight ahead at the target on the wall. Rise now.	0 - Holds for less than 3 sec.
		1 - Heels up, but not full range (smaller than when holding hands so no balance requirement - OR - slight instability & holds for 3 sec.
		2 - Normal: Stable for 3s with good height.

Item 3. Stand on one leg		
Allow the patient two attempts and record the best. Record the s they can hold posture, up to a maximum of 25 sec. If their legs touch, cue them to keep them apart but keep timing. If excessive trunk movement, hyperextension of the stance knee, excessive hip flexion, hover lifted toe or knees touching persists throughout the first 20 s, despite cues score 2. Stop timing when the subject moves their hands off hips or puts a foot down. Assess trunk movement and other signs of instability in the first 20 s only.	Look straight ahead at the target on the wall. Keep your hands on your hips. Bend one leg behind you to 90. Don’t touch your raised leg on your other leg or take your hands off your hips. Stay standing on one leg as long as you can. Look straight ahead. Lift now. (REPEAT other side)	0 - Unable.
		1 - Trunk motion AND/OR other signs of instability, OR 10 - 20 sec.
		2 - Normal: Stable for > 20 sec.
II. Reactive Postural responses		
Item 4. Compensatory stepping correction - Forward		
Stand in front, to the side of the child with one hand on each shoulder and ask them to push forward. (Make sure there is room for them to step forward). Require them to lean until their shoulders and hips are in front of their toes. Suddenly release your support when the subject is in place. The test must elicit a step. Be prepared to catch the child.	Stand with your feet shoulder width apart, arms at your sides. Lean forward against my hands beyond your forward limits. When I let go, do whatever is necessary, including taking a step, to avoid a fall.	0 - No step OR would fall if not caught, OR falls spontaneously.
		1 - More than 1 step used to recover equilibrium, but recovers stability independently OR 1 step with imbalance.
		2 - Recovers independently with a single, large step (second realignment step is allowed).
Item 5. Compensatory stepping correction - Backward		
Stand in back and to the side of the child with one hand on each scapula and ask them to lean backward. (Make sure there is room for them to step backward.) Require them to lean until their	Stand with your feet shoulder width apart, arms down at your sides. Lean backward against my hands beyond your backward limits. When I let go, do whatever is	0 - No step OR would fall if not caught, OR falls spontaneously.
		1 - More than 1 step used, but stable and recovers

shoulders and hips are in back of their heels. Release your support when the child is in place. Test must elicit a step.	necessary, including taking a step, to avoid a fall. NOTE: Be prepared to catch the child.	independently OR 1 step with imbalance. 2 - Recovers independently with a single, large step.
Item 6. Compensatory stepping correction - Lateral		
Stand in back and to the side of the child with one hand on each scapula and ask them to lean backward. (Make sure there is room for them to step backward.) Require them to lean until their shoulders and hips are in back of their heels. Release your support when the child is in place. Test must elicit a step.	Stand with your feet shoulder width apart, arms down at your sides. Lean backward against my hands beyond your backward limits. When I let go, do whatever is necessary, including taking a step, to avoid a fall. NOTE: Be prepared to catch the child.	0 - Falls, or cannot step. 1 - Several steps used, but recovers independently. 2 - Recovers independently with 1 step of normal length/width (crossover or lateral OK).
III. Sensory Orientation		
Item 7 & 8. Sensory integration for balance (Modified CTSIB)		
Do the tests first on a firm surface with eye open and then on a foam surface with eyes closed. Record the time the child was able to stand in each condition to a maximum of 30 s. Repeat condition if not able to stand for 30 s and record both trials (average for category). Use medium density Temper® foam, 10 cm thick. Assist the child in stepping onto foam. Have the child step off the foam between trials. Include leaning or hip strategy during a trial as "instability."	For the next 2 assessments, you'll either be standing on this foam or on the normal ground, with your eyes open or with this eye mask in place. Place your hands on your hips. Place your feet together until almost touching. Look straight ahead. Each time, stay as stable as possible until I say stop.	0 - Unable 1 - < 30 sec 2 - 30 s stable
Item 9. Incline eyes close		
Aid the child onto the ramp. Once the child closes their eyes, begin timing. Repeat condition if not able to stand for 30 s and average both	Please stand on the incline ramp with your toes toward the top. Place your feet shoulder width apart. Place	0 - Unable to stand >10 s OR will not attempt independent stand.

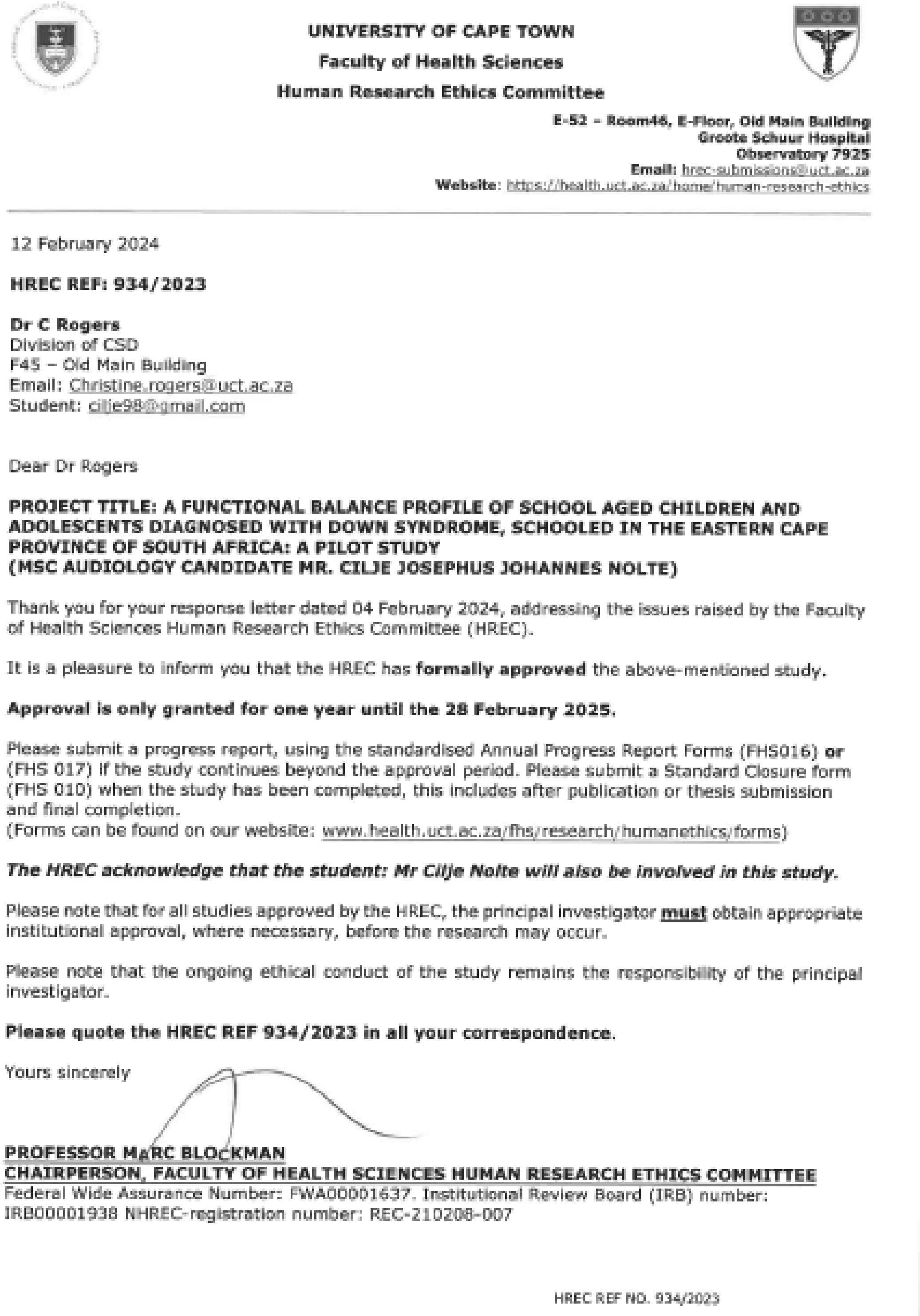
trials/ Note if sway is greater than when standing on level surface with eyes closed (Item 15B) or if poor alignment to vertical. Assist includes use of a walking aide or light touch any time during the trial. during a trial as “instability.”	your hands on your hips. I will start timing when you close your eyes.	1 - Stands 30 s independently with greater sway than in item 19b OR aligns with surface.
		2 - Stands independently, steady without excessive sway, holds 30 sec, and aligns with gravity.
IV. Stability in gait		
Item 10. Change in speed		
Allow the child to take 2-3 steps at their normal speed, and then say “fast”, after 2-3 fast steps, say “slow”. Allow 2-3 slow steps before they stop walking.	Begin walking at your normal speed, when I tell you “fast” walk as fast as you can. When I say “slow”, walk very slowly.	0 - Severe: Unable to achieve significant change in speed AND signs of imbalance.
		1 - Mild: Unable to change walking speed without imbalance.
		2 - Normal: Significantly changes walking speed without imbalance.
Item 11. Walk with head turns - Horizontal		
Ask the child to turn their head and hold it so they are looking over their shoulder until you tell them to look over the opposite shoulder every 2-3 steps. If the child has cervical restrictions allow combined head and trunk movements (enbloc).	Begin walking at your normal speed, when I say “right”, turn your head and look to the right. When I say “left” turn your head and look to the left. Try to keep yourself walking in a straight line.	0 - Severe: Performs head turns with reduced speed AND imbalance AND /OR will not move head within available range while walking.
		1 - Mild: Performs head turns smoothly with reduction in gait speed.

		2 - Normal: Performs head turns with no change in gait speed and good balance.
Item 12. Walk with pivot turns		
Demonstrate a pivot turn. Once the child is walking at normal speed, say “turn and stop.” Count the steps from turn until the child is stable. Instability is indicated by wide stance width, extra stepping or trunk and arm motion.	Begin walking at your normal speed. When I tell you to “turn and stop”, turn as quickly as you can to face the opposite direction and stop. After the turn, your feet should be close together.	0 - Severe: Cannot turn with feet close at any speed and significant imbalance.
		1 - Mild: Turns with feet close SLOW (>4 steps) with good balance.
		2 - Normal: Turns with feet close, FAST (<3 steps) with good balance.
Item 13. Step over obstacles		
Place an object (mid shin height) 3m away from where the patient will begin walking. Use a stopwatch to time gait duration to calculate average velocity by dividing the number of s into 6m. Look for hesitation, short steps, excessive trunk flexion/extension and touch on the obstacle.	Begin walking at your normal speed. When you come to the object, step over it, not around it and keep walking.	0 - Severe: Cannot step over the object AND slows down with imbalance OR cannot perform with assistance.
		1 - Moderate: Steps over the object with imbalance or touches the object or shows cautious behaviour by slowing gait
		2 - Normal: Able to step over the object at mid shin height without changing speed and with good balance.
Item 14. Timed “Up & Go” with dual task		

Before beginning, practice with the child how to count backward from a number between 90 and 100 by 2s, to make sure they can do the cognitive task. Then ask them to count backwards from a different number and after a few numbers say GO for the GET UP AND GO TASK. Time the child from when you say “go” until they return to sitting. Stop timing when the child’s buttocks touch the chair bottom. The chair should be firm with arms to push from if necessary.	a) Count backwards by 2’s starting at 100 OR b) List random numbers and when I say “GO,”stand up from the chair, walk, don't run across the tape on the floor, turn around, and come back to sit in the chair but continue listing numbers. For the purpose of this study, the participants will be asked to recite a nursery rhyme or sing a song.	0 - Severe: Can’t count backward while walking or stops walking while talking.
		1 - Mild: Noticeable slowing, hesitation or errors in counting backwards OR slow walking (10%) in dual task.
		2 - Normal: No noticeable change between sitting and standing in the rate or accuracy of backwards counting and no change in gait speed.

(Dewar et al., 2017)

Appendix E: Human Resources Ethics Committee (HREC) Approval letter (HREC Ref: 934/2023)



UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Human Research Ethics Committee

E-52 – Room46, E-Floor, Old Main Building
Groote Schuur Hospital
Observatory 7925
Email: hrec-submissions@uct.ac.za
Website: https://health.uct.ac.za/home/human-research-ethics

12 February 2024

HREC REF: 934/2023

Dr C Rogers
Division of CSD
F45 – Old Main Building
Email: Christine.rogers@uct.ac.za
Student: cilje98@gmail.com

Dear Dr Rogers

PROJECT TITLE: A FUNCTIONAL BALANCE PROFILE OF SCHOOL AGED CHILDREN AND ADOLESCENTS DIAGNOSED WITH DOWN SYNDROME, SCHOOLED IN THE EASTERN CAPE PROVINCE OF SOUTH AFRICA: A PILOT STUDY
(MSC AUDIOLOGY CANDIDATE MR. CILJE JOSEPHUS JOHANNES NOLTE)

Thank you for your response letter dated 04 February 2024, addressing the issues raised by the Faculty of Health Sciences Human Research Ethics Committee (HREC).

It is a pleasure to inform you that the HREC has **formally approved** the above-mentioned study.

Approval is only granted for one year until the 28 February 2025.

Please submit a progress report, using the standardised Annual Progress Report Forms (FHS016) **or** (FHS 017) if the study continues beyond the approval period. Please submit a Standard Closure form (FHS 010) when the study has been completed, this includes after publication or thesis submission and final completion.
(Forms can be found on our website: www.health.uct.ac.za/fhs/research/humanethics/forms)

The HREC acknowledge that the student: Mr Cilje Nolte will also be involved in this study.

Please note that for all studies approved by the HREC, the principal investigator **must** obtain appropriate institutional approval, where necessary, before the research may occur.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please quote the HREC REF 934/2023 in all your correspondence.

Yours sincerely

PROFESSOR MARC BLOCKMAN
CHAIRPERSON, FACULTY OF HEALTH SCIENCES HUMAN RESEARCH ETHICS COMMITTEE
Federal Wide Assurance Number: FWA00001637. Institutional Review Board (IRB) number: IRB00001938 NHREC-registration number: REC-210208-007

This serves to confirm that the University of Cape Town Human Research Ethics Committee complies to the Ethics Standards for Clinical Research with a new drug in patients, based on the Medical Research Council (MRC-SA), Food and Drug Administration (FDA-USA), International Council for Harmonisation of Technical Requirements for Pharmaceuticals for Human Use: Good Clinical Practice (ICH GCP), South African Good Clinical Practice Guidelines (DoH 2020), based on the Association of the British Pharmaceutical Industry Guidelines (ABPI), and Declaration of Helsinki (2013) guidelines. The Human Research Ethics Committee granting this approval is in compliance with the ICH Harmonised Tripartite Guidelines E6: Note for Guidance on Good Clinical Practice (CPMP/ICH/135/95) and FDA Code Federal Regulation Part 50, 56 and 312.

HREC REF NO. 934/2023

Appendix F: Letter to the Department of Basic Education

DHRS
Department of Health and Rehabilitation Sciences
FACULTY OF HEALTH SCIENCES
Divisions of Communication Sciences & Disorders • Disability Studies
• Nursing & Midwifery • Occupational Therapy •Physiotherapy
F45 Old Main Building, Groote Schuur Hospital
Observatory, Cape Town, South Africa, 7925
Telephone: +27 (0) 21 406 6401
Website: www.dhrs.uct.ac.za

Date:
Department of Basic Education
Ethel Valentine building
No 5 Sutton Road
Sidwell
Gqeberha
6056

RE: Permission to conduct research study concerning the functional balance abilities of children with Down Syndrome and typically developing children who are in mainstream schools in the Gqeberha area

To whom it may concern,

I am a student at the University of Cape Town, in the process of writing my Master’s thesis. The study is entitled “A functional balance profile of school aged children and adolescents diagnosed with Down Syndrome, schooled in the Eastern Cape province of South Africa: A pilot study.” and has been approved by the University of Cape Town Faculty of Health Sciences Human Research Ethics Committee (Reference number HREC 934/2023).

I hope that you will allow me to recruit learners who are diagnosed with Down Syndrome, aged between six to eighteen years at the Merryvale School for Specialised Education, as well as typically developing children schooled at the Westering Primary and – High Schools to complete a set of activities assessing their functional balance abilities along with an assessment of middle ear function and hearing. A height and weight measurement will also form part of the assessment. More information about these procedures can be found on the information sheet supplied. Information about the study will be distributed by the school and students who provide a signed consent form from their parents or legal guardians will be assessed for eligibility. Each participant will be asked if they are willing to complete each task, to ensure that their participation is willing and voluntary.

If parental consent is granted, learners will complete a set of activities assessing their functional balance abilities, for example, walking on a straight line, standing on one leg and sitting on a chair, as well as assessing middle ear status and hearing abilities in a quiet indoor space on the school premises. For more information regarding the exact procedures please refer to the procedures section in the research proposal attached to this document. The dates and times of the activities will be discussed to accommodate the school and learners. I expect each session with an individual child will take between 20 to 30 minutes and to avoid fatigue; the assessments will be split over 2 days. The results of the data obtained will be pooled for the thesis project and individual results will remain absolutely confidential and anonymous. Individual results will however be made available to the parents/legal guardians of each participant. Should this study be published, only pooled results will be documented. No costs will be incurred by either the school or individual participants.

Due to the children’s diagnosis of Down Syndrome, a functional balance deficit is present as described in previous literature, increasing their likelihood of falling. During the assessment tasks every effort will be made to ensure the safety of every child. Firstly a gait belt will be used to allow the researcher to help each child move around safely along with close guarding. In the event that a child should fall, a first aid kit will be available on site to use for any minor injuries. The school nurse will also be made aware of any falls that occur. Water will be available for consumption throughout the process and each child will receive small rewards after each activity

The methods used in this study have been reviewed and approved by the University of Cape Town Faculty of Health Sciences Human Research Ethics Committee (Reference: HREC 934/2023). This research will be used to aid other studies in the development and refinement of rehabilitative measures that can ultimately be used to improve the balance function of the school aged children and adolescents diagnosed with Down Syndrome, especially in a South African context.

Your approval to conduct this study will be greatly appreciated. If you have any concerns for the children’s human rights or welfare, you can contact the University of Cape Town Human Research Ethics Committee at 021 406 6338. You can also contact me at cilje98@gmail.com or 071 122 9224 and my supervisor, Dr. Christine Rogers at christine.rogers@uct.ac.za if you are in need of further information.

If you agree, kindly sign below and return the signed form via email to the email address that I have sent this letter to you on. Alternatively, kindly submit a signed letter of permission on your letterhead acknowledging your consent and permission for me to conduct this study.

Sincerely,

Ciljé Nolte
Clinical Audiologist (AU0010081)
BA(Audiology) – UP (2020)

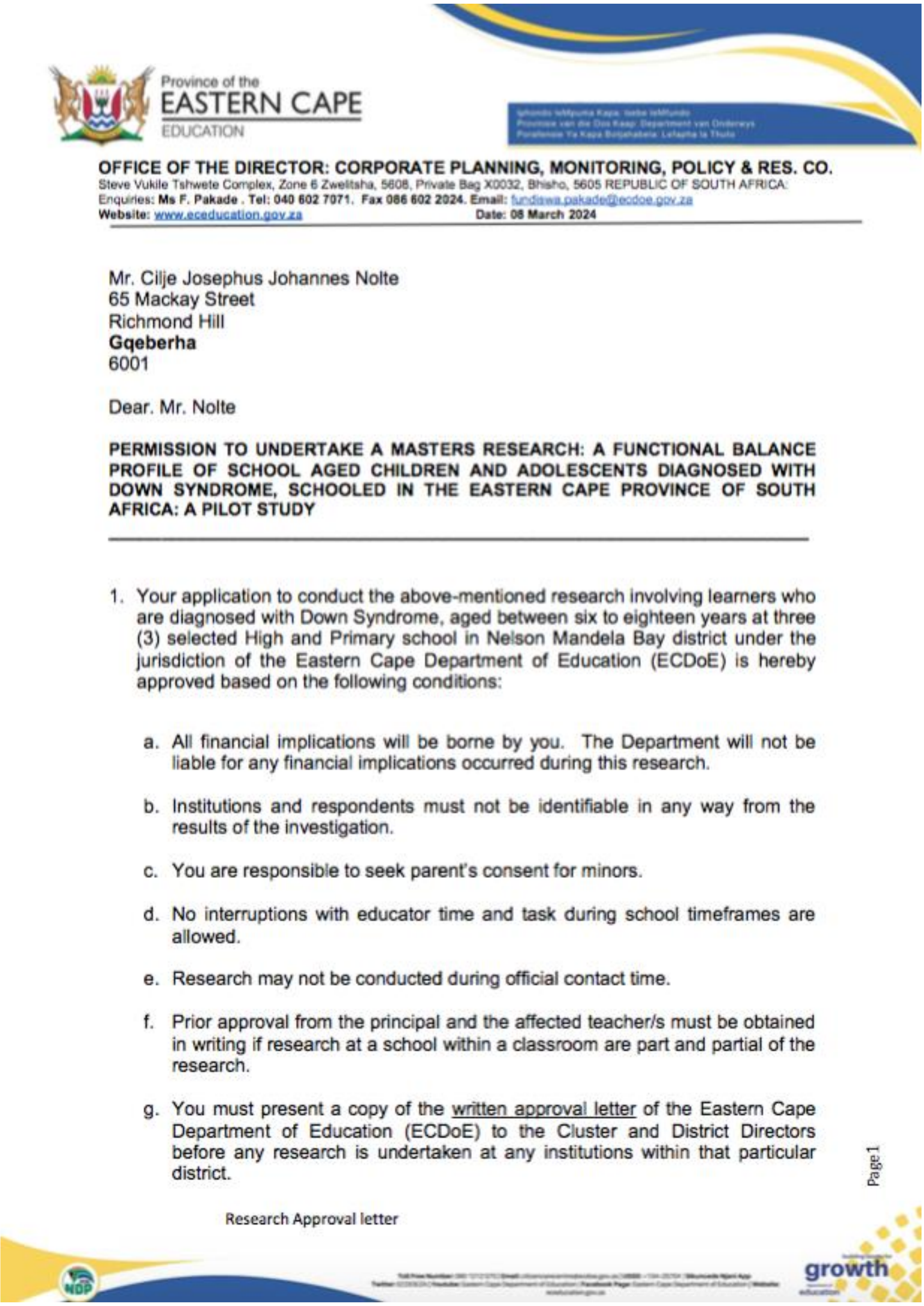
I, ___________________________, give permission to Mr. C.J.J. Nolte to complete the study, entitled “A functional balance profile of school aged children and adolescents diagnosed with Down’s Syndrome, schooled in the Eastern Cape province of South Africa: A pilot study” at the schools stipulated in this letter. The study has been explained to me and my questions have been answered to my satisfaction.

Approved by:________________________

Signature:__________________________

Date:______________________________

Appendix G: Approval letter from the Eastern Cape Department of Education



Province of the
EASTERN CAPE
EDUCATION

OFFICE OF THE DIRECTOR: CORPORATE PLANNING, MONITORING, POLICY & RES. CO.
Steve Vukile Tshwete Complex, Zone 6 Zwelitsha, 5608, Private Bag X0032, Bhisho, 5605 REPUBLIC OF SOUTH AFRICA:
Enquiries: **Ms F. Pakade . Tel: 040 602 7071. Fax 086 602 2024. Email:** fundiswa.pakade@ecdoe.gov.za
Website: www.eceducation.gov.za **Date: 08 March 2024**

Mr. Cilje Josephus Johannes Nolte
65 Mackay Street
Richmond Hill
Gqeberha
6001

Dear. Mr. Nolte

PERMISSION TO UNDERTAKE A MASTERS RESEARCH: A FUNCTIONAL BALANCE PROFILE OF SCHOOL AGED CHILDREN AND ADOLESCENTS DIAGNOSED WITH DOWN SYNDROME, SCHOOLED IN THE EASTERN CAPE PROVINCE OF SOUTH AFRICA: A PILOT STUDY

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1. Your application to conduct the above-mentioned research involving learners who are diagnosed with Down Syndrome, aged between six to eighteen years at three (3) selected High and Primary school in Nelson Mandela Bay district under the jurisdiction of the Eastern Cape Department of Education (ECDoE) is hereby approved based on the following conditions:

    a. All financial implications will be borne by you. The Department will not be liable for any financial implications occurred during this research.

    b. Institutions and respondents must not be identifiable in any way from the results of the investigation.

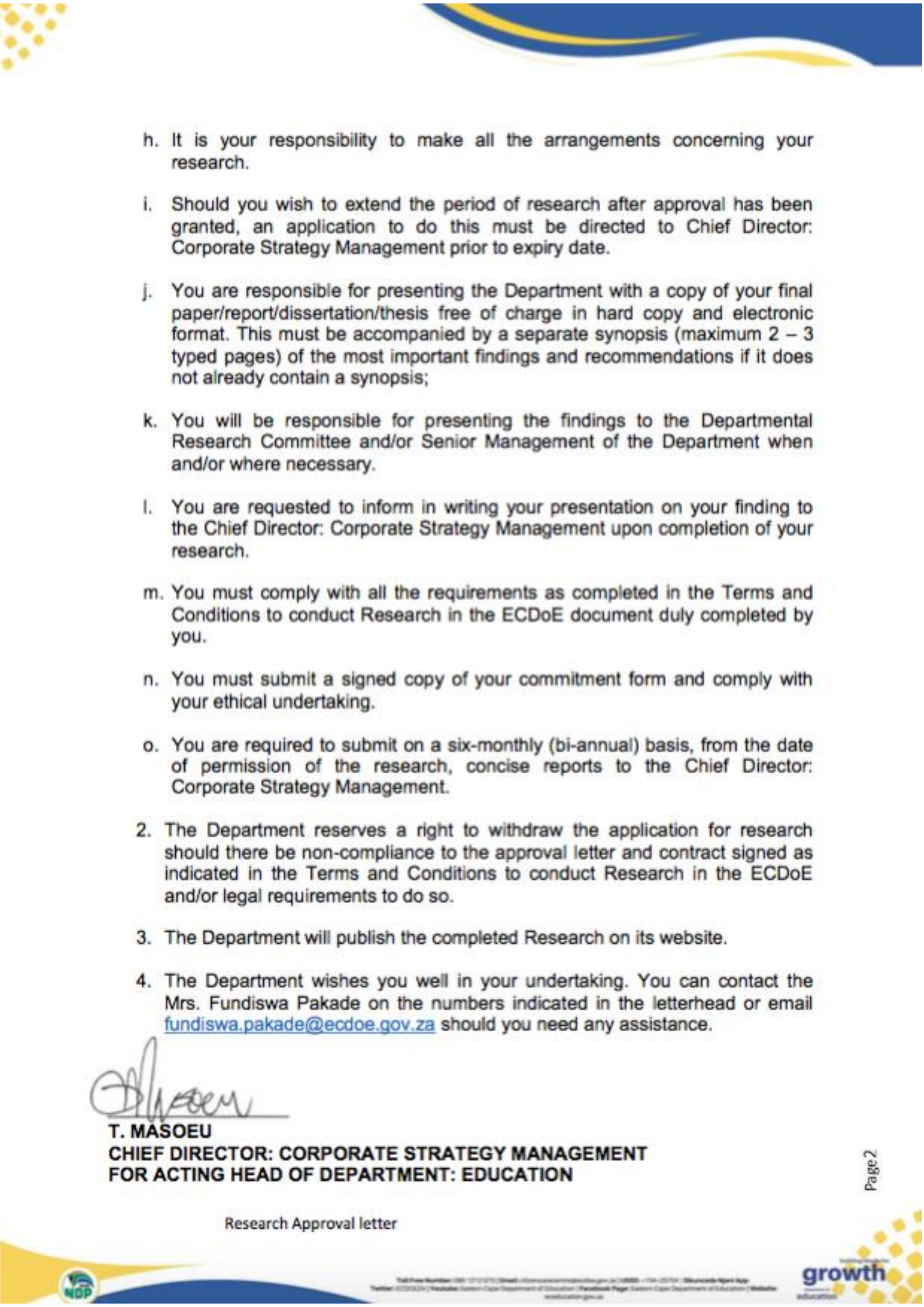
    c. You are responsible to seek parent's consent for minors.

    d. No interruptions with educator time and task during school timeframes are allowed.

    e. Research may not be conducted during official contact time.

    f. Prior approval from the principal and the affected teacher/s must be obtained in writing if research at a school within a classroom are part and partial of the research.

    g. You must present a copy of the written approval letter of the Eastern Cape Department of Education (ECDoE) to the Cluster and District Directors before any research is undertaken at any institutions within that particular district.



h. It is your responsibility to make all the arrangements concerning your research.

i. Should you wish to extend the period of research after approval has been granted, an application to do this must be directed to Chief Director: Corporate Strategy Management prior to expiry date.

j. You are responsible for presenting the Department with a copy of your final paper/report/dissertation/thesis free of charge in hard copy and electronic format. This must be accompanied by a separate synopsis (maximum 2 – 3 typed pages) of the most important findings and recommendations if it does not already contain a synopsis;

k. You will be responsible for presenting the findings to the Departmental Research Committee and/or Senior Management of the Department when and/or where necessary.

l. You are requested to inform in writing your presentation on your finding to the Chief Director: Corporate Strategy Management upon completion of your research.

m. You must comply with all the requirements as completed in the Terms and Conditions to conduct Research in the ECDoE document duly completed by you.

n. You must submit a signed copy of your commitment form and comply with your ethical undertaking.

o. You are required to submit on a six-monthly (bi-annual) basis, from the date of permission of the research, concise reports to the Chief Director: Corporate Strategy Management.

2. The Department reserves a right to withdraw the application for research should there be non-compliance to the approval letter and contract signed as indicated in the Terms and Conditions to conduct Research in the ECDoE and/or legal requirements to do so.

3. The Department will publish the completed Research on its website.

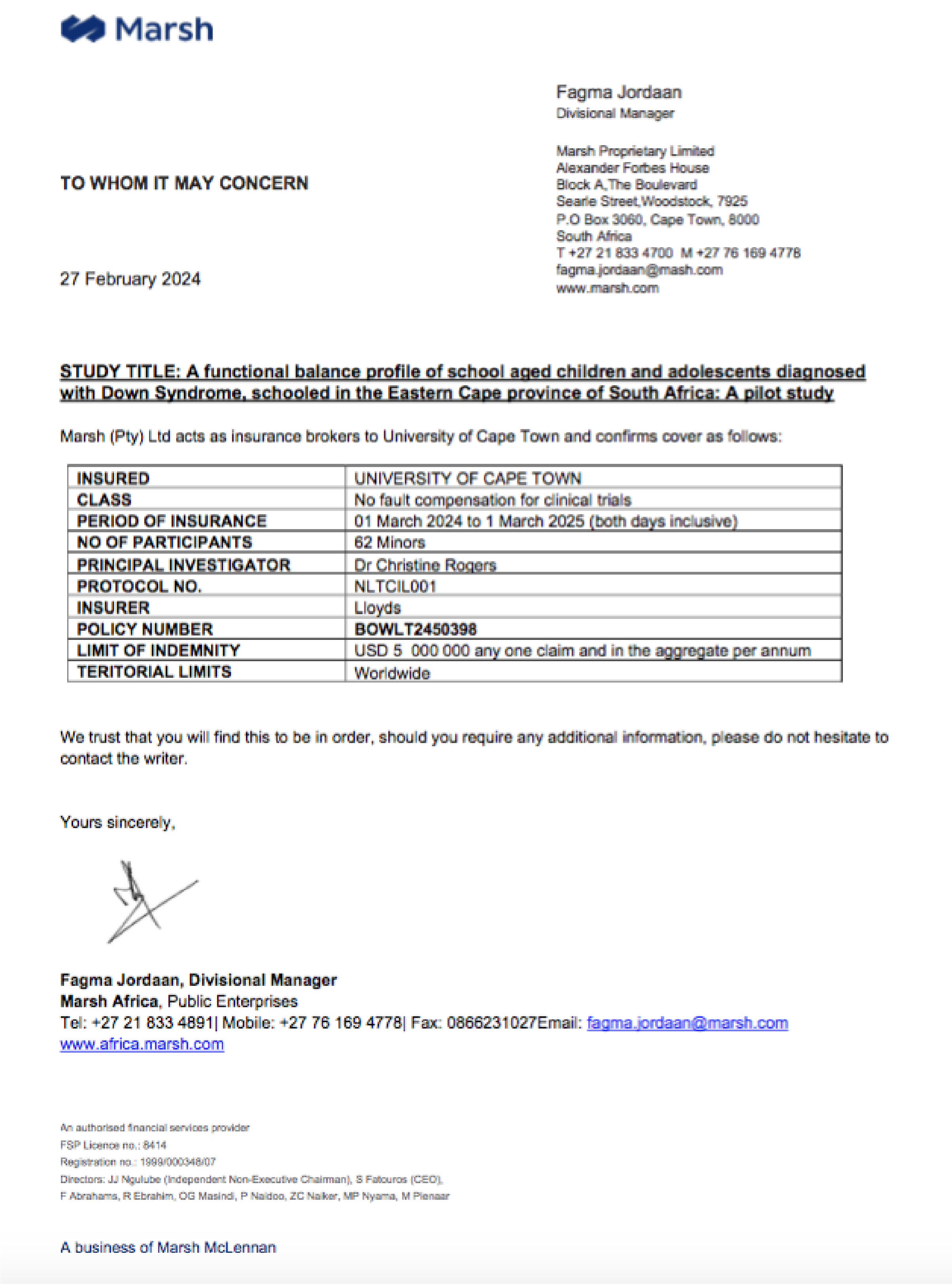
4. The Department wishes you well in your undertaking. You can contact the Mrs. Fundiswa Pakade on the numbers indicated in the letterhead or email fundiswa.pakade@ecdoe.gov.za should you need any assistance.

T. MASOEU
CHIEF DIRECTOR: CORPORATE STRATEGY MANAGEMENT
FOR ACTING HEAD OF DEPARTMENT: EDUCATION

Page 2

Research Approval letter

Appendix H: No-fault insurance



Marsh

Fagma Jordaan
Divisional Manager

Marsh Proprietary Limited
Alexander Forbes House
Block A,The Boulevard
Searle Street,Woodstock, 7925
P.O Box 3060, Cape Town, 8000
South Africa
T +27 21 833 4700 M +27 76 169 4778
fagma.jordaan@mash.com
www.marsh.com

TO WHOM IT MAY CONCERN

27 February 2024

STUDY TITLE: A functional balance profile of school aged children and adolescents diagnosed with Down Syndrome, schooled in the Eastern Cape province of South Africa: A pilot study

Marsh (Pty) Ltd acts as insurance brokers to University of Cape Town and confirms cover as follows:

INSURED	UNIVERSITY OF CAPE TOWN
CLASS	No fault compensation for clinical trials
PERIOD OF INSURANCE	01 March 2024 to 1 March 2025 (both days inclusive)
NO OF PARTICIPANTS	62 Minors
PRINCIPAL INVESTIGATOR	Dr Christine Rogers
PROTOCOL NO.	NLTCIL001
INSURER	Lloyds
POLICY NUMBER	**BOWLT2450398**
LIMIT OF INDEMNITY	USD 5 000 000 any one claim and in the aggregate per annum
TERITORIAL LIMITS	Worldwide

We trust that you will find this to be in order, should you require any additional information, please do not hesitate to contact the writer.

Yours sincerely,

Fagma Jordaan, Divisional Manager
Marsh Africa, Public Enterprises
Tel: +27 21 833 4891| Mobile: +27 76 169 4778| Fax: 0866231027Email: fagma.jordaan@marsh.com
www.africa.marsh.com

Appendix I: Letter to the Merryvale school principal

DHRS
Department of Health and Rehabilitation Sciences
Faculty of Health Sciences

Divisions of Communication Sciences & Disorders • Disability Studies
• Nursing & Midwifery • Occupational Therapy •Physiotherapy

F45 Old Main Building, Groote Schuur Hospital
Observatory, Cape Town, South Africa, 7925
Telephone: +27 (0) 21 406 6481
Website: www.dhrs.uct.ac.za

Date: 15 April 2024
Mrs. Saayman
Principal at Merryvale School for Specialised Education
1 Alan Drive
Mangold Park
Gqeberha
6070

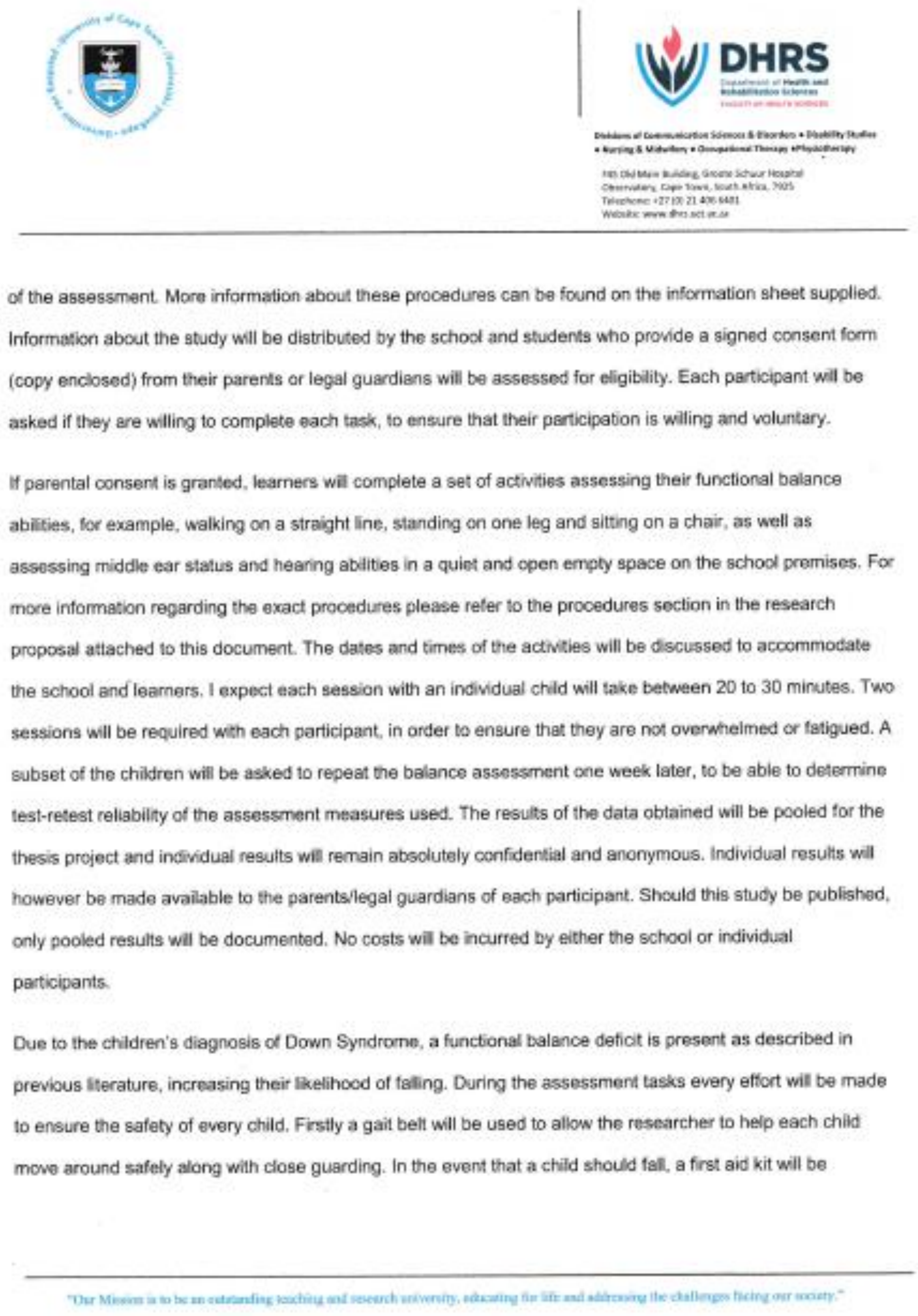
Dear Mrs. Saayman

RE: Permission to conduct research study concerning the functional balance abilities of children with Down Syndrome at your school.

I am writing to request permission to conduct a research study at your school. I am a student at the University of Cape Town, in the process of writing my Master's thesis. The study is entitled "A functional balance profile of school aged children and adolescents diagnosed with Down Syndrome, schooled in the Eastern Cape province of South Africa: A pilot study" and has been approved by the University of Cape Town Faculty of Health Sciences Human Research Ethics Committee (Reference number HREC 934/2023).

Children with Down Syndrome have shown to have decreased balance ability and abnormal gait patterns, as well as delayed motor development (Jung et al., 2017). Limits in motor abilities cause an increased strain in maintaining a state of equilibrium in an ever-changing environment, especially in the Down Syndrome population (Malak et al., 2013). Further detailed knowledge is needed to explore balance deficits and possible remediation strategies of children and adolescents with Down Syndrome in South Africa, as the current research available appears to be very scant and flawed. My study aims to determine the feasibility of doing a larger scale study, assessing the balance function of South African children and adolescents with Down Syndrome.

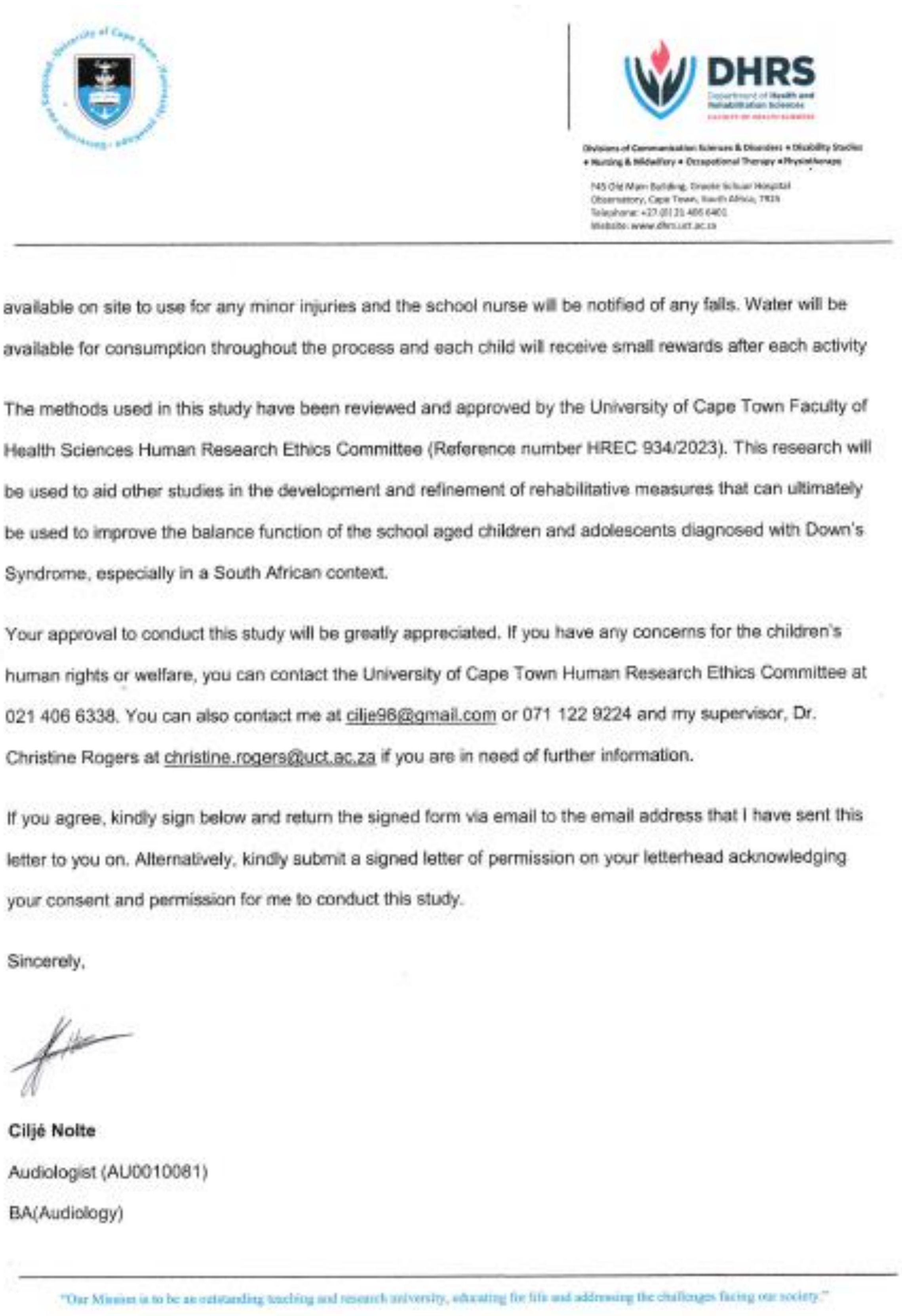
I hope that you will allow me to recruit learners who are diagnosed with Down Syndrome, aged between six to eighteen years at your school to complete a set of activities assessing their functional balance abilities along with an assessment of middle ear function and hearing. A height and weight measurement will also form part



of the assessment. More information about these procedures can be found on the information sheet supplied. Information about the study will be distributed by the school and students who provide a signed consent form (copy enclosed) from their parents or legal guardians will be assessed for eligibility. Each participant will be asked if they are willing to complete each task, to ensure that their participation is willing and voluntary.

If parental consent is granted, learners will complete a set of activities assessing their functional balance abilities, for example, walking on a straight line, standing on one leg and sitting on a chair, as well as assessing middle ear status and hearing abilities in a quiet and open empty space on the school premises. For more information regarding the exact procedures please refer to the procedures section in the research proposal attached to this document. The dates and times of the activities will be discussed to accommodate the school and learners. I expect each session with an individual child will take between 20 to 30 minutes. Two sessions will be required with each participant, in order to ensure that they are not overwhelmed or fatigued. A subset of the children will be asked to repeat the balance assessment one week later, to be able to determine test-retest reliability of the assessment measures used. The results of the data obtained will be pooled for the thesis project and individual results will remain absolutely confidential and anonymous. Individual results will however be made available to the parents/legal guardians of each participant. Should this study be published, only pooled results will be documented. No costs will be incurred by either the school or individual participants.

Due to the children's diagnosis of Down Syndrome, a functional balance deficit is present as described in previous literature, increasing their likelihood of falling. During the assessment tasks every effort will be made to ensure the safety of every child. Firstly a gait belt will be used to allow the researcher to help each child move around safely along with close guarding. In the event that a child should fall, a first aid kit will be



available on site to use for any minor injuries and the school nurse will be notified of any falls. Water will be available for consumption throughout the process and each child will receive small rewards after each activity

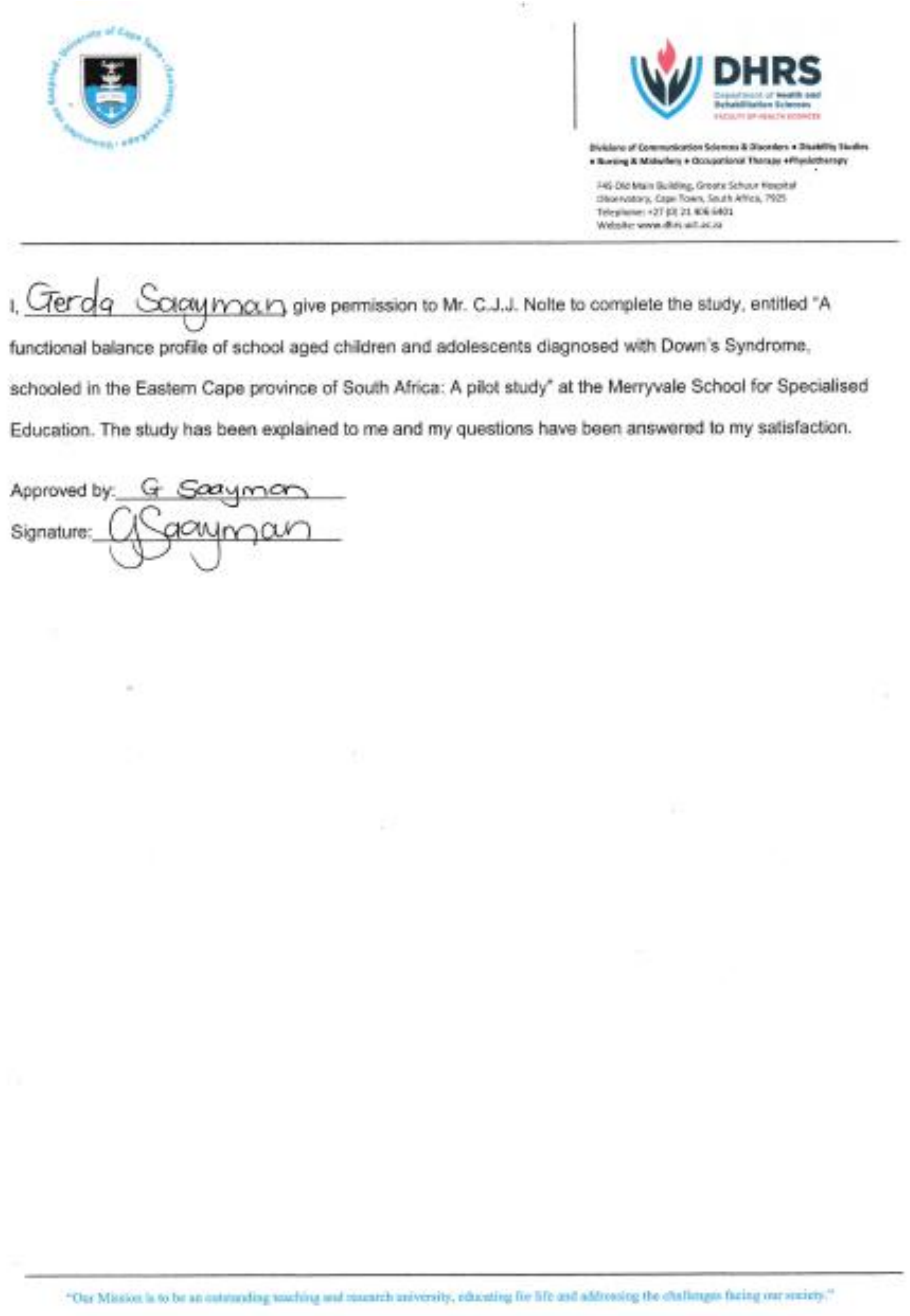
The methods used in this study have been reviewed and approved by the University of Cape Town Faculty of Health Sciences Human Research Ethics Committee (Reference number HREC 934/2023). This research will be used to aid other studies in the development and refinement of rehabilitative measures that can ultimately be used to improve the balance function of the school aged children and adolescents diagnosed with Down's Syndrome, especially in a South African context.

Your approval to conduct this study will be greatly appreciated. If you have any concerns for the children's human rights or welfare, you can contact the University of Cape Town Human Research Ethics Committee at 021 406 6338. You can also contact me at cilje98@gmail.com or 071 122 9224 and my supervisor, Dr. Christine Rogers at christine.rogers@uct.ac.za if you are in need of further information.

If you agree, kindly sign below and return the signed form via email to the email address that I have sent this letter to you on. Alternatively, kindly submit a signed letter of permission on your letterhead acknowledging your consent and permission for me to conduct this study.

Sincerely,

Cilјé Nolte
Audiologist (AU0010081)
BA(Audiology)



DHRS
Department of Health and Rehabilitation Sciences
FACULTY OF HEALTH SCIENCES

Divisions of Communication Sciences & Disorders • Disability Studies
• Nursing & Midwifery • Occupational Therapy •Physiotherapy

F45 Old Main Building, Groote Schuur Hospital
Observatory, Cape Town, South Africa, 7925
Telephone: +27 (0) 21 406 6401
Website: www.dhrs.uct.ac.za

I, Gerda Saayman give permission to Mr. C.J.J. Nolte to complete the study, entitled "A functional balance profile of school aged children and adolescents diagnosed with Down's Syndrome, schooled in the Eastern Cape province of South Africa: A pilot study" at the Merryvale School for Specialised Education. The study has been explained to me and my questions have been answered to my satisfaction.

Approved by: G Saayman
Signature: GSaayman

"Our Mission is to be an outstanding teaching and research university, educating for life and addressing the challenges facing our society."

Appendix J: Letter to the Westering Primary School principal

DHRS

Date: 11 April 2024
Mr. R. Hamilton
Principal at Westering Primary School
Papenkuils Street
Westering
Gqeberha
6025

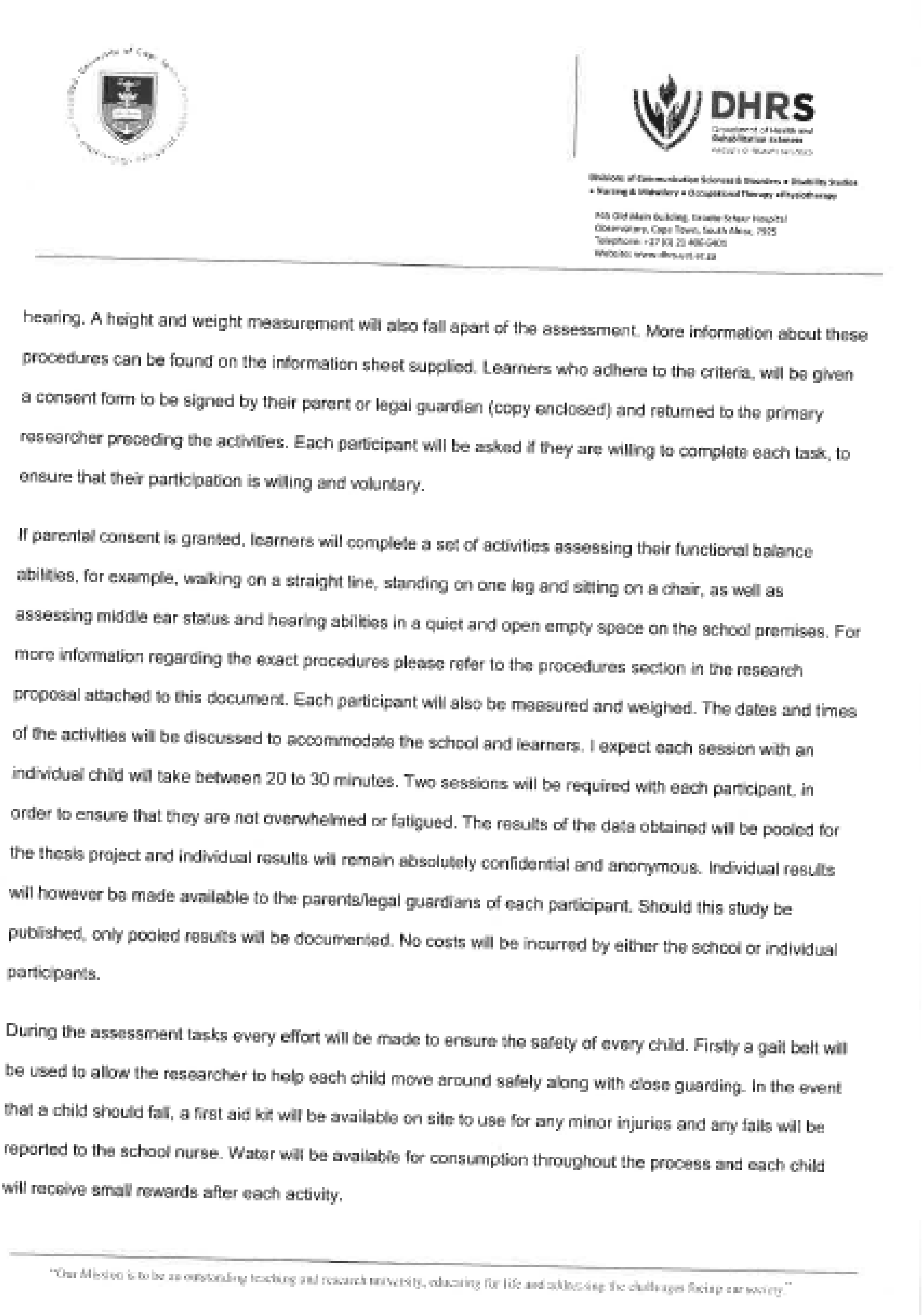
Dear Mr. Hamilton

RE: Permission to conduct a research study concerning the functional balance abilities of children at your school.

I am writing to request permission to conduct a research study at your school. I am a student at the University of Cape Town, in the process of writing my Master's thesis. The study is entitled "A functional balance profile of school aged children and adolescents diagnosed with Down Syndrome, schooled in the Eastern Cape province of South Africa: A pilot study." and has been approved by the University of Cape Town Faculty of Health Sciences Human Research Ethics Committee (Reference number HREC 934/2023).

Children with Down Syndrome have shown to have decreased balance ability and abnormal gait patterns, as well as delayed motor development (Jung et al., 2017). Limits in motor abilities cause an increased strain in maintaining a state of equilibrium in an ever-changing environment, especially in the Down Syndrome population (Malak et al., 2013). Further detailed knowledge is needed to explore balance deficits and possible remediation strategies of children and adolescents with Down Syndrome in South Africa, as the current research available appears to be very scant and flawed. My study aims to determine the feasibility of doing a larger scale study, assessing the balance function of South African children and adolescents with Down Syndrome.

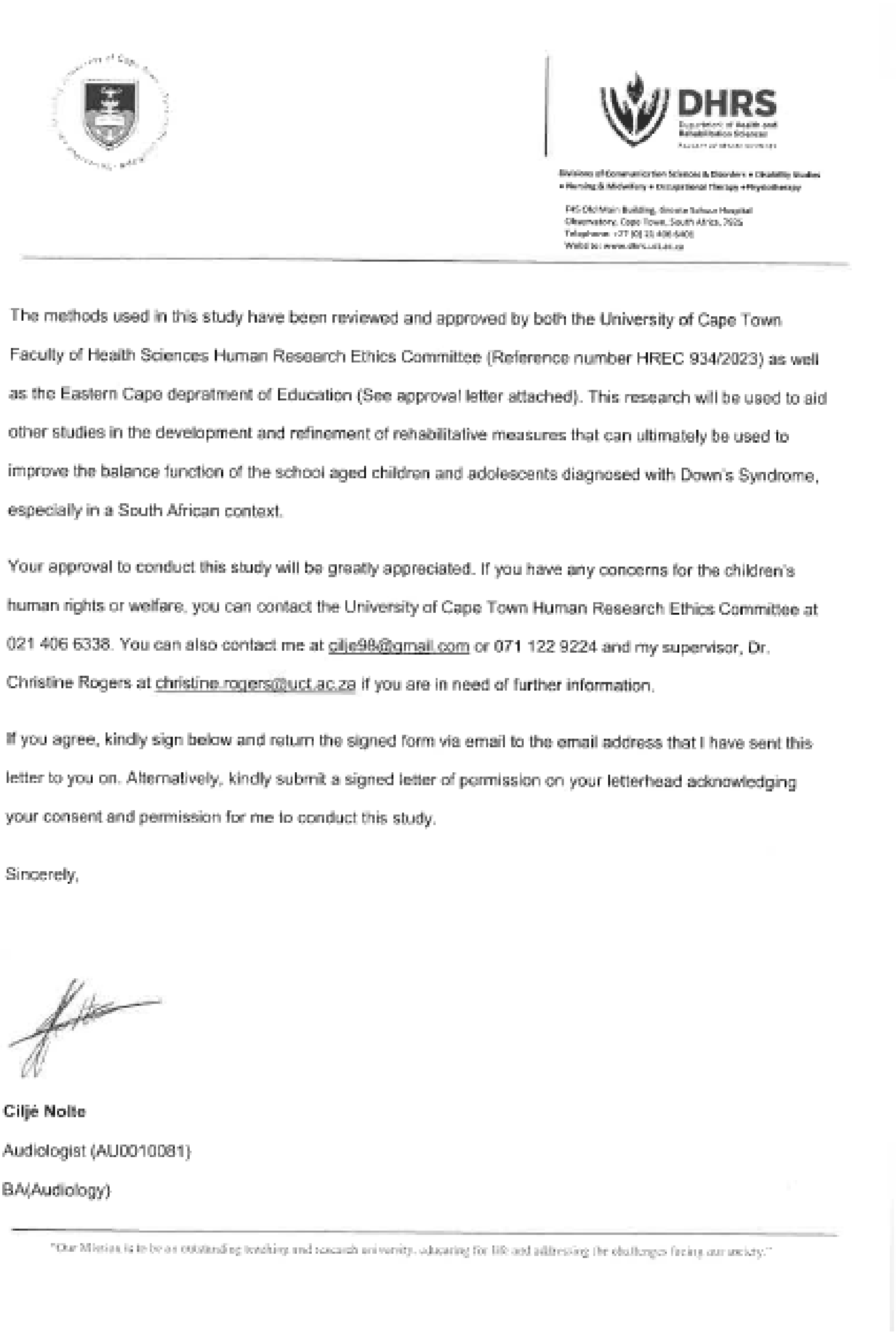
I hope that you will allow me to recruit typically developing learners who are aged between six to thirteen years at your school to participate in the control group for my study. They will be expected to complete a set of activities assessing their functional balance abilities along with an assessment of middle ear function and



hearing. A height and weight measurement will also fall apart of the assessment. More information about these procedures can be found on the information sheet supplied. Learners who adhere to the criteria, will be given a consent form to be signed by their parent or legal guardian (copy enclosed) and returned to the primary researcher preceding the activities. Each participant will be asked if they are willing to complete each task, to ensure that their participation is willing and voluntary.

If parental consent is granted, learners will complete a set of activities assessing their functional balance abilities, for example, walking on a straight line, standing on one leg and sitting on a chair, as well as assessing middle ear status and hearing abilities in a quiet and open empty space on the school premises. For more information regarding the exact procedures please refer to the procedures section in the research proposal attached to this document. Each participant will also be measured and weighed. The dates and times of the activities will be discussed to accommodate the school and learners. I expect each session with an individual child will take between 20 to 30 minutes. Two sessions will be required with each participant, in order to ensure that they are not overwhelmed or fatigued. The results of the data obtained will be pooled for the thesis project and individual results will remain absolutely confidential and anonymous. Individual results will however be made available to the parents/legal guardians of each participant. Should this study be published, only pooled results will be documented. No costs will be incurred by either the school or individual participants.

During the assessment tasks every effort will be made to ensure the safety of every child. Firstly a gait belt will be used to allow the researcher to help each child move around safely along with close guarding. In the event that a child should fall, a first aid kit will be available on site to use for any minor injuries and any falls will be reported to the school nurse. Water will be available for consumption throughout the process and each child will receive small rewards after each activity.



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Department of Health and Rehabilitation Sciences

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• Nursing & Midwifery • Occupational Therapy • Physiotherapy

F45 Old Main Building, Groote Schuur Hospital
Observatory, Cape Town, South Africa, 7925
Telephone: +27 (0) 21 406 6401
Website: www.dhrs.uct.ac.za

The methods used in this study have been reviewed and approved by both the University of Cape Town Faculty of Health Sciences Human Research Ethics Committee (Reference number HREC 934/2023) as well as the Eastern Cape depratment of Education (See approval letter attached). This research will be used to aid other studies in the development and refinement of rehabilitative measures that can ultimately be used to improve the balance function of the school aged children and adolescents diagnosed with Down's Syndrome, especially in a South African context.

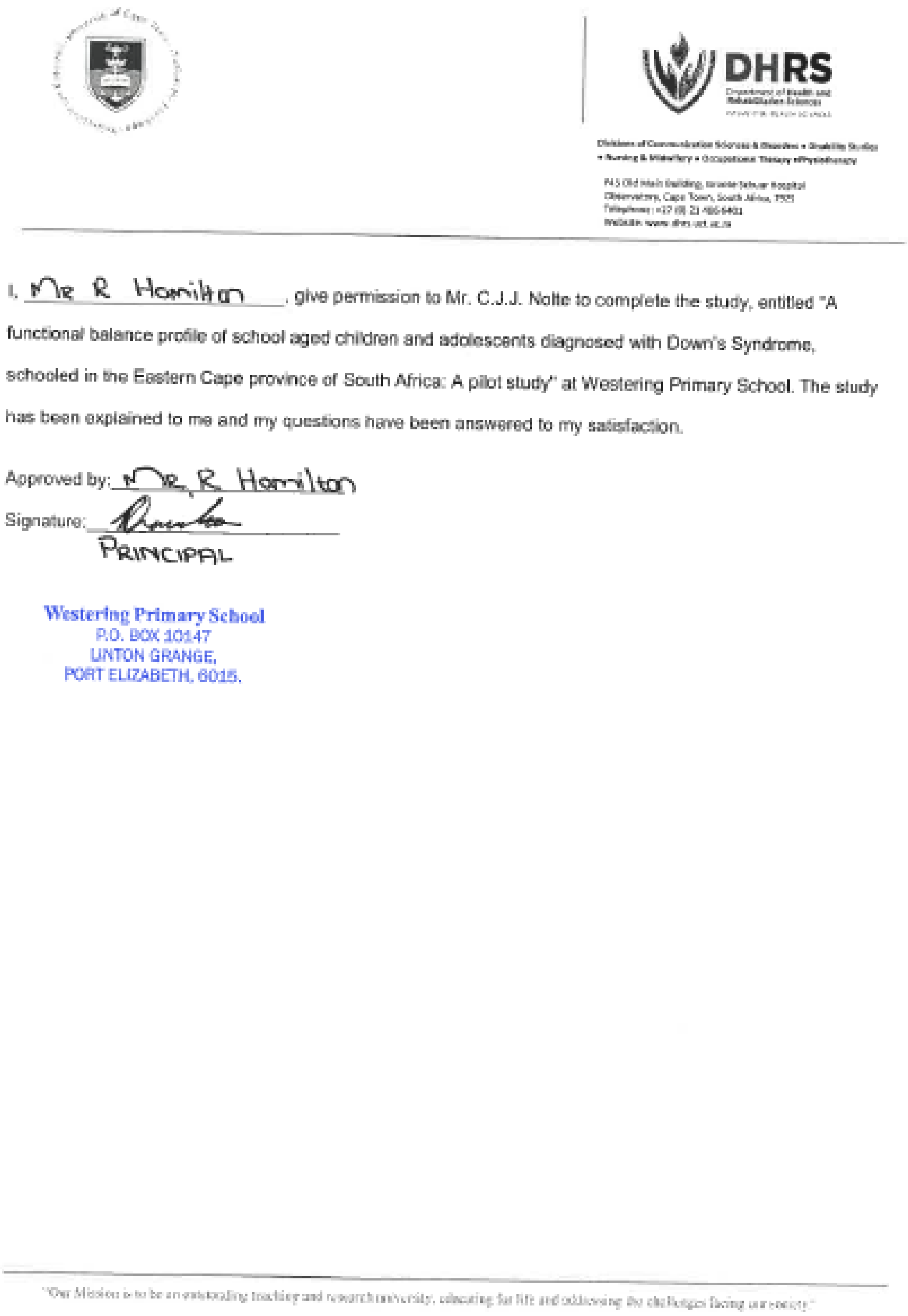
Your approval to conduct this study will be greatly appreciated. If you have any concerns for the children's human rights or welfare, you can contact the University of Cape Town Human Research Ethics Committee at 021 406 6338. You can also contact me at cilje98@gmail.com or 071 122 9224 and my supervisor, Dr. Christine Rogers at christine.rogers@uct.ac.za if you are in need of further information.

If you agree, kindly sign below and return the signed form via email to the email address that I have sent this letter to you on. Alternatively, kindly submit a signed letter of permission on your letterhead acknowledging your consent and permission for me to conduct this study.

Sincerely,

Ciljé Nolte
Audiologist (AU0010081)
BA(Audiology)

"Our Mission is to be an outstanding teaching and research university, educating for life and addressing the challenges facing our society."



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F45 Old Main Building, Groote Schuur Hospital
Observatory, Cape Town, South Africa, 7925
Telephone: +27 (0) 21 406 6401
Website: www.dhrs.uct.ac.za

I, Mr R Hamilton, give permission to Mr. C.J.J. Nolte to complete the study, entitled "A functional balance profile of school aged children and adolescents diagnosed with Down's Syndrome, schooled in the Eastern Cape province of South Africa: A pilot study" at Westering Primary School. The study has been explained to me and my questions have been answered to my satisfaction.

Approved by: Mr. R. Hamilton
Signature:
PRINCIPAL

Westering Primary School
P.O. BOX 10147
LINTON GRANGE,
PORT ELIZABETH, 6015.

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Appendix K: Letter to the Westering High School principal

DHRS
Department of Health and Rehabilitation Sciences
Faculty of Health Sciences

Divisions of Communication Sciences & Disorders • Disability Studies
• Nursing & Midwifery • Occupational Therapy •Physiotherapy

F45 Old Main Building, Groote Schuur Hospital
Observatory, Cape Town, South Africa, 7925
Telephone: +27 (0) 21 406 6401
Website: www.dhrs.uct.ac.za

Date:
Ms. E. Smith
Vice-principal at Westering High School
79 Papenkuils Street
Westering
Gqeberha
6025

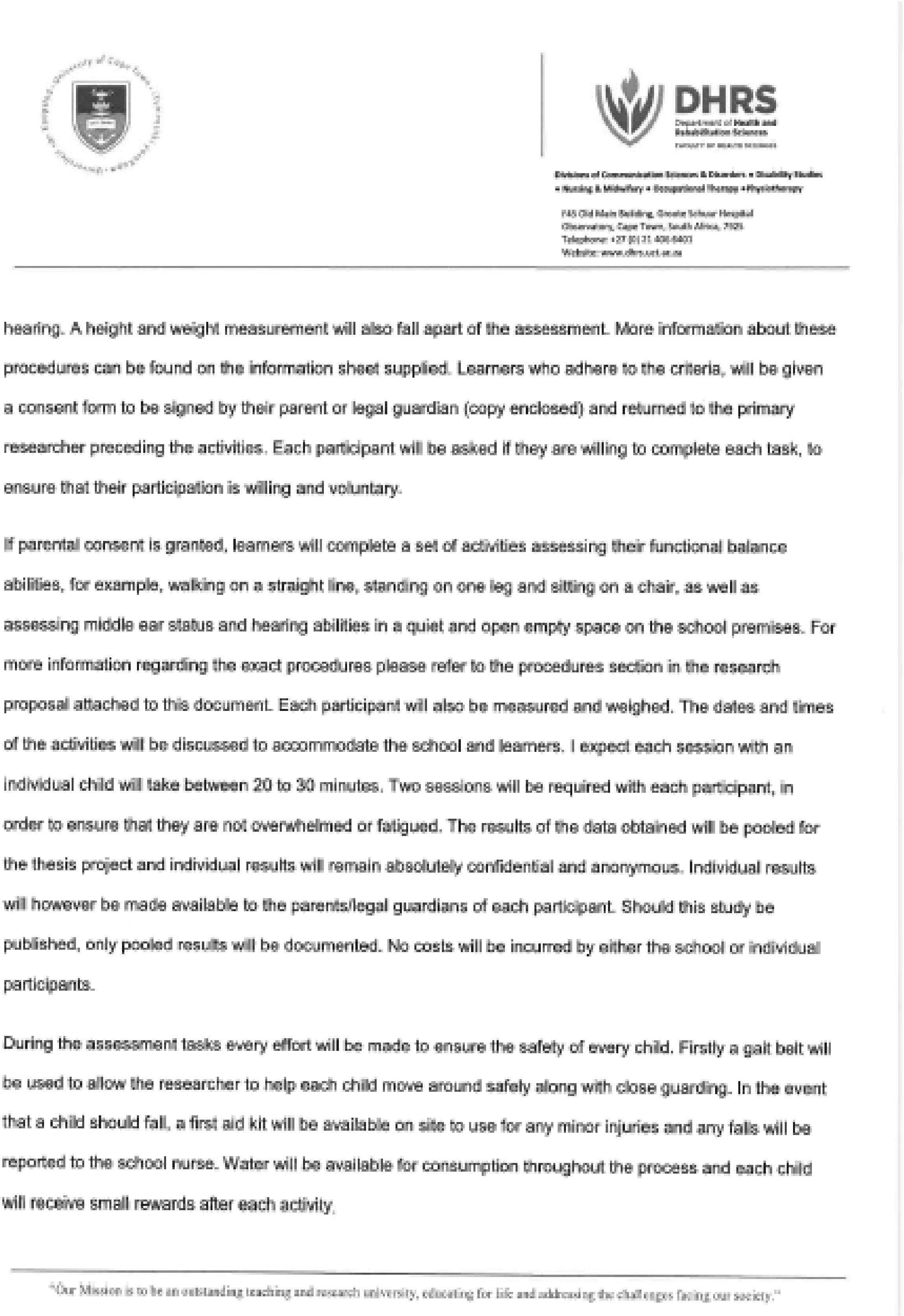
Dear Ms. Smith

RE: Permission to conduct research study concerning the functional balance abilities of children at your school.

I am writing to request permission to conduct a research study at your school. I am a student at the University of Cape Town, in the process of writing my Master's thesis. The study is entitled "A functional balance profile of school aged children and adolescents diagnosed with Down Syndrome, schooled in the Eastern Cape province of South Africa: A pilot study" and has been approved by the University of Cape Town Faculty of Health Sciences Human Research Ethics Committee (Reference number HREC 934/2023).

Children with Down Syndrome have shown to have decreased balance ability and abnormal gait patterns, as well as delayed motor development (Jung et al., 2017). Limits in motor abilities cause an increased strain in maintaining a state of equilibrium in an ever-changing environment, especially in the Down Syndrome population (Malak et al., 2013). Further detailed knowledge is needed to explore balance deficits and possible remediation strategies of children and adolescents with Down Syndrome in South Africa, as the current research available appears to be very scant and flawed. My study aims to determine the feasibility of doing a larger scale study, assessing the balance function of South African children and adolescents with Down Syndrome.

I hope that you will allow me to recruit typically developing learners who are aged between thirteen to eighteen years at your school to participate in the control group for my study. They will be expected to complete a set of activities assessing their functional balance abilities along with an assessment of middle ear function and



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Department of Health and Rehabilitation Sciences
Faculty of Health Sciences

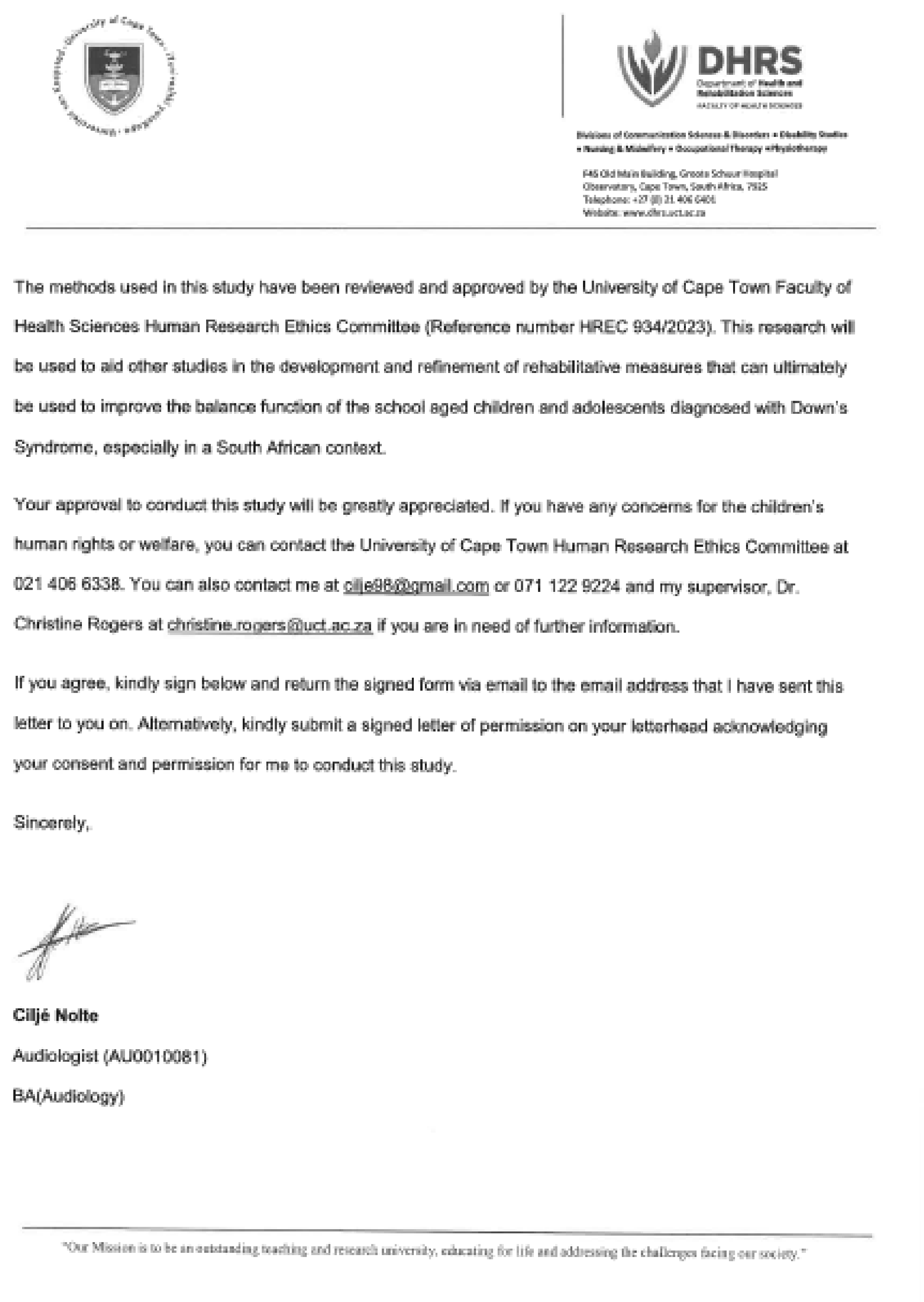
Divisions of Communication Sciences & Disorders • Disability Studies
• Nursing & Midwifery • Occupational Therapy • Physiotherapy

F45 Old Main Building, Groote Schuur Hospital
Observatory, Cape Town, South Africa, 7925
Telephone: +27 (0) 21 406 6403
Website: www.dhrs.uct.ac.za

hearing. A height and weight measurement will also fall apart of the assessment. More information about these procedures can be found on the information sheet supplied. Learners who adhere to the criteria, will be given a consent form to be signed by their parent or legal guardian (copy enclosed) and returned to the primary researcher preceding the activities. Each participant will be asked if they are willing to complete each task, to ensure that their participation is willing and voluntary.

If parental consent is granted, learners will complete a set of activities assessing their functional balance abilities, for example, walking on a straight line, standing on one leg and sitting on a chair, as well as assessing middle ear status and hearing abilities in a quiet and open empty space on the school premises. For more information regarding the exact procedures please refer to the procedures section in the research proposal attached to this document. Each participant will also be measured and weighed. The dates and times of the activities will be discussed to accommodate the school and learners. I expect each session with an individual child will take between 20 to 30 minutes. Two sessions will be required with each participant, in order to ensure that they are not overwhelmed or fatigued. The results of the data obtained will be pooled for the thesis project and individual results will remain absolutely confidential and anonymous. Individual results will however be made available to the parents/legal guardians of each participant. Should this study be published, only pooled results will be documented. No costs will be incurred by either the school or individual participants.

During the assessment tasks every effort will be made to ensure the safety of every child. Firstly a gait belt will be used to allow the researcher to help each child move around safely along with close guarding. In the event that a child should fall, a first aid kit will be available on site to use for any minor injuries and any falls will be reported to the school nurse. Water will be available for consumption throughout the process and each child will receive small rewards after each activity.



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Department of Health and Rehabilitation Sciences
FACULTY OF HEALTH SCIENCES
Divisions of Communication Sciences & Disorders • Disability Studies
• Nursing & Midwifery • Occupational Therapy •Physiotherapy
F45 Old Main Building, Groote Schuur Hospital
Observatory, Cape Town, South Africa, 7925
Telephone: +27 (0) 21 406 6401
Website: www.dhrs.uct.ac.za

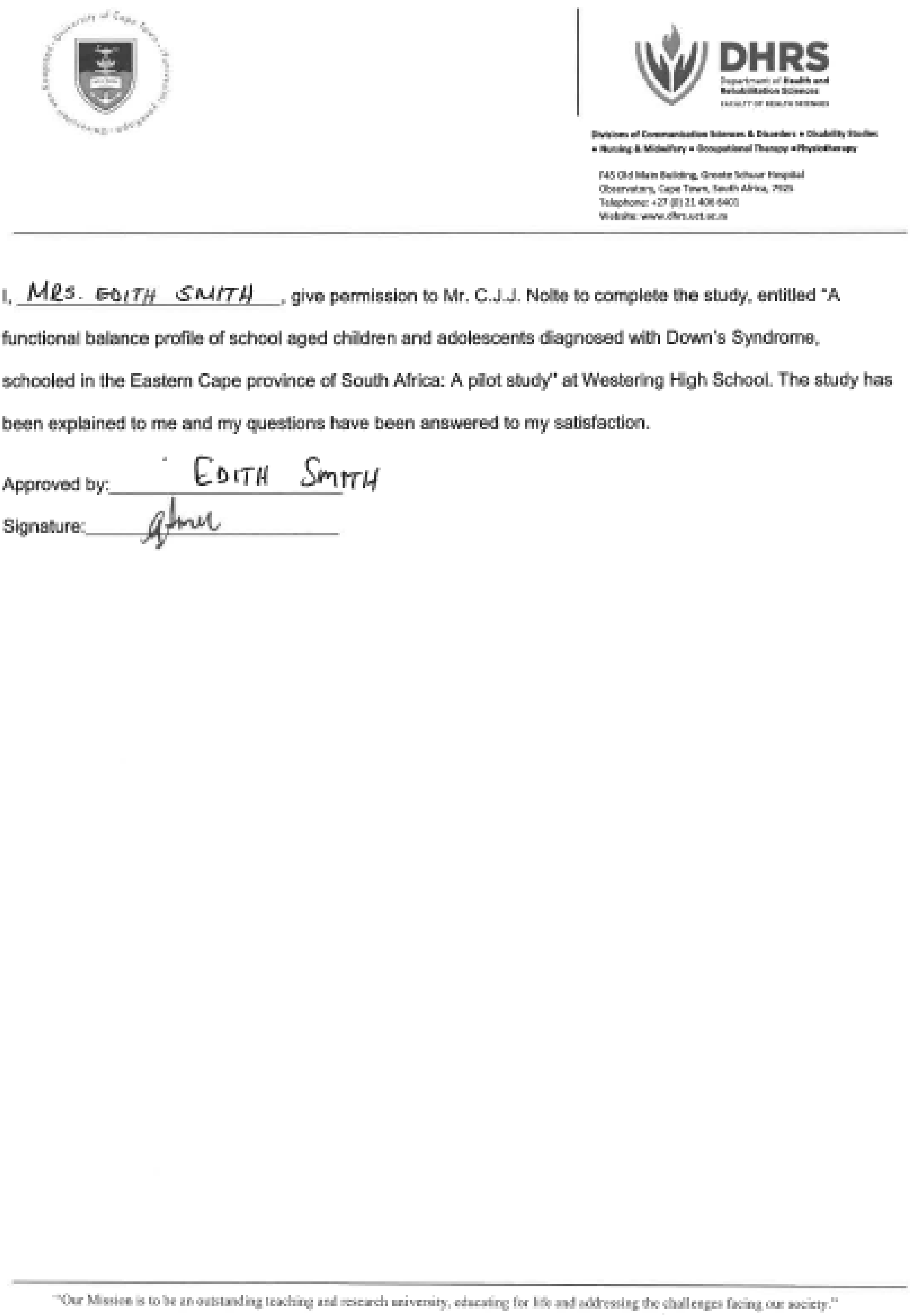
The methods used in this study have been reviewed and approved by the University of Cape Town Faculty of Health Sciences Human Research Ethics Committee (Reference number HREC 934/2023). This research will be used to aid other studies in the development and refinement of rehabilitative measures that can ultimately be used to improve the balance function of the school aged children and adolescents diagnosed with Down's Syndrome, especially in a South African context.

Your approval to conduct this study will be greatly appreciated. If you have any concerns for the children's human rights or welfare, you can contact the University of Cape Town Human Research Ethics Committee at 021 406 6338. You can also contact me at cilje98@gmail.com or 071 122 9224 and my supervisor, Dr. Christine Rogers at christine.rogers@uct.ac.za if you are in need of further information.

If you agree, kindly sign below and return the signed form via email to the email address that I have sent this letter to you on. Alternatively, kindly submit a signed letter of permission on your letterhead acknowledging your consent and permission for me to conduct this study.

Sincerely,

Ciljé Nolte
Audiologist (AU0010081)
BA(Audiology)



DHRS
Department of Health and Rehabilitation Sciences

Divisions of Communication Sciences & Disorders • Disability Studies • Nursing & Midwifery • Occupational Therapy • Physiotherapy

F45 Old Main Building, Groote Schuur Hospital
Observatory, Cape Town, South Africa, 7925
Telephone: +27 (0) 21 406 6401
Website: www.dhrs.uct.ac.za

I, MRS. EDITH SMITH, give permission to Mr. C.J.J. Nolte to complete the study, entitled "A functional balance profile of school aged children and adolescents diagnosed with Down's Syndrome, schooled in the Eastern Cape province of South Africa: A pilot study" at Westering High School. The study has been explained to me and my questions have been answered to my satisfaction.

Approved by: EDITH SMITH

Signature:

"Our Mission is to be an outstanding teaching and research university, educating for life and addressing the challenges facing our society."

Appendix L: Letter to parents at the Merryvale school

DHRS
Department of Health and Rehabilitation Sciences
FACULTY OF HEALTH SCIENCES

Divisions of Communication Sciences & Disorders • Disability Studies
• Nursing & Midwifery • Occupational Therapy •Physiotherapy

F45 Old Main Building, Groote Schuur Hospital
Observatory, Cape Town, South Africa, 7925
Telephone: +27 (0) 21 406 6401
Website: www.dhrs.uct.ac.za

Dear Parent,

My name is Ciljé Nolte, and I am a student at the University of Cape Town doing an MSc(Audiology) degree. My study is about the balance function of children and adolescents with Down Syndrome and I would like to ask your permission to include your child in my study.

What is the study about?

We know children with Down syndrome can have problems with hearing and balance. My study is to find out if this is true in South Africa. I want to do some easy, fun activities with your child to test their balance and if they are at more risk of falling due to a possible balance problem. I will also do two simple tests to tell me about your child's hearing.

What will happen with my child?

After you have given me permission to include your child, I will fetch them from the classroom or playground. I will put a little probe into their ear, which is not painful or scary, and the machine will tell me how different parts of the ear are working. Next, I will weigh him/her and measure how tall they are. I will demonstrate each balance test to your child, to make sure they know what to do. The activities are things like standing on one leg, walking in a straight line, standing up from sitting and standing on their toes. Please find a copy of the information sheet explaining each activity enclosed. The activities are fun and I will make them like a game so your child will enjoy them. After each activity, there will be a sticker as a reward. I will keep checking that your child wants to carry on. If there is any upset or sign that your child has had enough, I will stop immediately. Some of the children may be asked to repeat the balance tests one week later. For more information on these activities, please refer to the information sheet attached.

What are the risks?

The activities are fun and like what your child would normally do in the playground. There is a small chance that your child might fall, but I will be close by and make sure everything is as safe as can be. I have a first aid kit, although it is very unlikely I will have to use it. I will also put a special belt around your child's waist to hold them and make sure they are as safe as possible. The school nurse will also be notified of any falls.

How will the activities help?

I will send you a letter explaining what the results of the activities show. If your child is in danger of falling in the future, I will give you some tips about how to make things safe in your home.

What happens if my child changes their mind?

You can change your mind about allowing your child to be in my study at any time. I will carry on asking your child if they would like to do the next activity, and if they say no, I will respect that. You and your child have the right to ask any questions you may have at any time. I will watch your child carefully for any sign of being upset and will make sure they are comforted before sending them back to the classroom.

What other choices do I have?

You do not have to agree to your child being in my study. If you are worried about their balance or if they are falling, you can mention this to your doctor or physiotherapist who can look into this in more detail.

What happens to our information?

I will give your child a number which I will use instead of their name. No-one will be able to know who your particular child is and what their results are. I will keep the information safe. Only me and my supervisor will be able to look at the information before it is written up in my work. This means it will stay private.

Where can I get more information?

If you have any concerns for your child's human rights or welfare, you can contact the University of Cape Town Human Research Ethics Committee at 021 406 6338. You can also contact me at cilje98@gmail.com or 071 122 9224 and my supervisor, Dr. Christine Rogers at christine.rogers@uct.ac.za if you are in need of further information.

What do I have to do now?

If you would like to have your child in my study, please sign the form on the next page and send it back to school.

Sincerely,

Ciljé Nolte
Audiologist (AU0010081)
BA(Audiology) – UP (2020)

Informed consent statement

I, ____________________________, give permission for my child, ____________________________, to participate in the research project entitled, “A functional balance profile of school aged children and adolescents diagnosed with Down’s Syndrome, schooled in the Eastern Cape province of South Africa: A pilot study”. The study has been explained to me and my questions have been answered to my satisfaction. I understand that my child’s right to withdraw from participating or refusal to participate will be respected and that his/her responses and identity will be kept confidential. I give this consent voluntarily.

Parent/Guardian Signature:

___________________________________ ______________________

Signature *Date*

Appendix M: Letter to parents of the control group

DHRS
Department of Health and Rehabilitation Sciences
FACULTY OF HEALTH SCIENCES

Divisions of Communication Sciences & Disorders • Disability Studies
• Nursing & Midwifery • Occupational Therapy •Physiotherapy

F45 Old Main Building, Groote Schuur Hospital
Observatory, Cape Town, South Africa, 7925
Telephone: +27 (0) 21 406 6401
Website: www.dhrs.uct.ac.za

Dear Parent,

My name is Ciljé Nolte, and I am a student at the University of Cape Town doing an MSc(Audiology) degree. My study is about the balance function of children and adolescents with Down Syndrome, compared with typically developing children and I would like to ask your permission to include your child in my study.

What is the study about?

All children have some risk of imbalance and falls as they develop and mature towards adulthood. Some medical problems, for example ear disease, can increase this risk at times. In addition, we know children with Down syndrome can have problems with hearing and balance. My study is to find out if this is true in South Africa by comparing the results that I obtain in children with Down Syndrome to the same results that I obtain in children who have typical development. Therefore, I am asking for your help to assemble an idea of what a typical South African child's balance looks like at various ages. I would like to do some easy, fun activities with your child to test their balance and if they are likely to fall. I will also do two simple tests to tell me about your child's hearing.

What will happen with my child?

After you have given me permission to include your child, I will fetch them from the classroom or playground. I will put a little probe into their ear, which is not painful or scary, and the machine will tell me how different parts of the ear are working. Next, I will weigh him/her and measure how tall they are. I will demonstrate each activity to your child, to make sure they know what to do. The activities are things like standing on one leg, walking in a straight line, standing up from sitting and standing on their toes. Please find a copy of the information sheet explaining each activity enclosed. The activities are fun and I will make them like a game so your child will enjoy them. After each activity, there will be a chocolate and cool drink of their choice as reward. I will keep checking that your child wants to carry on. If there is any upset or sign that your child has had enough, I will stop immediately. For more information on these activities, please refer to the information sheet attached.

What are the risks?

The activities are fun and like what your child would normally do in the playground. There is a small chance that your child might fall, but I will be close by and make sure everything is as safe as can be. I have a first aid kit, although it is very unlikely I will have to use it. I will also put a special belt around your child’s waist to hold them if I think they are going to fall.

How will the activities help?

I will send you a letter explaining what the results of the activities show. If your child is in danger of falling in the future, I will give you some tips about how to make things safe in your home.

What happens if my child changes their mind?

You can change your mind about allowing your child to be in my study at any time. I will carry on asking your child if they would like to do the next activity, and if they say no, I will respect that. You and your child have the right to ask any questions you may have at any time. I will watch your child carefully for any sign of being upset and will make sure they are comforted before sending them back to the classroom.

What other choices do I have?

You do not have to agree to your child being in my study. If you are worried about their balance or if they are falling, you can mention this to your doctor or physiotherapist who can look into this in more detail.

What happens to our information?

I will give your child a number which I will use instead of their name. No-one will be able to know who your particular child is and what their results are. I will keep the information safe. Only me and my supervisor will be able to look at the information before it is written up in my work. This means it will stay private.

Where can I get more information?

If you have any concerns for your child’s welfare, you can contact the University of Cape Town Human Research Ethics Committee at 021 406 6338. You can contact me at cilje98@gmail.com and my supervisor, Dr. Christine Rogers at christine.rogers@uct.ac.za if you are in need of further information.

What do I have to do now?

If you would like to have your child in my study, please sign the form on the next page and send it back to school.

Sincerely,

Ciljé Nolte
Audiologist (AU0010081)

BA(Audiology)

Informed consent statement

I, ___________________________, give permission for my child,

___________________________, to participate in the research project entitled, “A functional balance profile of school aged children and adolescents diagnosed with Down’s Syndrome, schooled in the Eastern Cape province of South Africa: A pilot study”. The study has been explained to me and my questions have been answered to my satisfaction. I understand that my child’s right to withdraw from participating or refusal to participate will be respected and that his/her responses and identity will be kept confidential. I give this consent voluntarily.

Parent/Guardian Signature:

_________________________________ _____________________

Signature *Date*

Appendix N: Information sheet

The following activities will be included during the assessments done with each child: Firstly, a screening of middle and inner ear function will be done using otoscopy, tympanometry and otoacoustic emissions (OAE) testing. Please note that these procedures are very safe and pose no heightened risk to your child:

- Otoscopy: A light will be used to look into the child's ear and examine the ear canal and ear drum. This will be done for both ears.
- Tympanometry: A small probe will be placed into the child's ear and a soft droning sound will be played into their ear for a few s and they might also feel a slight pressure. This will be done for both ears.
- OAE testing: A small probe will be placed into the child's ear and a series of high pitched sounds will be played into the ear for a few s. This will be done for both ears.

Each child will also be weighed and measured:

- Weighing: Each child will be asked to step onto a bathroom scale for a few s, until their weight has been recorded.
- Measuring: Each child will be asked to stand up against a wall, where a tape measure has been stuck onto, for a few s until their height has been recorded.

The following activities will be included in the balance assessment with each child:

- A close examination of each child's feet, to look for any deformities or complaints of pain. Standing and rising onto the toes.
- Standing and lifting the legs to the side.
- Sitting on the floor and standing up.
- Sitting on a chair and leaning to the side with an eye mask on.
- Standing with arms out next to a wall and reaching forward and to the side as far as possible.
- Standing and lifting a 1kg weight up into the air as fast as possible and holding it there for 3 s.
- The test administrator will push against the child from the front, back and sides while they lean back.
- The test administrator will quickly let go to see if they can keep their balance without taking a step.
- The test administrator will push against the child from the front, back and sides while they lean back.
- The test administrator will quickly let go to see if they can keep themselves from falling, by taking a step.
- Standing with arms crossed over the chest.
- Standing with arms crossed over the chest while wearing a blindfold.
- Standing with arms crossed over the chest on a piece of medium density foam.
- Standing with arms crossed over the chest on a piece of medium density foam while wearing a blindfold.
- Standing on a small incline with eyes closed.
- Changing from a normal walking speed to a faster walking speed.
- Walking while turning the head from side to side.
- Walking and turning around quickly and stopping.
- Walking and stepping over small shin-height obstacles.

- Standing up from a chair, walking to a mark, turning around and sitting back down on the chair.
- Standing with hands on hips with eyes open and eyes closed.
- Walking on a straight line.
- Standing on one leg with eyes open and eyes closed.
- Walking on a small balance beam.
- Standing on a balance beam with eyes open and eyes closed.
- Standing up from sitting on a chair and sitting down again.
- Standing up from a chair and moving to another chair.
- Sitting still on a chair.
- Standing still with one foot in front of the other.
- Turning around completely in one place.
- Looking over both shoulders.
- Picking up an object from the floor while standing.
- Lifting each foot and touching the front of the foot on a stair while alternating the feet.
- Standing and reaching forward with outstretched arms.

Appendix O: Referral letter for abnormal middle and/or inner ear function

DHRS
Department of Health and Rehabilitation Sciences
FACULTY OF HEALTH SCIENCES

Divisions of Communication Sciences & Disorders • Disability Studies
• Nursing & Midwifery • Occupational Therapy •Physiotherapy

F45 Old Main Building, Groote Schuur Hospital
Observatory, Cape Town, South Africa, 7925
Telephone: +27 (0) 21 406 6401
Website: www.dhrs.uct.ac.za

Date

Dear colleague,

RE: MST./MISS X (DOB)

Mst./Miss X participated in a study titled “A functional balance profile of school aged children and adolescents diagnosed with Down Syndrome, schooled in the Eastern Cape province of South Africa: A pilot study”. During this study it was identified that Mst./Miss X presents with middle ear pathology/possible hearing loss/a balance deficit and it is my recommendation to consult with you for further assessment and management.

Please see their results below:

RESULTS

If you have any questions or queries, please do not hesitate to contact me.

Sincerely,

Ciljé Nolte
Audiologist (AU0010081)
BA(Audiology) – UP (2020)

Appendix P: Fact sheet: Preventing and Treating Ear Infections

Accessible version: https://www.cdc.gov/antibiotic-use/ear-infection.html

Preventing and Treating Ear Infections

Is your child's ear hurting? It could be an ear infection. Children are more likely than adults to get ear infections. Talk to your child's doctor about the best treatment.

Some ear infections, such as middle ear infections, need antibiotic treatment, but many can get better on their own without antibiotics.

What is an ear infection?

There are different types of ear infections. **Middle ear infection** (acute otitis media) is an infection in the middle ear.

Another condition that affects the middle ear is called **otitis media with effusion.** It occurs when fluid builds up in the middle ear without being infected and without causing fever, ear pain, or pus buildup in the middle ear.

When the outer ear canal is infected, the condition is called "swimmer's ear," which is different from a middle ear infection.

Causes

Middle ear infections can be caused by:

- Bacteria, like *Streptococcus pneumoniae* and *Haemophilus influenzae* (nontypeable) —the two most common bacterial causes
- Viruses, like those that cause colds or flu

Symptoms

Common symptoms of middle ear infection in children can include:

- Ear pain
- Fever
- Fussiness or irritability
- Rubbing or tugging at an ear
- Difficulty sleeping

When to Seek Medical Care

See a doctor if your child has:

- A fever of 102.2°F (39°C) or higher
- Pus, discharge, or fluid coming from the ear
- Worsening symptoms
- Symptoms of a middle ear infection that last for more than 2–3 days
- Hearing loss

See a doctor right away if your child is younger than 3 months old and has a fever greater than 100.4 °F (38 °C).

CS322870-B

Preventing and Treating Ear Infections

Treatment

A doctor will determine what type of illness your child has by asking about symptoms and doing a physical examination. Your doctor can make the diagnosis of a middle ear infection by looking inside your child's ear to examine the eardrum and see if there is pus in the middle ear.

Antibiotics are often not needed for middle ear infections because the body's immune system can fight off the infection on its own. But sometimes antibiotics, such as amoxicillin, are needed to treat infants, severe cases, or cases that last longer than 2–3 days.

For mild cases of middle ear infection, your doctor might recommend **watchful waiting** or **delayed antibiotic prescribing.**

- **Watchful waiting:** Your child's doctor may suggest watching and waiting to see if your child needs antibiotics. This gives the immune system time to fight off the infection. If your child doesn't feel better after 2–3 days of rest, extra fluids, and pain relievers, the doctor will write a prescription for an antibiotic.
- **Delayed prescribing:** Your child's doctor may give an antibiotic prescription but will suggest that you wait 2–3 days to see if your child is still sick before filling it.

How to Feel Better

Some ways to feel better—whether or not antibiotics are needed for an ear infection:

- Rest.
- Drink extra water or other fluids.
- Take acetaminophen or ibuprofen to relieve pain or fever. Ask your doctor or pharmacist what medications are safe for your child to take and what dose to give your child.

Over-the-Counter Medicine and Children

Be careful about giving over-the-counter medicines to children. **Not all over-the-counter medicines are recommended for children of certain ages.**

- Pain relievers:
    - Children younger than 6 months: only give acetaminophen.
    - Children 6 months or older: it is OK to give acetaminophen or ibuprofen.
    - Never give aspirin to children because it can cause Reye's syndrome, a rare but very serious illness that harms the liver and brain.

Be sure to ask your doctor or pharmacist about the right dosage of over-the-counter medicines for your child's age and size. Also, tell your child's doctor and pharmacist about all the prescription and over-the-counter medicines they are taking.

Prevention

You can help prevent ear infections by doing your best to stay healthy and keep others healthy.

- Make sure your child is up to date on vaccinations and gets a flu vaccine every year. The pneumococcal vaccine protects against *Streptococcus pneumoniae*, a common cause of middle ear infections.
- Clean your hands.
- Breastfeed exclusively until your baby is 6 months old and continue to breastfeed for at least 12 months.
- Don't smoke and avoid exposure to secondhand smoke.

To learn more about antibiotic prescribing and use, visit www.cdc.gov/antibiotic-use.

Appendix Q: Referral letter for BMI referral

University of Cape Town · iYunivesithi yaseKapa · Universiteit van Kaapstad

DHRS
Department of Health and Rehabilitation Sciences
FACULTY OF HEALTH SCIENCES

Divisions of Communication Sciences & Disorders • Disability Studies
• Nursing & Midwifery • Occupational Therapy •Physiotherapy

F45 Old Main Building, Groote Schuur Hospital
Observatory, Cape Town, South Africa, 7925
Telephone: +27 (0) 21 406 6401
Website: www.dhrs.uct.ac.za

Date

Dear colleague,

RE: MST./MISS X (DOB)

Mst./Miss X participated in a study titled “A functional balance profile of school aged children and adolescents diagnosed with Down Syndrome, schooled in the Eastern Cape province of South Africa: A pilot study”. During this study it was identified that Mst./Miss X presents with obesity and it is my recommendation to consult with you for further assessment and management.

Please see their results below:

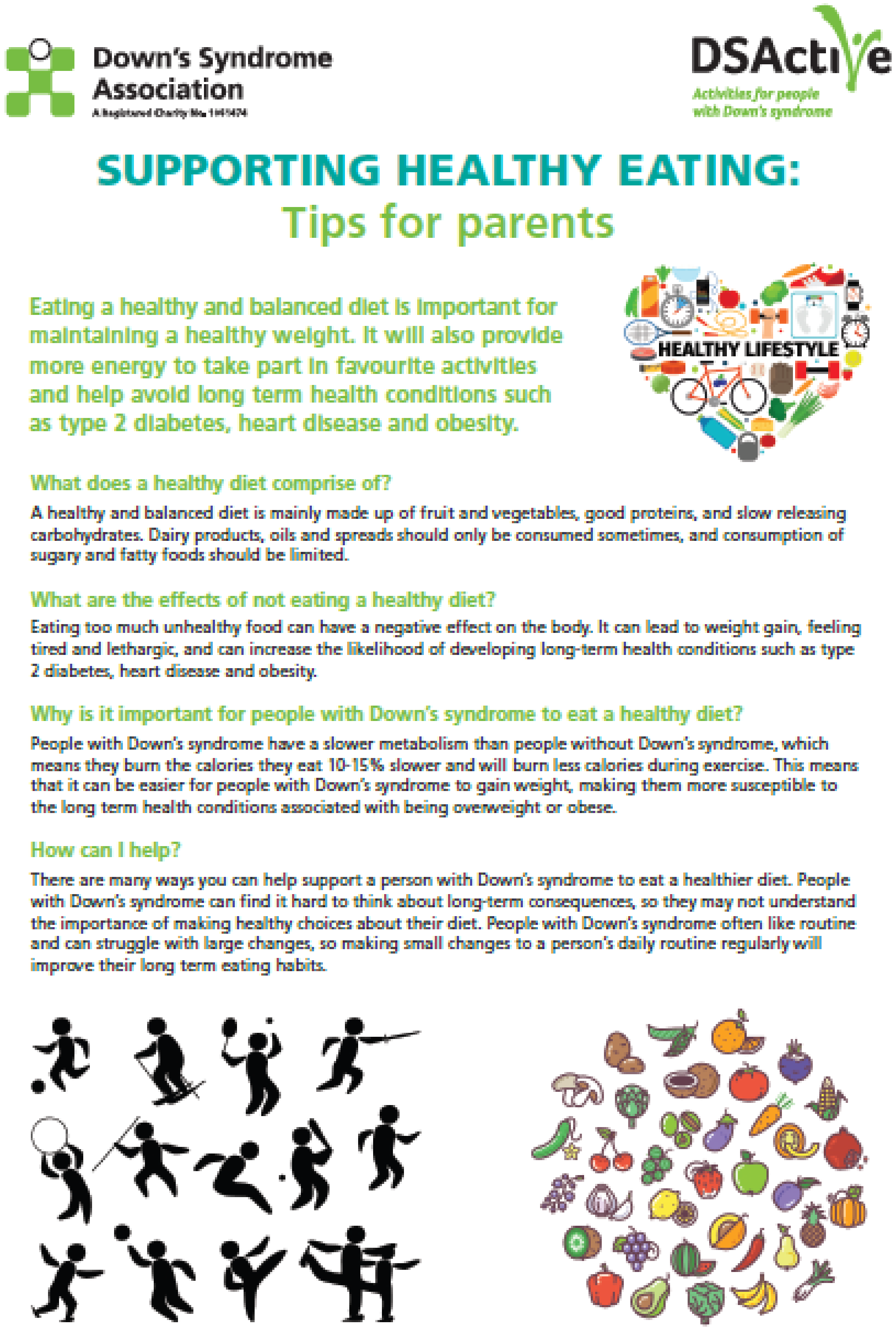
RESULTS

If you have any questions or queries, please do not hesitate to contact me.

Sincerely,

Ciljé Nolte
Audiologist (AU0010081)
BA(Audiology) – UP (2020)

Appendix R: Fact sheet: Supporting Healthy Eating: Tips for parents



Down's Syndrome Association
A Registered Charity No. [illegible]

DSActive
Activities for people
with Down's syndrome

SUPPORTING HEALTHY EATING:
Tips for parents

Eating a healthy and balanced diet is important for maintaining a healthy weight. It will also provide more energy to take part in favourite activities and help avoid long term health conditions such as type 2 diabetes, heart disease and obesity.

What does a healthy diet comprise of?

A healthy and balanced diet is mainly made up of fruit and vegetables, good proteins, and slow releasing carbohydrates. Dairy products, oils and spreads should only be consumed sometimes, and consumption of sugary and fatty foods should be limited.

What are the effects of not eating a healthy diet?

Eating too much unhealthy food can have a negative effect on the body. It can lead to weight gain, feeling tired and lethargic, and can increase the likelihood of developing long-term health conditions such as type 2 diabetes, heart disease and obesity.

Why is it important for people with Down's syndrome to eat a healthy diet?

People with Down's syndrome have a slower metabolism than people without Down's syndrome, which means they burn the calories they eat 10-15% slower and will burn less calories during exercise. This means that it can be easier for people with Down's syndrome to gain weight, making them more susceptible to the long term health conditions associated with being overweight or obese.

How can I help?

There are many ways you can help support a person with Down's syndrome to eat a healthier diet. People with Down's syndrome can find it hard to think about long-term consequences, so they may not understand the importance of making healthy choices about their diet. People with Down's syndrome often like routine and can struggle with large changes, so making small changes to a person's daily routine regularly will improve their long term eating habits.

Down's Syndrome Association
A Registered Charity No. 1061474

DSActive
Activities for people with Down's syndrome

HOW YOU CAN HELP?
Top Tips

Eat a rainbow

Planning ahead

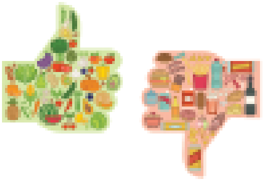
Food swaps

Eat a rainbow

It can be difficult to eat enough fruit and vegetables everyday, so why not make it a fun game and try and eat a rainbow. Eat a wide variety of fruit and vegetables, and try and eat one piece of fruit and one vegetable from each colour of the rainbow. For example, red peppers, carrots, sweetcorn, spinach, blueberries and beetroot.

Food swaps

It can be easy to make your favourite meals healthier by swapping some of the ingredients in the meal with healthier alternatives. For example, swapping spaghetti for butternut squash spaghetti, swapping new potatoes for sweet potatoes, swapping chips for kale chips or parsnip chips, or trying a bread-less burger. Making small changes to your favourite meals is a good way to start making positive changes to your meals, and it is less daunting for people with Down's syndrome who may struggle with change.



Planning ahead

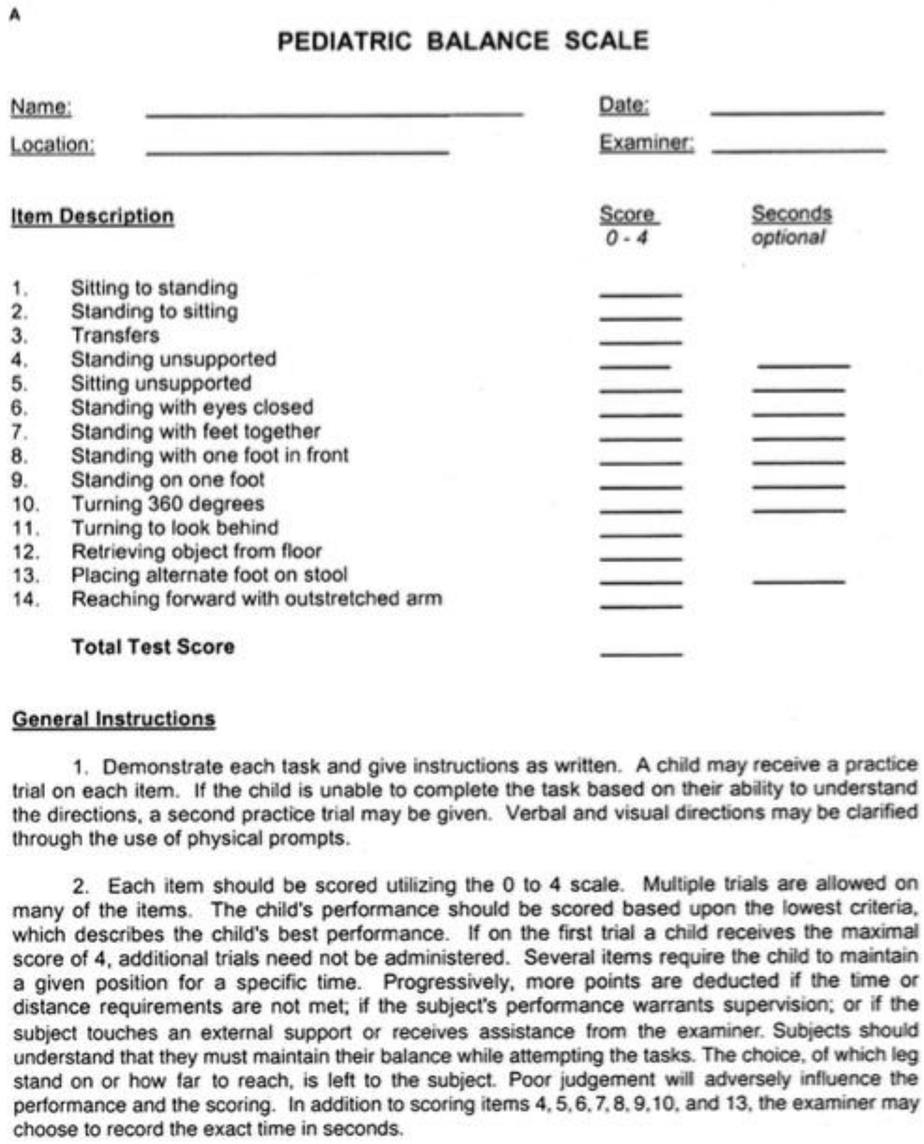
Life can get busy for everyone, which can sometimes make eating healthy hard! Sometimes it can be easier to get a take-away or a microwave meal. However, if you plan your meals ahead when you do your food shop this will save you the stress of having to think of a healthy recipe without having the ingredients.

Resources

If you would like more information about Down's syndrome and healthy eating, take a look at the list of resources below:

- NHS Livewell website www.nhs.uk/Livewell
- *"The Down syndrome nutrition handbook – A guide to promoting healthy lifestyles."* By Joan Medlen. Woobine House, 2002.
- To find out more about DSActive or the Down's Syndrome Association please visit our website www.dsactive.org.uk and www.downs-syndrome.org.uk

Appendix S: PBS Score Sheet



A

PEDIATRIC BALANCE SCALE

Name: ____________________ Date: ____________

Location: ____________________ Examiner: ____________

Item Description	Score *0 - 4*	Seconds *optional*
1. Sitting to standing	____	
2. Standing to sitting	____	
3. Transfers	____	
4. Standing unsupported	____	____
5. Sitting unsupported	____	____
6. Standing with eyes closed	____	____
7. Standing with feet together	____	____
8. Standing with one foot in front	____	____
9. Standing on one foot	____	____
10. Turning 360 degrees	____	____
11. Turning to look behind	____	
12. Retrieving object from floor	____	
13. Placing alternate foot on stool	____	____
14. Reaching forward with outstretched arm	____	
Total Test Score	____	

General Instructions

1. Demonstrate each task and give instructions as written. A child may receive a practice trial on each item. If the child is unable to complete the task based on their ability to understand the directions, a second practice trial may be given. Verbal and visual directions may be clarified through the use of physical prompts.

2. Each item should be scored utilizing the 0 to 4 scale. Multiple trials are allowed on many of the items. The child's performance should be scored based upon the lowest criteria, which describes the child's best performance. If on the first trial a child receives the maximal score of 4, additional trials need not be administered. Several items require the child to maintain a given position for a specific time. Progressively, more points are deducted if the time or distance requirements are not met; if the subject's performance warrants supervision; or if the subject touches an external support or receives assistance from the examiner. Subjects should understand that they must maintain their balance while attempting the tasks. The choice, of which leg stand on or how far to reach, is left to the subject. Poor judgement will adversely influence the performance and the scoring. In addition to scoring items 4, 5, 6, 7, 8, 9, 10, and 13, the examiner may choose to record the exact time in seconds.

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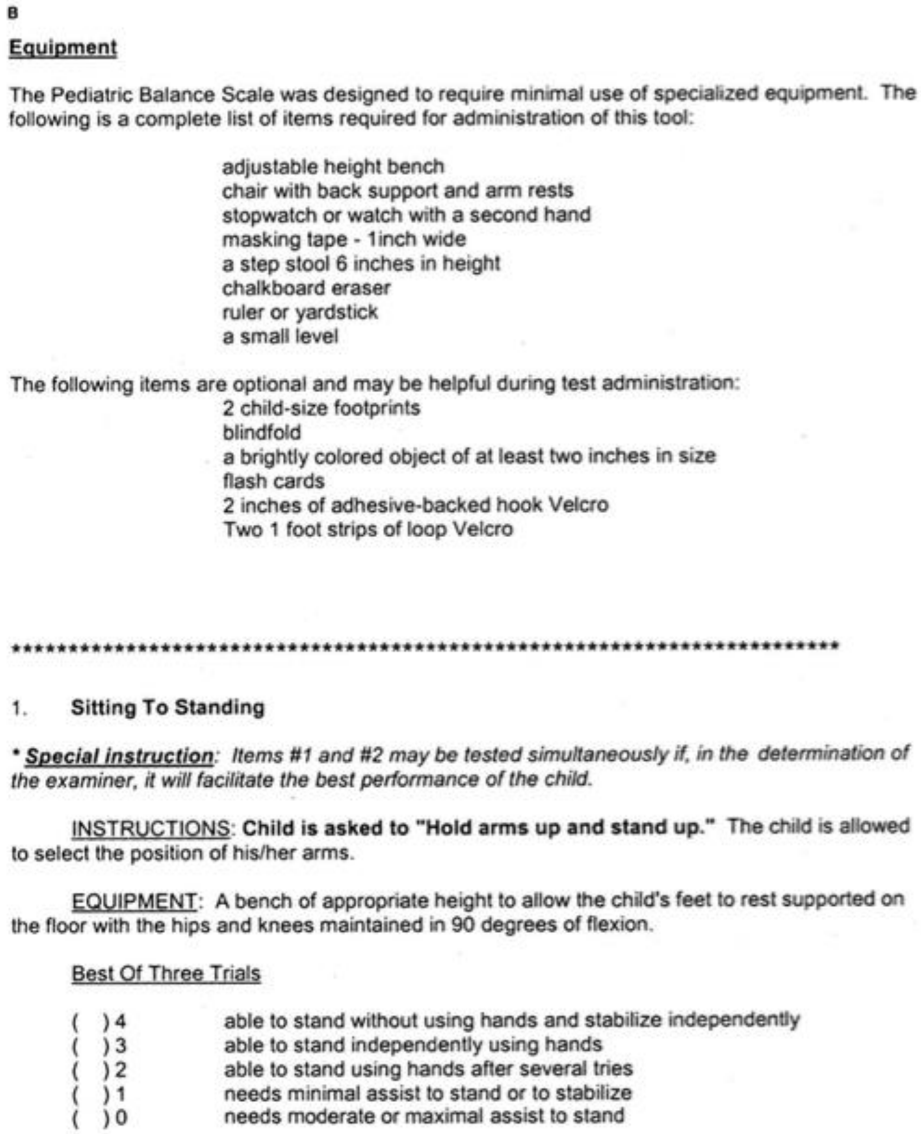

B

Equipment

The Pediatric Balance Scale was designed to require minimal use of specialized equipment. The following is a complete list of items required for administration of this tool:

adjustable height bench
chair with back support and arm rests
stopwatch or watch with a second hand
masking tape - 1inch wide
a step stool 6 inches in height
chalkboard eraser
ruler or yardstick
a small level

The following items are optional and may be helpful during test administration:
2 child-size footprints
blindfold
a brightly colored object of at least two inches in size
flash cards
2 inches of adhesive-backed hook Velcro
Two 1 foot strips of loop Velcro

****

1. **Sitting To Standing**

* ***Special instruction**: Items #1 and #2 may be tested simultaneously if, in the determination of the examiner, it will facilitate the best performance of the child.*

INSTRUCTIONS: **Child is asked to "Hold arms up and stand up."** The child is allowed to select the position of his/her arms.

EQUIPMENT: A bench of appropriate height to allow the child's feet to rest supported on the floor with the hips and knees maintained in 90 degrees of flexion.

Best Of Three Trials

( ) 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

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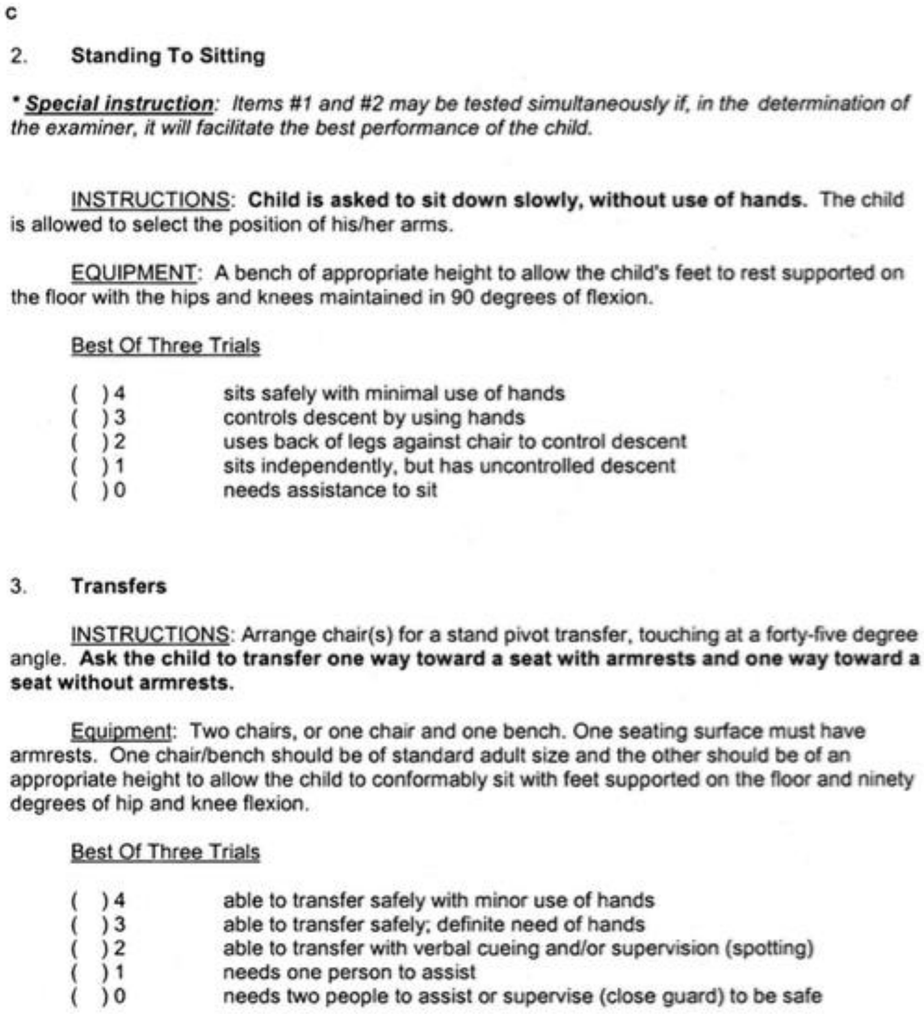


c

2. Standing To Sitting

* ***Special instruction***: *Items #1 and #2 may be tested simultaneously if, in the determination of the examiner, it will facilitate the best performance of the child.*

INSTRUCTIONS: **Child is asked to sit down slowly, without use of hands.** The child is allowed to select the position of his/her arms.

EQUIPMENT: A bench of appropriate height to allow the child's feet to rest supported on the floor with the hips and knees maintained in 90 degrees of flexion.

Best Of Three Trials

( ) 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

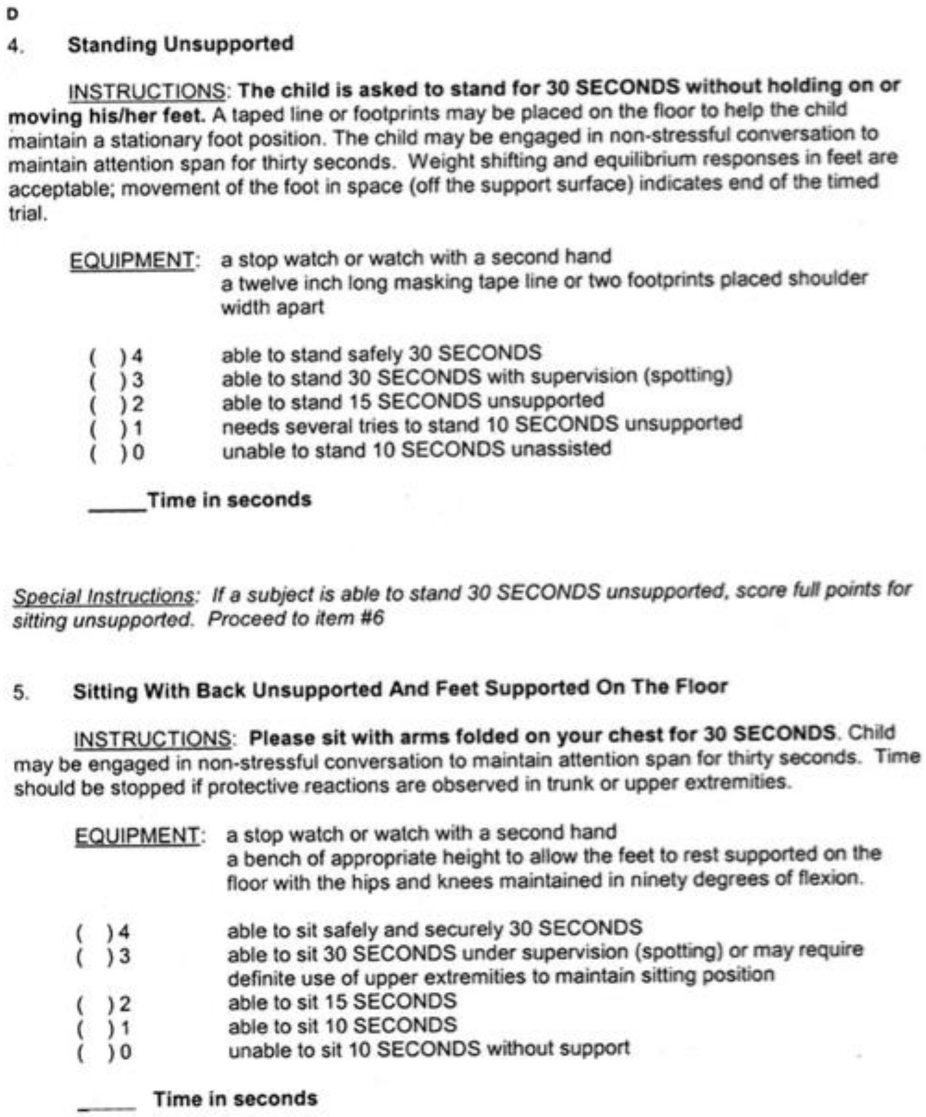
INSTRUCTIONS: Arrange chair(s) for a stand pivot transfer, touching at a forty-five degree angle. **Ask the child to transfer one way toward a seat with armrests and one way toward a seat without armrests.**

Equipment: Two chairs, or one chair and one bench. One seating surface must have armrests. One chair/bench should be of standard adult size and the other should be of an appropriate height to allow the child to conformably sit with feet supported on the floor and ninety degrees of hip and knee flexion.

Best Of Three Trials

( ) 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 cueing and/or supervision (spotting)
( ) 1	needs one person to assist
( ) 0	needs two people to assist or supervise (close guard) to be safe

Figure. No caption available.



D

4. **Standing Unsupported**

INSTRUCTIONS: **The child is asked to stand for 30 SECONDS without holding on or moving his/her feet.** A taped line or footprints may be placed on the floor to help the child maintain a stationary foot position. The child may be engaged in non-stressful conversation to maintain attention span for thirty seconds. Weight shifting and equilibrium responses in feet are acceptable; movement of the foot in space (off the support surface) indicates end of the timed trial.

EQUIPMENT: a stop watch or watch with a second hand
a twelve inch long masking tape line or two footprints placed shoulder width apart

( ) 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

_____**Time in seconds**

Special Instructions: If a subject is able to stand 30 SECONDS unsupported, score full points for sitting unsupported. Proceed to item #6

5. **Sitting With Back Unsupported And Feet Supported On The Floor**

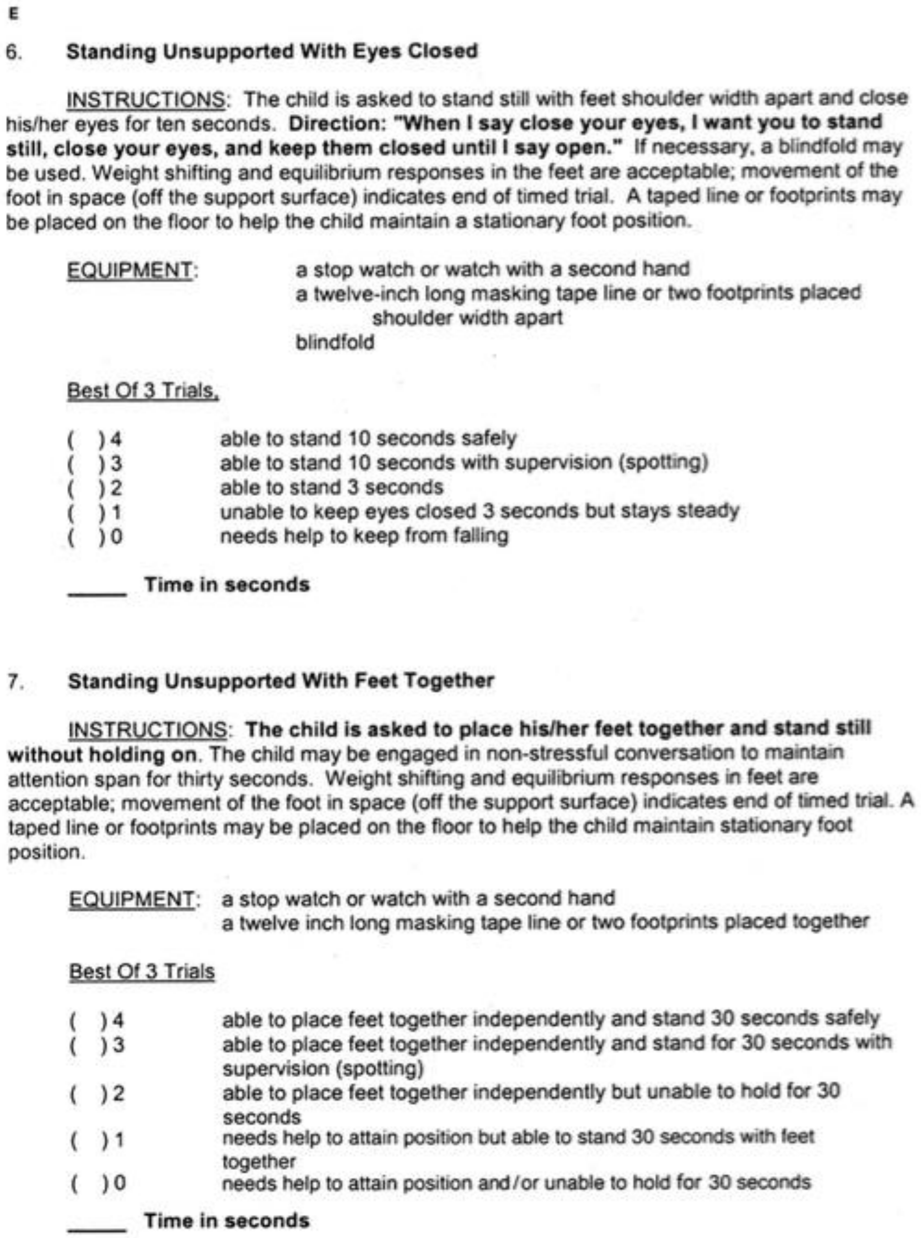
INSTRUCTIONS: **Please sit with arms folded on your chest for 30 SECONDS.** Child may be engaged in non-stressful conversation to maintain attention span for thirty seconds. Time should be stopped if protective reactions are observed in trunk or upper extremities.

EQUIPMENT: a stop watch or watch with a second hand
a bench of appropriate height to allow the feet to rest supported on the floor with the hips and knees maintained in ninety degrees of flexion.

( ) 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

_____ **Time in seconds**

Figure. No caption available.



E

6. Standing Unsupported With Eyes Closed

INSTRUCTIONS: The child is asked to stand still with feet shoulder width apart and close his/her eyes for ten seconds. **Direction: "When I say close your eyes, I want you to stand still, close your eyes, and keep them closed until I say open."** If necessary, a blindfold may be used. Weight shifting and equilibrium responses in the feet are acceptable; movement of the foot in space (off the support surface) indicates end of timed trial. A taped line or footprints may be placed on the floor to help the child maintain a stationary foot position.

EQUIPMENT:
a stop watch or watch with a second hand
a twelve-inch long masking tape line or two footprints placed shoulder width apart
blindfold

Best Of 3 Trials.

( ) 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

_____ **Time in seconds**

7. Standing Unsupported With Feet Together

INSTRUCTIONS: **The child is asked to place his/her feet together and stand still without holding on**. The child may be engaged in non-stressful conversation to maintain attention span for thirty seconds. Weight shifting and equilibrium responses in feet are acceptable; movement of the foot in space (off the support surface) indicates end of timed trial. A taped line or footprints may be placed on the floor to help the child maintain stationary foot position.

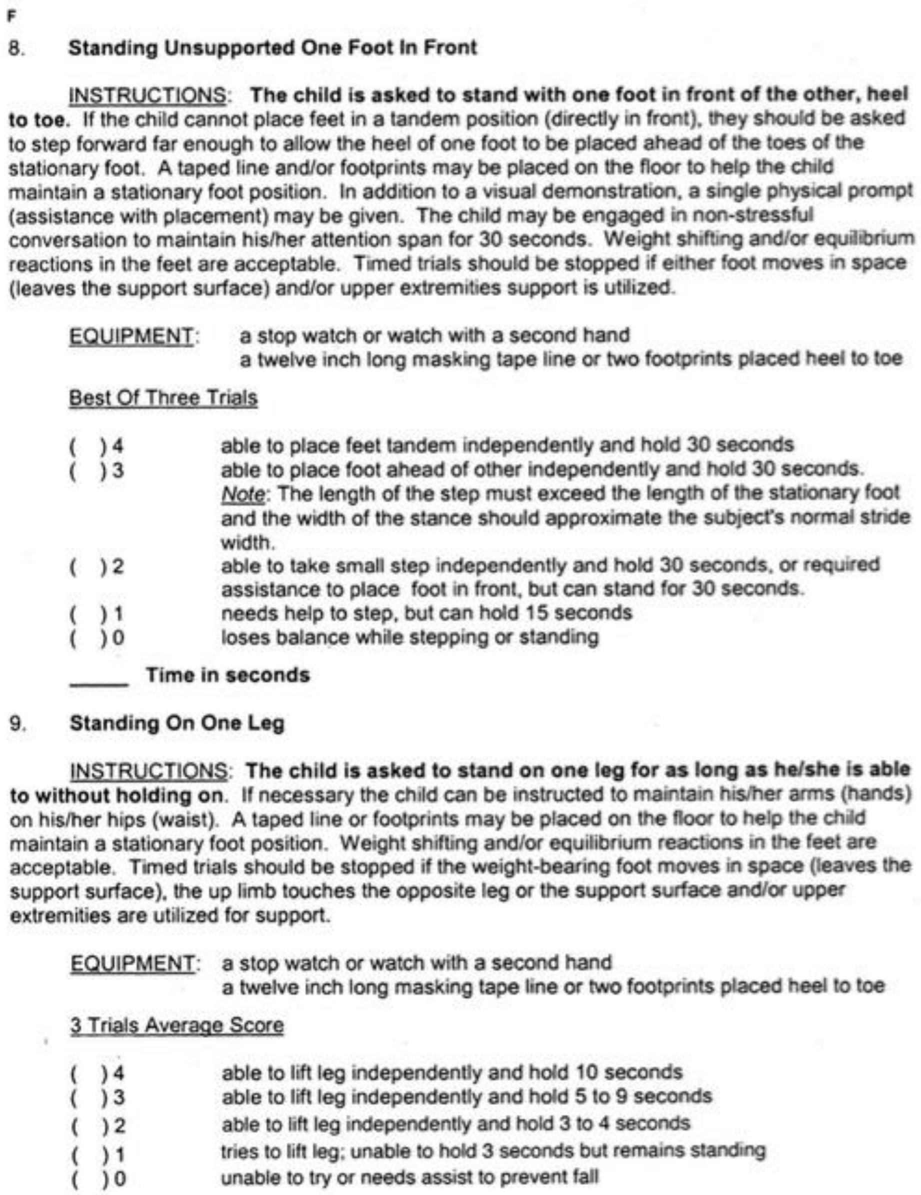
EQUIPMENT:
a stop watch or watch with a second hand
a twelve inch long masking tape line or two footprints placed together

Best Of 3 Trials

( ) 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

_____ **Time in seconds**

Figure. No caption available.



F

8. **Standing Unsupported One Foot In Front**

INSTRUCTIONS: **The child is asked to stand with one foot in front of the other, heel to toe.** If the child cannot place feet in a tandem position (directly in front), they should be asked to step forward far enough to allow the heel of one foot to be placed ahead of the toes of the stationary foot. A taped line and/or footprints may be placed on the floor to help the child maintain a stationary foot position. In addition to a visual demonstration, a single physical prompt (assistance with placement) may be given. The child may be engaged in non-stressful conversation to maintain his/her attention span for 30 seconds. Weight shifting and/or equilibrium reactions in the feet are acceptable. Timed trials should be stopped if either foot moves in space (leaves the support surface) and/or upper extremities support is utilized.

EQUIPMENT: a stop watch or watch with a second hand
a twelve inch long masking tape line or two footprints placed heel to toe

Best Of Three Trials

( ) 4	able to place feet tandem independently and hold 30 seconds
( ) 3	able to place foot ahead of other independently and hold 30 seconds. *Note*: The length of the step must exceed the length of the stationary foot and the width of the stance should approximate the subject's normal stride width.
( ) 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

_____ **Time in seconds**

9. **Standing On One Leg**

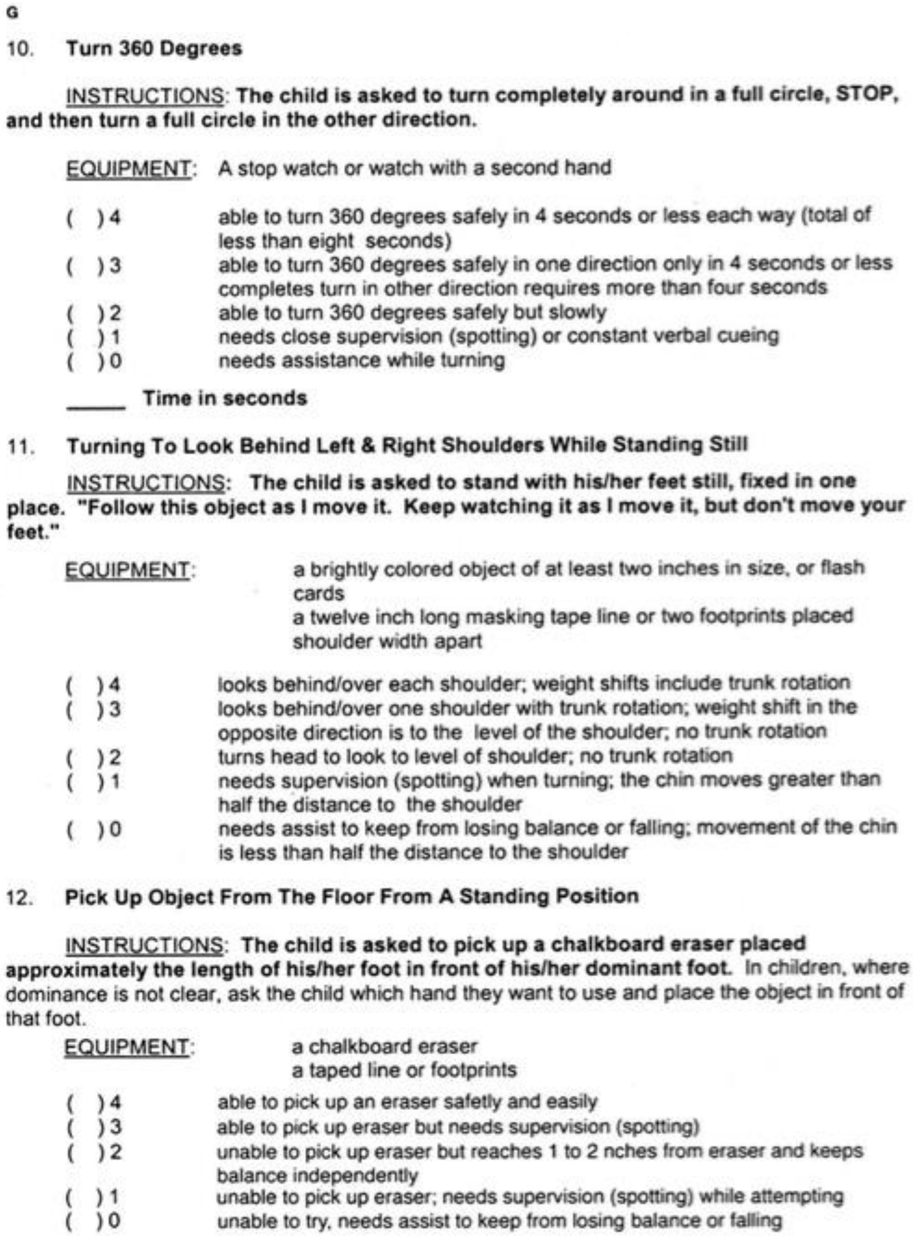
INSTRUCTIONS: **The child is asked to stand on one leg for as long as he/she is able to without holding on.** If necessary the child can be instructed to maintain his/her arms (hands) on his/her hips (waist). A taped line or footprints may be placed on the floor to help the child maintain a stationary foot position. Weight shifting and/or equilibrium reactions in the feet are acceptable. Timed trials should be stopped if the weight-bearing foot moves in space (leaves the support surface), the up limb touches the opposite leg or the support surface and/or upper extremities are utilized for support.

EQUIPMENT: a stop watch or watch with a second hand
a twelve inch long masking tape line or two footprints placed heel to toe

3 Trials Average Score

( ) 4	able to lift leg independently and hold 10 seconds
( ) 3	able to lift leg independently and hold 5 to 9 seconds
( ) 2	able to lift leg independently and hold 3 to 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

Figure. No caption available.



G

10. Turn 360 Degrees

INSTRUCTIONS: **The child is asked to turn completely around in a full circle, STOP, and then turn a full circle in the other direction.**

EQUIPMENT: A stop watch or watch with a second hand

( ) 4	able to turn 360 degrees safely in 4 seconds or less each way (total of less than eight seconds)
( ) 3	able to turn 360 degrees safely in one direction only in 4 seconds or less completes turn in other direction requires more than four seconds
( ) 2	able to turn 360 degrees safely but slowly
( ) 1	needs close supervision (spotting) or constant verbal cueing
( ) 0	needs assistance while turning

_____ **Time in seconds**

11. Turning To Look Behind Left & Right Shoulders While Standing Still

INSTRUCTIONS: **The child is asked to stand with his/her feet still, fixed in one place. "Follow this object as I move it. Keep watching it as I move it, but don't move your feet."**

EQUIPMENT: a brightly colored object of at least two inches in size, or flash cards
a twelve inch long masking tape line or two footprints placed shoulder width apart

( ) 4	looks behind/over each shoulder; weight shifts include trunk rotation
( ) 3	looks behind/over one shoulder with trunk rotation; weight shift in the opposite direction is to the level of the shoulder; no trunk rotation
( ) 2	turns head to look to level of shoulder; no trunk rotation
( ) 1	needs supervision (spotting) when turning; the chin moves greater than half the distance to the shoulder
( ) 0	needs assist to keep from losing balance or falling; movement of the chin is less than half the distance to the shoulder

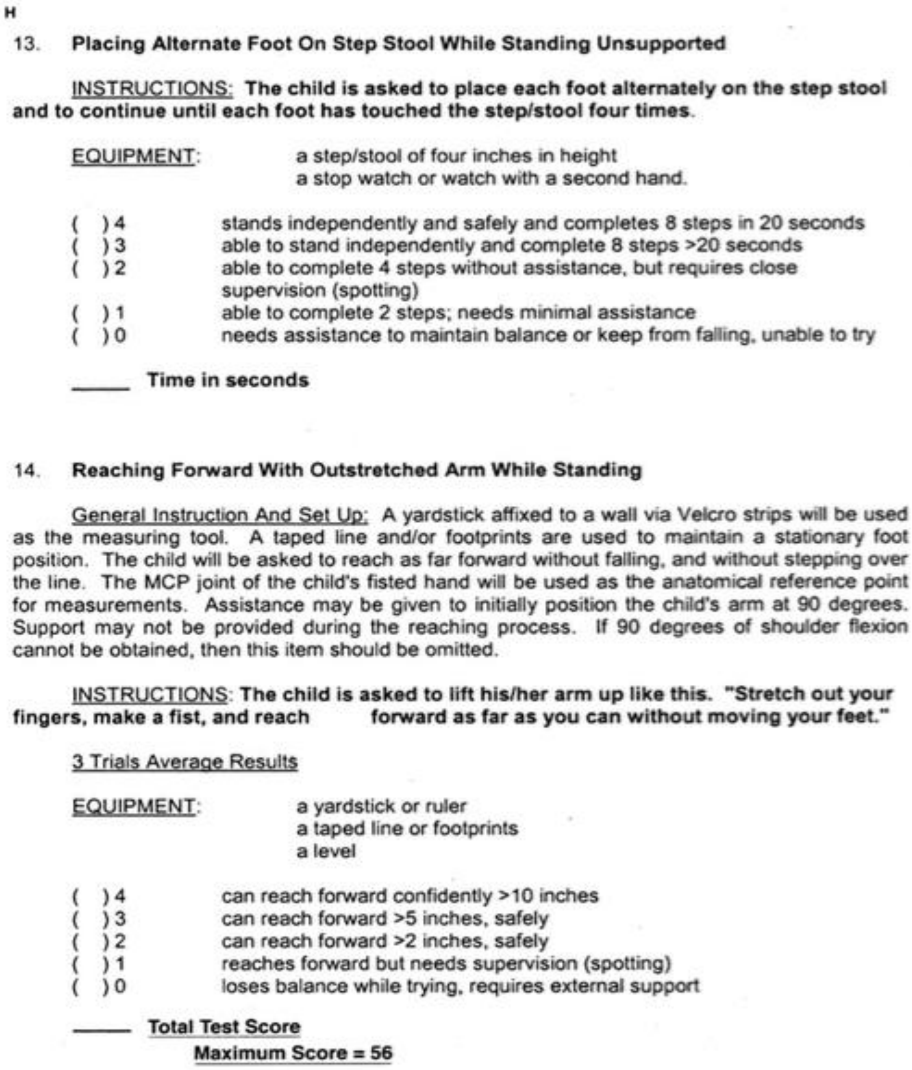
12. Pick Up Object From The Floor From A Standing Position

INSTRUCTIONS: **The child is asked to pick up a chalkboard eraser placed approximately the length of his/her foot in front of his/her dominant foot.** In children, where dominance is not clear, ask the child which hand they want to use and place the object in front of that foot.

EQUIPMENT: a chalkboard eraser
a taped line or footprints

( ) 4	able to pick up an eraser safetly and easily
( ) 3	able to pick up eraser but needs supervision (spotting)
( ) 2	unable to pick up eraser but reaches 1 to 2 nches from eraser and keeps balance independently
( ) 1	unable to pick up eraser; needs supervision (spotting) while attempting
( ) 0	unable to try, needs assist to keep from losing balance or falling

Figure. No caption available.



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13. **Placing Alternate Foot On Step Stool While Standing Unsupported**

INSTRUCTIONS: **The child is asked to place each foot alternately on the step stool and to continue until each foot has touched the step/stool four times.**

EQUIPMENT: a step/stool of four inches in height
a stop watch or watch with a second hand.

( ) 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

_____ **Time in seconds**

14. **Reaching Forward With Outstretched Arm While Standing**

General Instruction And Set Up: A yardstick affixed to a wall via Velcro strips will be used as the measuring tool. A taped line and/or footprints are used to maintain a stationary foot position. The child will be asked to reach as far forward without falling, and without stepping over the line. The MCP joint of the child's fisted hand will be used as the anatomical reference point for measurements. Assistance may be given to initially position the child's arm at 90 degrees. Support may not be provided during the reaching process. If 90 degrees of shoulder flexion cannot be obtained, then this item should be omitted.

INSTRUCTIONS: **The child is asked to lift his/her arm up like this. "Stretch out your fingers, make a fist, and reach forward as far as you can without moving your feet."**

3 Trials Average Results

EQUIPMENT: a yardstick or ruler
a taped line or footprints
a level

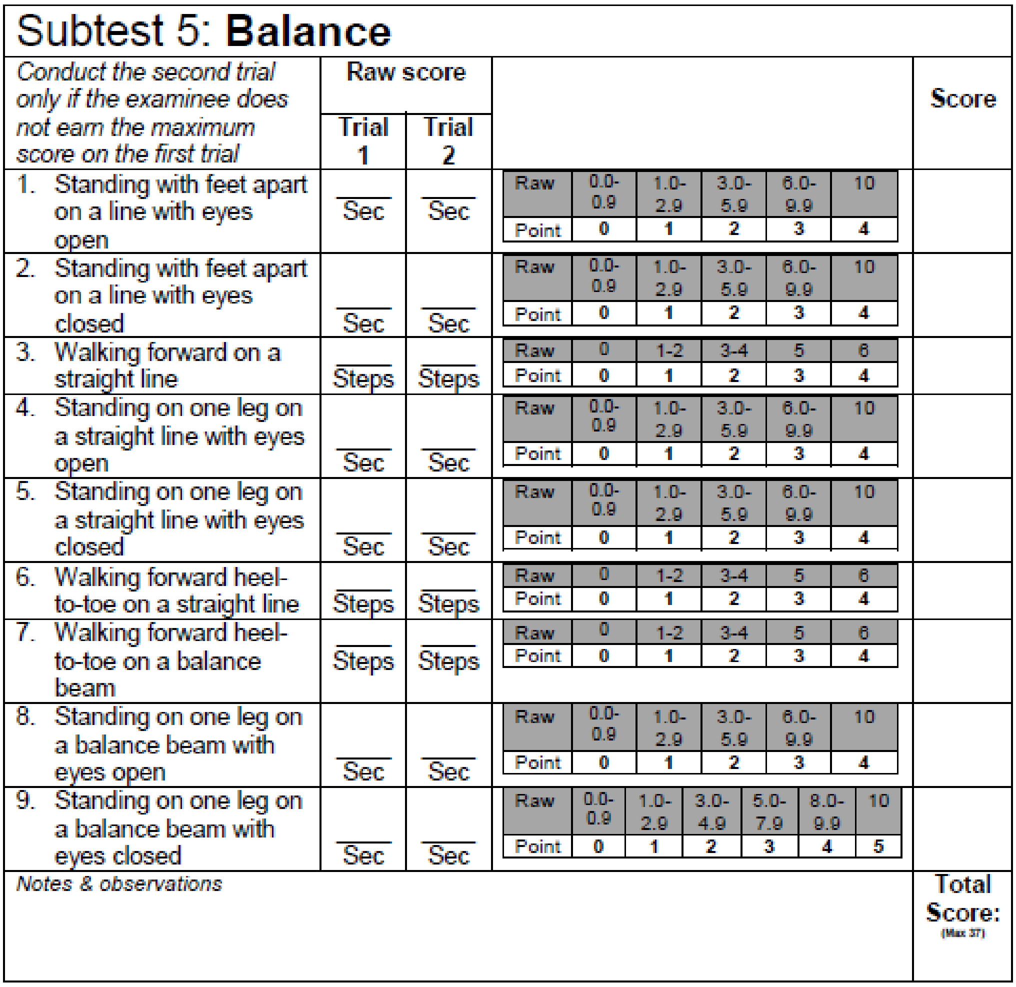
( ) 4 can reach forward confidently >10 inches
( ) 3 can reach forward >5 inches, safely
( ) 2 can reach forward >2 inches, safely
( ) 1 reaches forward but needs supervision (spotting)
( ) 0 loses balance while trying, requires external support

_____ **Total Test Score**

Maximum Score = 56

Figure. No caption available.

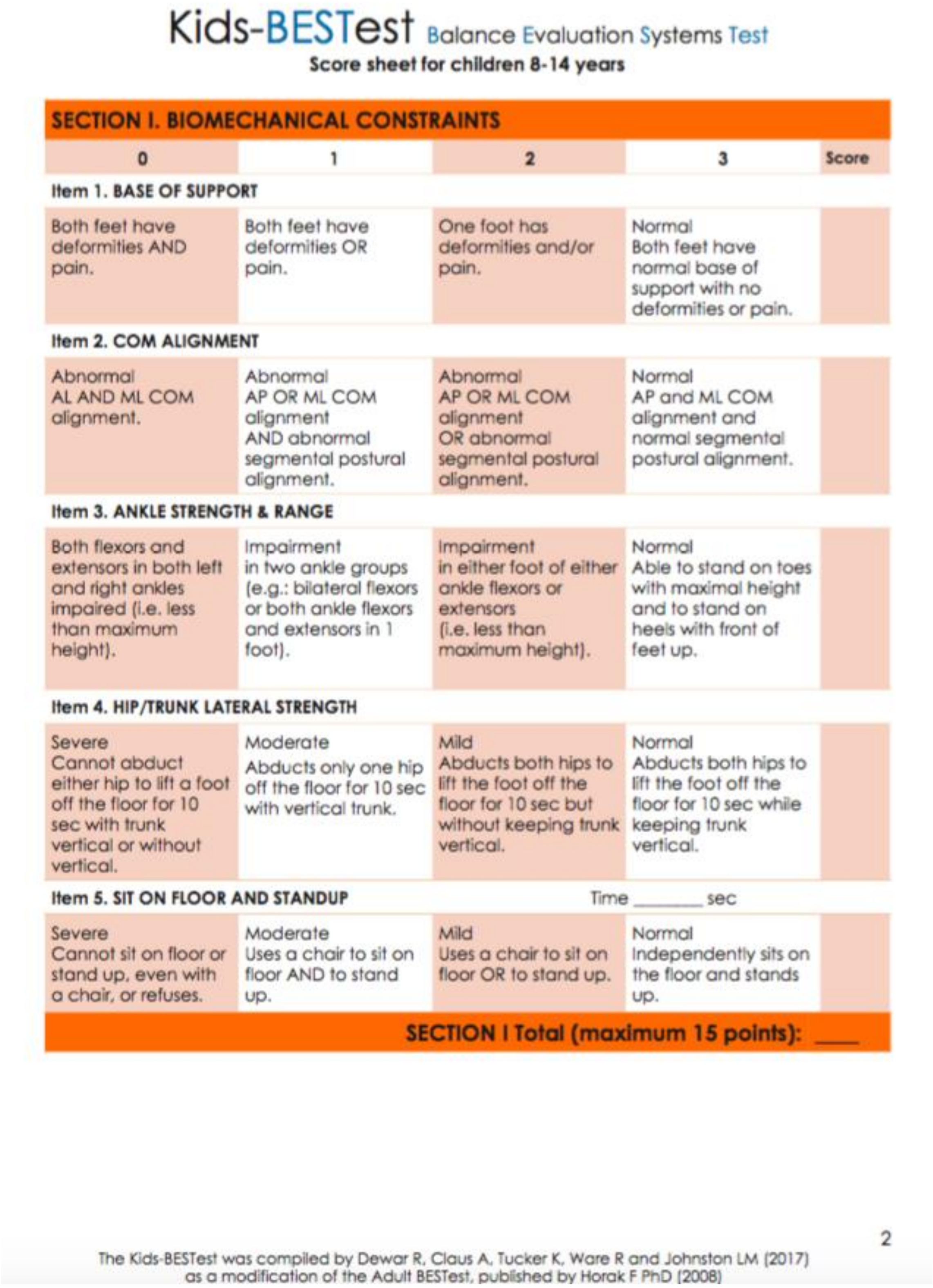
Appendix T: BOT-2, Subtest 5 Score sheet



Subtest 5: **Balance**

Conduct the second trial only if the examinee does not earn the maximum score on the first trial	Raw score			Score
	Trial 1	Trial 2		
1. Standing with feet apart on a line with eyes open	___ Sec	___ Sec	Raw: 0.0-0.9 | 1.0-2.9 | 3.0-5.9 | 6.0-9.9 | 10 Point: 0 | 1 | 2 | 3 | 4	
2. Standing with feet apart on a line with eyes closed	___ Sec	___ Sec	Raw: 0.0-0.9 | 1.0-2.9 | 3.0-5.9 | 6.0-9.9 | 10 Point: 0 | 1 | 2 | 3 | 4	
3. Walking forward on a straight line	___ Steps	___ Steps	Raw: 0 | 1-2 | 3-4 | 5 | 6 Point: 0 | 1 | 2 | 3 | 4	
4. Standing on one leg on a straight line with eyes open	___ Sec	___ Sec	Raw: 0.0-0.9 | 1.0-2.9 | 3.0-5.9 | 6.0-9.9 | 10 Point: 0 | 1 | 2 | 3 | 4	
5. Standing on one leg on a straight line with eyes closed	___ Sec	___ Sec	Raw: 0.0-0.9 | 1.0-2.9 | 3.0-5.9 | 6.0-9.9 | 10 Point: 0 | 1 | 2 | 3 | 4	
6. Walking forward heel-to-toe on a straight line	___ Steps	___ Steps	Raw: 0 | 1-2 | 3-4 | 5 | 6 Point: 0 | 1 | 2 | 3 | 4	
7. Walking forward heel-to-toe on a balance beam	___ Steps	___ Steps	Raw: 0 | 1-2 | 3-4 | 5 | 6 Point: 0 | 1 | 2 | 3 | 4	
8. Standing on one leg on a balance beam with eyes open	___ Sec	___ Sec	Raw: 0.0-0.9 | 1.0-2.9 | 3.0-5.9 | 6.0-9.9 | 10 Point: 0 | 1 | 2 | 3 | 4	
9. Standing on one leg on a balance beam with eyes closed	___ Sec	___ Sec	Raw: 0.0-0.9 | 1.0-2.9 | 3.0-4.9 | 5.0-7.9 | 8.0-9.9 | 10 Point: 0 | 1 | 2 | 3 | 4 | 5	
Notes & observations				Total Score: (Max 37)

Appendix U: Kids-BESTest Score Sheet



Kids-BESTest Balance Evaluation Systems Test

Score sheet for children 8-14 years

SECTION I. BIOMECHANICAL CONSTRAINTS

0	1	2	3	Score
Item 1. BASE OF SUPPORT				
Both feet have deformities AND pain.	Both feet have deformities OR pain.	One foot has deformities and/or pain.	Normal Both feet have normal base of support with no deformities or pain.	
Item 2. COM ALIGNMENT				
Abnormal AL AND ML COM alignment.	Abnormal AP OR ML COM alignment AND abnormal segmental postural alignment.	Abnormal AP OR ML COM alignment OR abnormal segmental postural alignment.	Normal AP and ML COM alignment and normal segmental postural alignment.	
Item 3. ANKLE STRENGTH & RANGE				
Both flexors and extensors in both left and right ankles impaired (i.e. less than maximum height).	Impairment in two ankle groups (e.g.: bilateral flexors or both ankle flexors and extensors in 1 foot).	Impairment in either foot of either ankle flexors or extensors (i.e. less than maximum height).	Normal Able to stand on toes with maximal height and to stand on heels with front of feet up.	
Item 4. HIP/TRUNK LATERAL STRENGTH				
Severe Cannot abduct either hip to lift a foot off the floor for 10 sec with trunk vertical or without vertical.	Moderate Abducts only one hip off the floor for 10 sec with vertical trunk.	Mild Abducts both hips to lift the foot off the floor for 10 sec but without keeping trunk vertical.	Normal Abducts both hips to lift the foot off the floor for 10 sec while keeping trunk vertical.	
Item 5. SIT ON FLOOR AND STANDUP		Time ________ sec		
Severe Cannot sit on floor or stand up, even with a chair, or refuses.	Moderate Uses a chair to sit on floor AND to stand up.	Mild Uses a chair to sit on floor OR to stand up.	Normal Independently sits on the floor and stands up.	

SECTION I Total (maximum 15 points): ____

2

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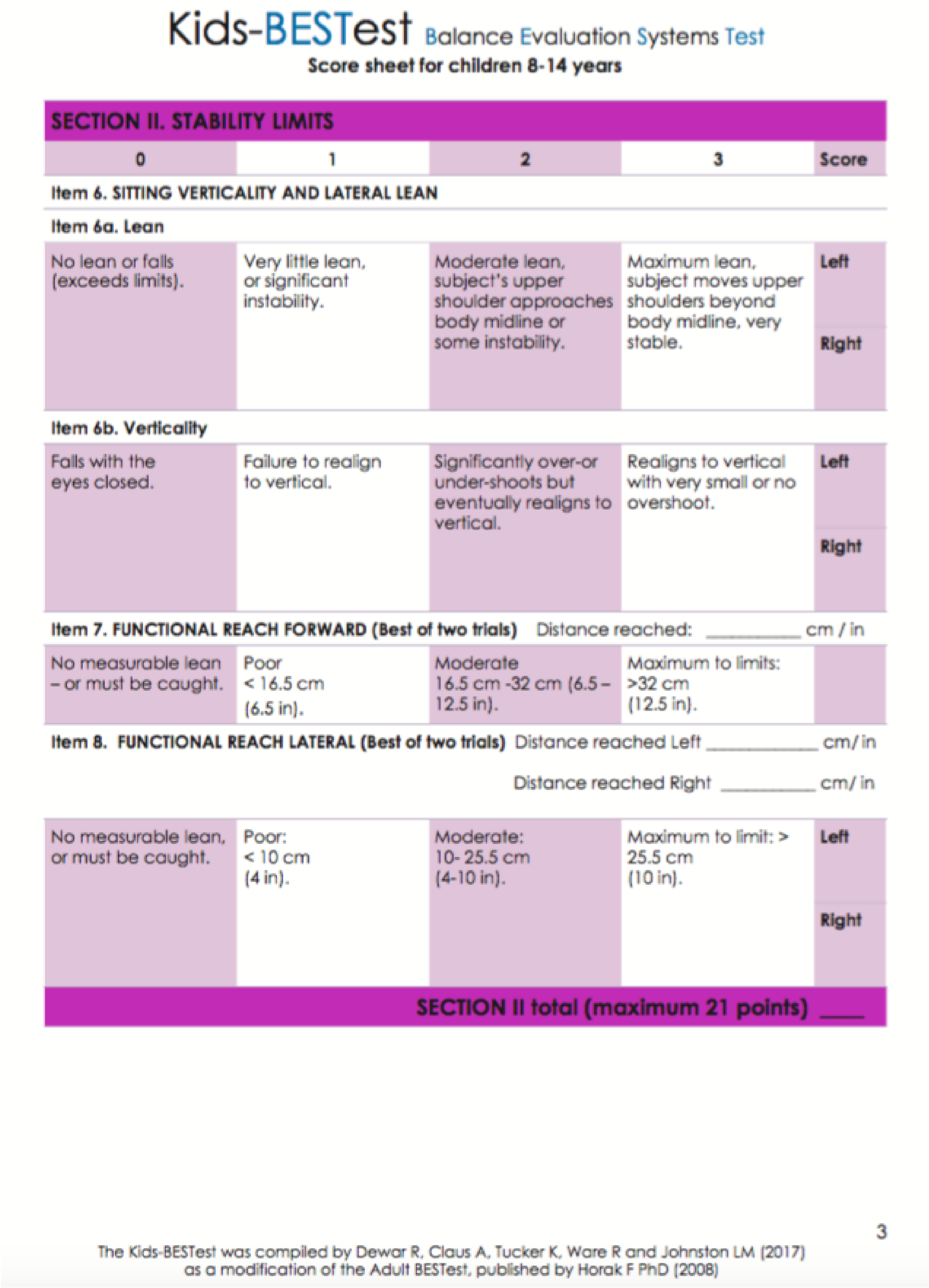

Kids-BESTest Balance Evaluation Systems Test

Score sheet for children 8-14 years

SECTION II. STABILITY LIMITS				
0	**1**	**2**	**3**	**Score**
Item 6. SITTING VERTICALITY AND LATERAL LEAN				
Item 6a. Lean				
No lean or falls (exceeds limits).	Very little lean, or significant instability.	Moderate lean, subject's upper shoulder approaches body midline or some instability.	Maximum lean, subject moves upper shoulders beyond body midline, very stable.	**Left** **Right**
Item 6b. Verticality				
Falls with the eyes closed.	Failure to realign to vertical.	Significantly over-or under-shoots but eventually realigns to vertical.	Realigns to vertical with very small or no overshoot.	**Left** **Right**
Item 7. FUNCTIONAL REACH FORWARD (Best of two trials) Distance reached: __________ cm / in				
No measurable lean – or must be caught.	Poor < 16.5 cm (6.5 in).	Moderate 16.5 cm -32 cm (6.5 – 12.5 in).	Maximum to limits: >32 cm (12.5 in).	
Item 8. FUNCTIONAL REACH LATERAL (Best of two trials) Distance reached Left __________ cm/ in Distance reached Right __________ cm/ in				
No measurable lean, or must be caught.	Poor: < 10 cm (4 in).	Moderate: 10- 25.5 cm (4-10 in).	Maximum to limit: > 25.5 cm (10 in).	**Left** **Right**
SECTION II total (maximum 21 points) ____				

3

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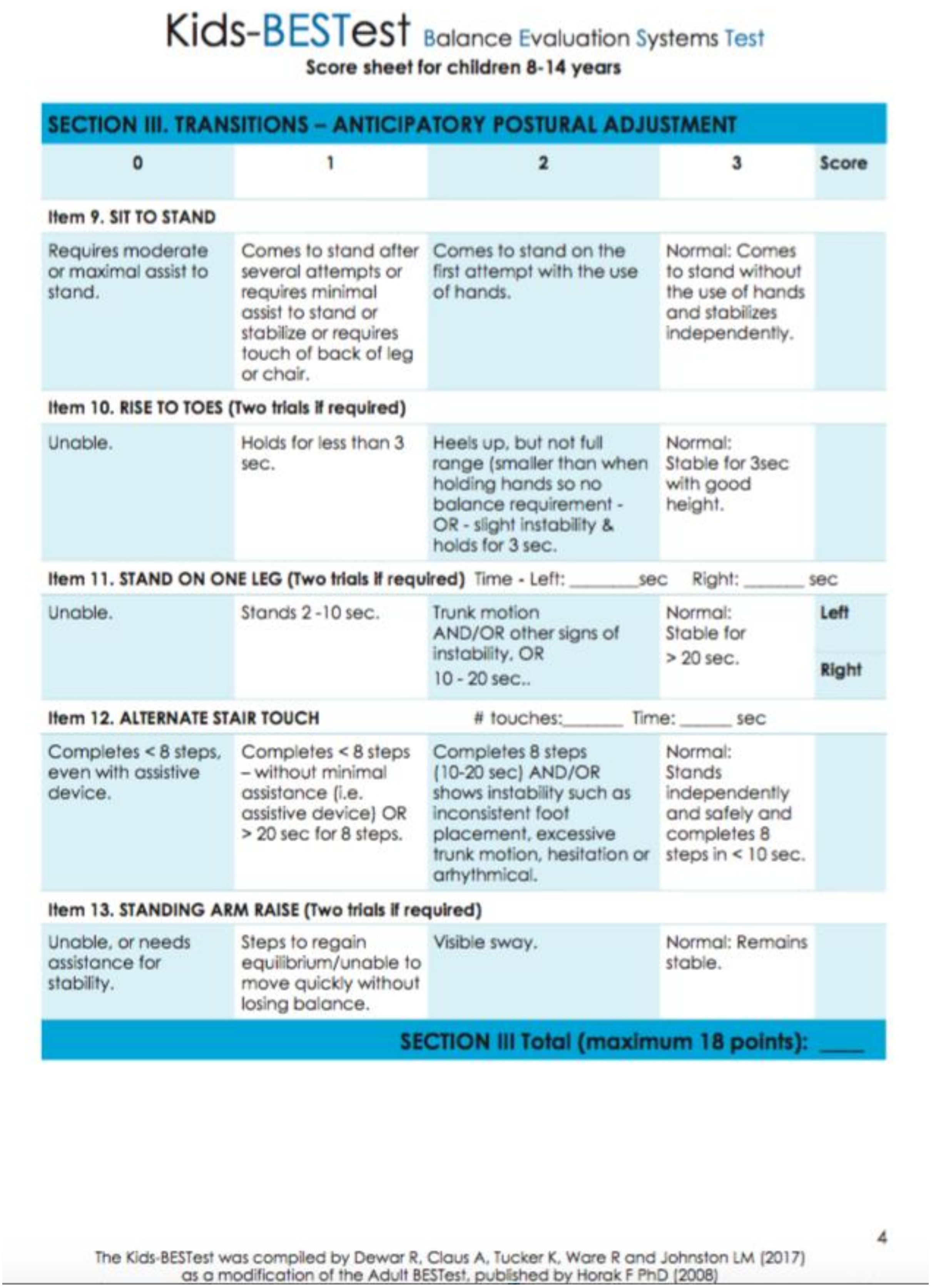

Kids-BESTest Balance Evaluation Systems Test

Score sheet for children 8-14 years

SECTION III. TRANSITIONS – ANTICIPATORY POSTURAL ADJUSTMENT				
0	**1**	**2**	**3**	**Score**
Item 9. SIT TO STAND				
Requires moderate or maximal assist to stand.	Comes to stand after several attempts or requires minimal assist to stand or stabilize or requires touch of back of leg or chair.	Comes to stand on the first attempt with the use of hands.	Normal: Comes to stand without the use of hands and stabilizes independently.	
Item 10. RISE TO TOES (Two trials if required)				
Unable.	Holds for less than 3 sec.	Heels up, but not full range (smaller than when holding hands so no balance requirement - OR - slight instability & holds for 3 sec.	Normal: Stable for 3sec with good height.	
Item 11. STAND ON ONE LEG (Two trials if required) Time - Left: _______sec Right: _______ sec				
Unable.	Stands 2 -10 sec.	Trunk motion AND/OR other signs of instability, OR 10 - 20 sec..	Normal: Stable for > 20 sec.	**Left** **Right**
Item 12. ALTERNATE STAIR TOUCH		# touches:______ Time: ______ sec		
Completes < 8 steps, even with assistive device.	Completes < 8 steps – without minimal assistance (i.e. assistive device) OR > 20 sec for 8 steps.	Completes 8 steps (10-20 sec) AND/OR shows instability such as inconsistent foot placement, excessive trunk motion, hesitation or arhythmical.	Normal: Stands independently and safely and completes 8 steps in < 10 sec.	
Item 13. STANDING ARM RAISE (Two trials if required)				
Unable, or needs assistance for stability.	Steps to regain equilibrium/unable to move quickly without losing balance.	Visible sway.	Normal: Remains stable.	
		SECTION III Total (maximum 18 points): ____		

4

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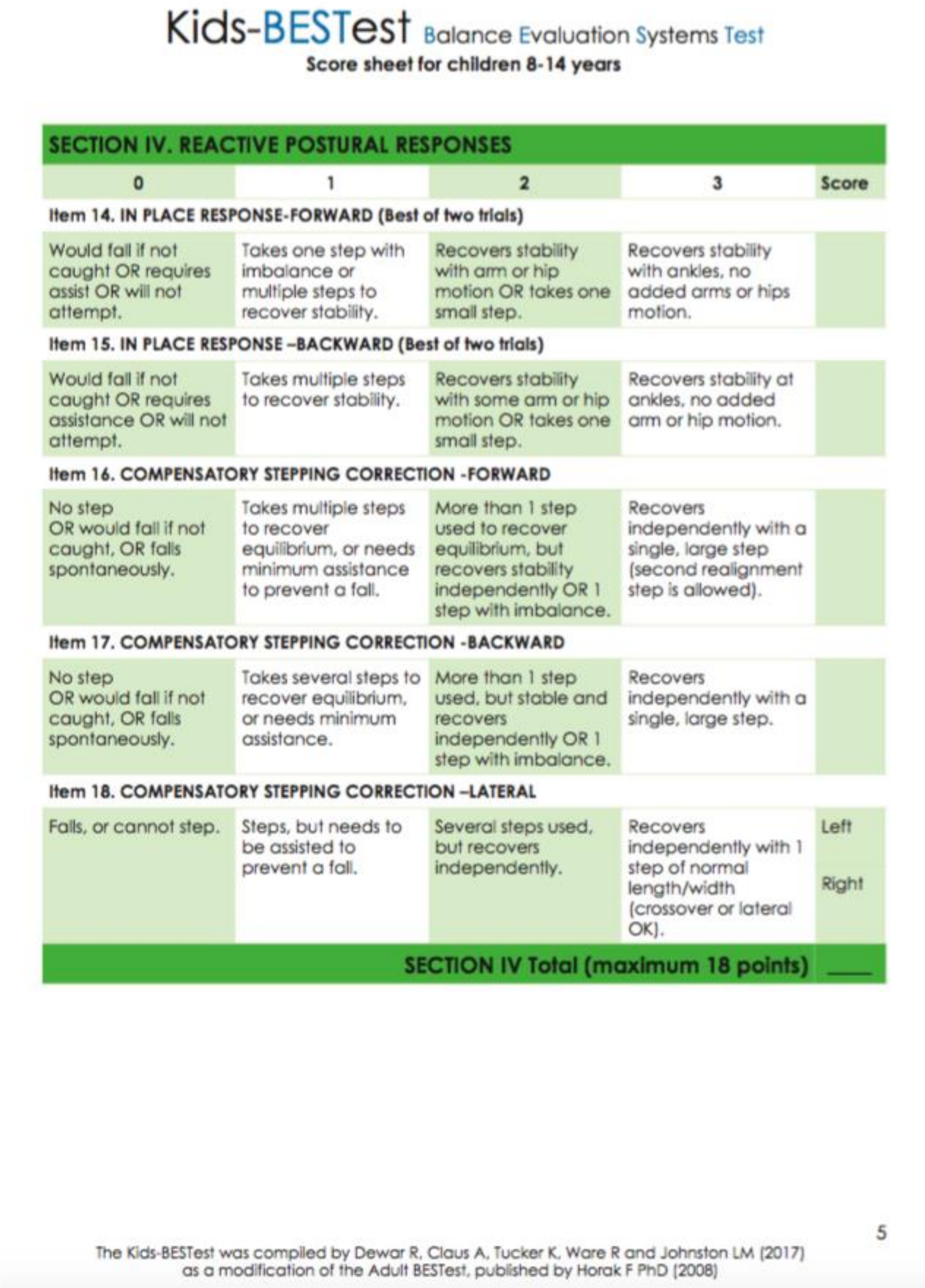

Kids-BESTest Balance Evaluation Systems Test

Score sheet for children 8-14 years

SECTION IV. REACTIVE POSTURAL RESPONSES				
0	**1**	**2**	**3**	**Score**
Item 14. IN PLACE RESPONSE-FORWARD (Best of two trials)				
Would fall if not caught OR requires assist OR will not attempt.	Takes one step with imbalance or multiple steps to recover stability.	Recovers stability with arm or hip motion OR takes one small step.	Recovers stability with ankles, no added arms or hips motion.	
Item 15. IN PLACE RESPONSE –BACKWARD (Best of two trials)				
Would fall if not caught OR requires assistance OR will not attempt.	Takes multiple steps to recover stability.	Recovers stability with some arm or hip motion OR takes one small step.	Recovers stability at ankles, no added arm or hip motion.	
Item 16. COMPENSATORY STEPPING CORRECTION -FORWARD				
No step OR would fall if not caught, OR falls spontaneously.	Takes multiple steps to recover equilibrium, or needs minimum assistance to prevent a fall.	More than 1 step used to recover equilibrium, but recovers stability independently OR 1 step with imbalance.	Recovers independently with a single, large step (second realignment step is allowed).	
Item 17. COMPENSATORY STEPPING CORRECTION -BACKWARD				
No step OR would fall if not caught, OR falls spontaneously.	Takes several steps to recover equilibrium, or needs minimum assistance.	More than 1 step used, but stable and recovers independently OR 1 step with imbalance.	Recovers independently with a single, large step.	
Item 18. COMPENSATORY STEPPING CORRECTION –LATERAL				
Falls, or cannot step.	Steps, but needs to be assisted to prevent a fall.	Several steps used, but recovers independently.	Recovers independently with 1 step of normal length/width (crossover or lateral OK).	Left Right
		SECTION IV Total (maximum 18 points)		____

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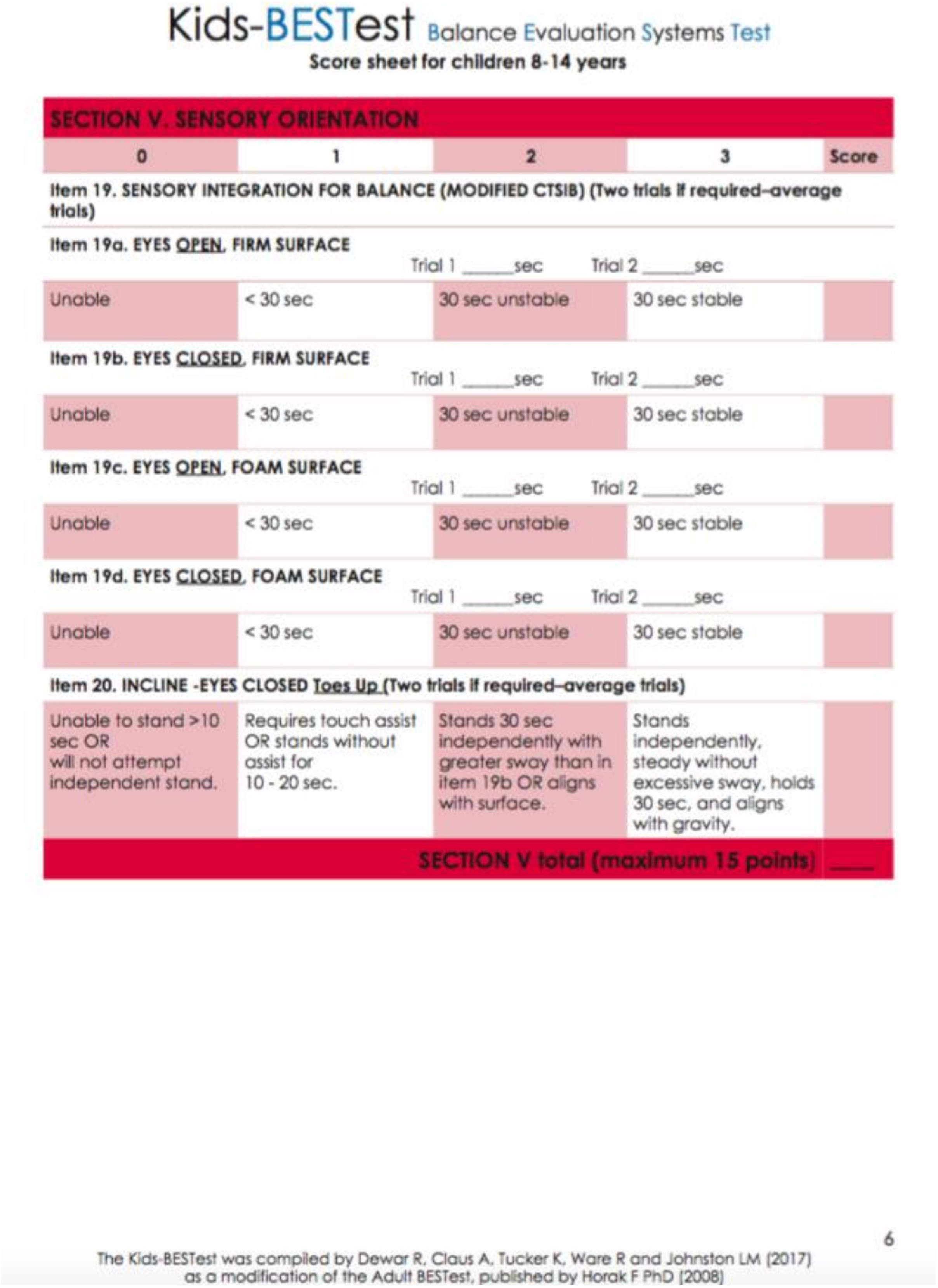

Kids-BESTest Balance Evaluation Systems Test

Score sheet for children 8-14 years

SECTION V. SENSORY ORIENTATION

0	1	2	3	Score
Item 19. SENSORY INTEGRATION FOR BALANCE (MODIFIED CTSIB) (Two trials if required–average trials)				
Item 19a. EYES OPEN, FIRM SURFACE		Trial 1 _____sec	Trial 2 _____sec	
Unable	< 30 sec	30 sec unstable	30 sec stable	
Item 19b. EYES CLOSED, FIRM SURFACE		Trial 1 _____sec	Trial 2 _____sec	
Unable	< 30 sec	30 sec unstable	30 sec stable	
Item 19c. EYES OPEN, FOAM SURFACE		Trial 1 _____sec	Trial 2 _____sec	
Unable	< 30 sec	30 sec unstable	30 sec stable	
Item 19d. EYES CLOSED, FOAM SURFACE		Trial 1 _____sec	Trial 2 _____sec	
Unable	< 30 sec	30 sec unstable	30 sec stable	
Item 20. INCLINE -EYES CLOSED Toes Up (Two trials if required–average trials)				
Unable to stand >10 sec OR will not attempt independent stand.	Requires touch assist OR stands without assist for 10 - 20 sec.	Stands 30 sec independently with greater sway than in item 19b OR aligns with surface.	Stands independently, steady without excessive sway, holds 30 sec, and aligns with gravity.	
			SECTION V total (maximum 15 points)	____

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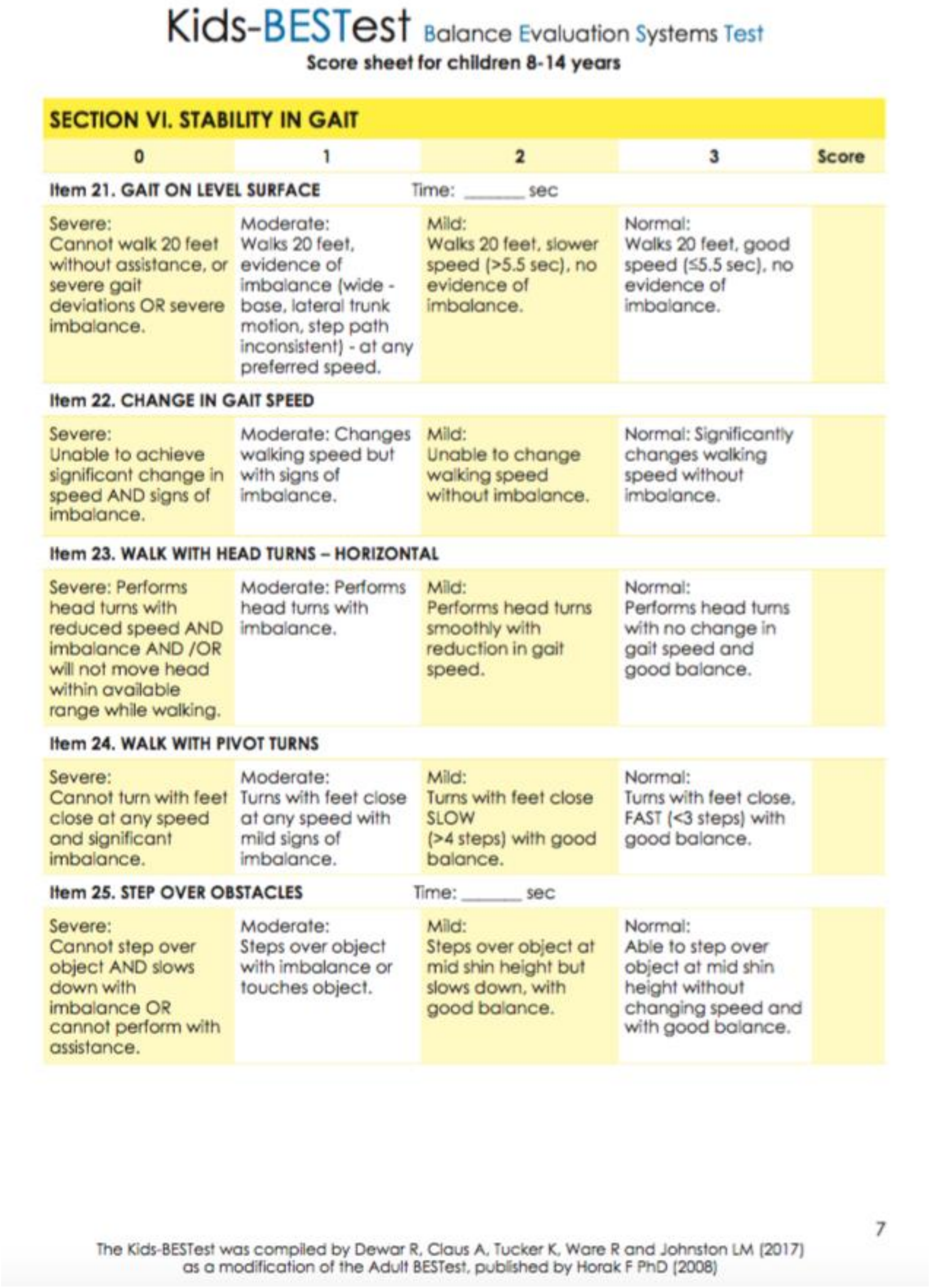

Kids-BESTest Balance Evaluation Systems Test

Score sheet for children 8-14 years

SECTION VI. STABILITY IN GAIT

0	1	2	3	Score
Item 21. GAIT ON LEVEL SURFACE		Time: ______ sec		
Severe: Cannot walk 20 feet without assistance, or severe gait deviations OR severe imbalance.	Moderate: Walks 20 feet, evidence of imbalance (wide - base, lateral trunk motion, step path inconsistent) - at any preferred speed.	Mild: Walks 20 feet, slower speed (>5.5 sec), no evidence of imbalance.	Normal: Walks 20 feet, good speed (≤5.5 sec), no evidence of imbalance.	
Item 22. CHANGE IN GAIT SPEED				
Severe: Unable to achieve significant change in speed AND signs of imbalance.	Moderate: Changes walking speed but with signs of imbalance.	Mild: Unable to change walking speed without imbalance.	Normal: Significantly changes walking speed without imbalance.	
Item 23. WALK WITH HEAD TURNS – HORIZONTAL				
Severe: Performs head turns with reduced speed AND imbalance AND /OR will not move head within available range while walking.	Moderate: Performs head turns with imbalance.	Mild: Performs head turns smoothly with reduction in gait speed.	Normal: Performs head turns with no change in gait speed and good balance.	
Item 24. WALK WITH PIVOT TURNS				
Severe: Cannot turn with feet close at any speed and significant imbalance.	Moderate: Turns with feet close at any speed with mild signs of imbalance.	Mild: Turns with feet close SLOW (>4 steps) with good balance.	Normal: Turns with feet close, FAST (<3 steps) with good balance.	
Item 25. STEP OVER OBSTACLES		Time: ______ sec		
Severe: Cannot step over object AND slows down with imbalance OR cannot perform with assistance.	Moderate: Steps over object with imbalance or touches object.	Mild: Steps over object at mid shin height but slows down, with good balance.	Normal: Able to step over object at mid shin height without changing speed and with good balance.	

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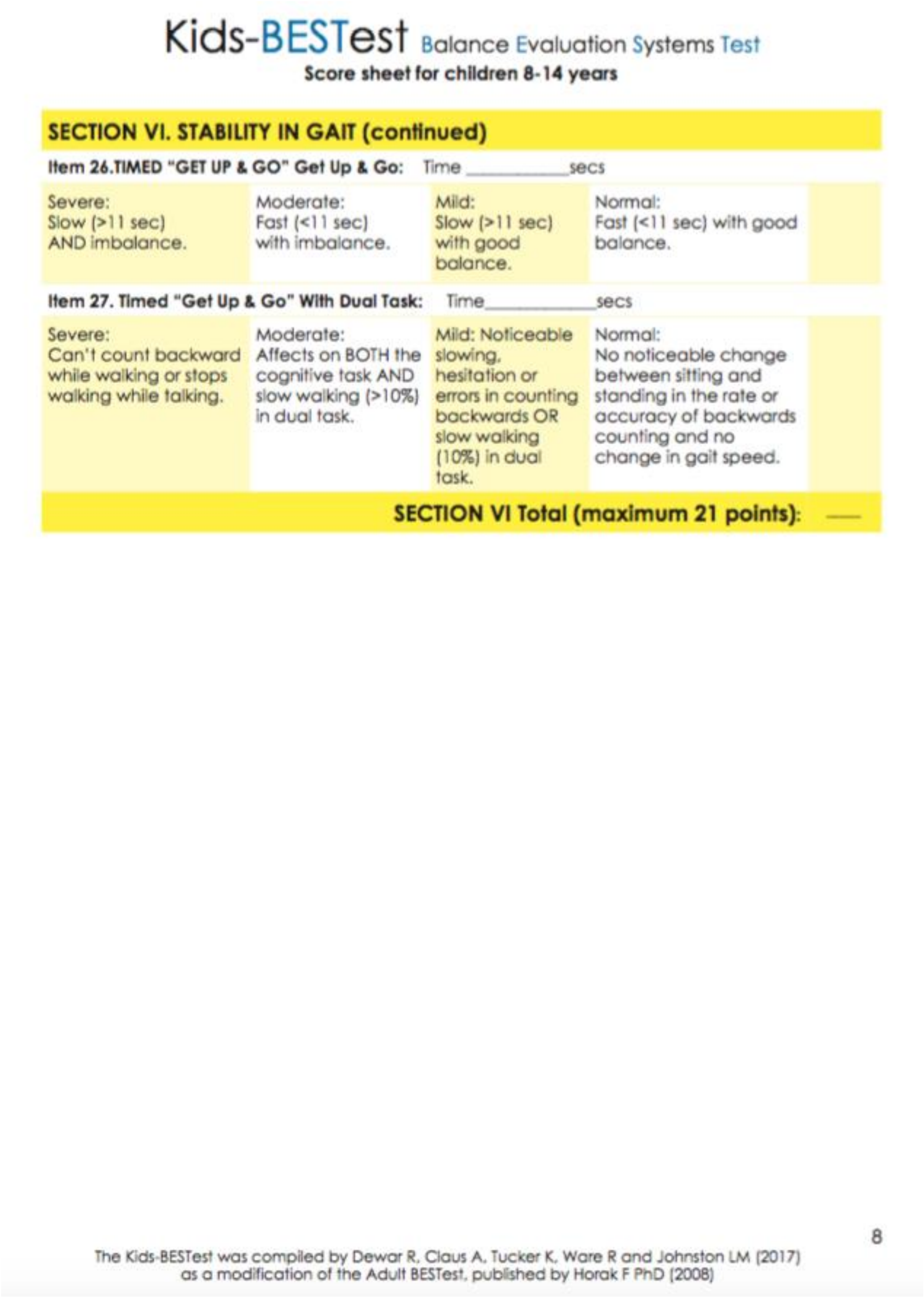

Kids-BESTest Balance Evaluation Systems Test

Score sheet for children 8-14 years

SECTION VI. STABILITY IN GAIT (continued)

Item 26.TIMED "GET UP & GO" Get Up & Go: Time __________secs

Severe: Slow (>11 sec) AND imbalance.	Moderate: Fast (<11 sec) with imbalance.	Mild: Slow (>11 sec) with good balance.	Normal: Fast (<11 sec) with good balance.	

Item 27. Timed "Get Up & Go" With Dual Task: Time__________secs

Severe: Can't count backward while walking or stops walking while talking.	Moderate: Affects on BOTH the cognitive task AND slow walking (>10%) in dual task.	Mild: Noticeable slowing, hesitation or errors in counting backwards OR slow walking (10%) in dual task.	Normal: No noticeable change between sitting and standing in the rate or accuracy of backwards counting and no change in gait speed.	

SECTION VI Total (maximum 21 points): ___

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