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Clinical balance assessment tools for children with hearing loss: a scoping review

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Abstract
Balance dysfunction exists in children with hearing loss, especially sensorineural loss, impacting on cognitive development, socio-emotional development and literacy. However, there is limited assessment of balance in this population, which further impedes childhood development. The objective of this review was to identify clinical, low- technology and inexpensive tools used to evaluate balance in children with hearing loss. Methods: A scoping review method with reference to the JBI, was used where a search was conducted on electronic databases including, but not limited to, EBSCOHost, MEDLINE, PubMED, Web of Science and Wiley. In addition, grey literature and hand searches were also used. The review included children between 3 and 15 years of age with hearing loss. Results: A total of 68 articles were found where 27% of the tests were norm-referenced tests, 64% were criterion referenced tests and 9% could not be identified. Conclusion: Tests such as the Tandem gait test, Pediatric Balance Scale (PBS), Clinical Test of Sensory Interaction for Balance (mCTSIB)/Pediatric Version of Clinical Test for Sensory Interaction of Balance (P-CTSIB), Dynamic Gait Index and the Timed-up-and-Go were identified to be relatively inexpensive and low-technology clinical tools and have thus, been summarized in this review.

Keywords Paediatric, Balance assessment, Motor development, Hearing loss, Vestibular deficit

Introduction

The balance system is a complex system that facilitates multisensory integration of vestibular, visual, proprioceptive and cognitive input to maintain balance and equilibrium [1, 2]. Throughout childhood, this system continues to develop such that it reaches a stage of adult-like sensory integration by the age of 12 years [3]. Furthermore, spatial cues received from the auditory system assist with maintaining posture and balance [4]. In children, balance involves maintaining postural control and ensuring the coordination and accuracy of movement with ongoing motor development [5]. Thus, injury or defect to either the auditory or vestibular system can result in balance dysfunction [4, 6, 7].

Due to the anatomical and physiological relationship between hearing and the vestibular system, children with hearing loss have been noted to present with motor and balance deficits [8]. Hearing loss is often accompanied by debilitating effects on children such as impaired language, communication, socio-emotional, psychological and academic difficulties [9]. In addition, it has been found that children with severe to profound hearing loss usually present with significant delays in fine and gross motor development [10], postural and balance deficits [11], and poor visual and spatial orientation [12]. Psychological issues such as hyperactivity and increased risk of anxiety-related disorders have also been noted in children with more severe forms of hearing impairment [13].

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Moreover, negative impact on cognitive development, socio-emotional development and literacy may also be noted; such that hearing-impaired children may later experience learning difficulties, developmental delays and poor academic performance (Martens et al., 2020; Rine & Wiener-Vacher, 2013). Due to such difficulties, children have increased risk of falls and injuries [14]. Falls are the most common cause of hospitalizations (30%) and visits to the emergency department (15%) in children [15]. In a low-middle income country like South African, falls were found to be the second commonest cause of unintentional injury to children [16, 17].

Regardless of the aforemetioned evidence, vestibular and balance dysfunction in the paediatric population have been historically underdiagnosed [18]. Although caregivers and teachers may report clumsiness and coordination difficulties, healthcare professionals who service this population often lack the appropriate training and time to effectively screen for both balance and developmental issues during routine clinic visits [19]. High patient caseload, expensive equipment and lack of competence in training have contributed to balance dysfunction going unheeded [19–24]. Assessment tools such as dynamic posturography, electrophysiological measures and other high-technology equipment may not be readily available to audiologists, especially those in low- and middle-income countries (LMIC) [25]. Thus, further restricting access to balance assessment services. Therefore, the need to collate a battery of clinical tools for balance assessment may address such an issue, as they may be relatively inexpensive and easily available.

Although hearing screening programmes have been able to provide early identification of hearing; the screening is limited in its inclusion of balance and motor assessments [21, 26]. Although some countries like Belgium have initiated vestibular screening in neonates, it is not routinely performed on all children with hearing loss; unless obvious vertigo and balance disorders are noted or for cochlear implant candidacy [21]. Consequently, limitations in the management of the adverse effects of vestibular and resultant balance deficits can be noted as assessments are not incoporated as part of a standard healthcare service [27, 28]. There is evidently a significant gap in practice for vestibular and balance screening in children with hearing loss, especially those presenting with severe to profound SNHL, and psychological disorders such as hyperactivity and anxiety disorders [10, 13]. Therefore, the main objective of this review was to develop a literature map of clinical balance assessment tools for children between the ages of three to fifteen years with hearing loss. Thereafter, it also aimed to identify gaps in literature for future research. A scoping review was an appropriate method to achieve these objectives as it is necessary to uncover the existing and available body of literature regarding a particular topic, in order to provide clarity and create a platform for the development of a systematic review [29].

A preliminary search was conducted in the JBI Database of Systematic Reviews, Cochrane Database of Systematic Reviews and PROSPERO databases to outline the availability and characteristics of balance assessments in children. Thus, the current scoping review sought to critically analyse and synthesize findings from existing literature relating to clinical balance assessment tools which are suitable for children with hearing loss.

Methods

A scoping review was conducted. Scoping reviews are necessary to uncover the existing and available body of literature regarding a particular topic, in order to provide clarity and create a platform for the development of a systematic review (Munn et al., 2018). The methodology followed Arksey and O'Malley's framework for scoping reviews (Arksey & O'Malley, 2005). Arksey and O'Malley (2005) recommend following a five-step process for scoping reviews, that was the method used for this study and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) was used for reporting the data.

Selection criteria

The review included studies involving (1) children older than 3 years to 15 years of age, by this age children should have received intervention for hearing impairment [30], also taking into account late diagnosis of hearing loss. Furthermore, the function of the vestibular system is present from birth and continually matures until the age of fifteen years [31] (2) clinical assessment tools that measure paediatric balance function (3) all research methodological frameworks written in English. The Joanna Briggs Institute (JBI) recommendations for pilot testing was followed using two randomly sampled databases (Cochrane Library PROSPERO and MEDLINE). The researcher screened titles and abstracts of 25 randomly sampled literature and thereafter, consultation with supervisor was done (M.D.J. Peters et al., 2021).

Search strategy

A qualified librarian was consulted to assist in developing search terms and an appropriate strategy. The following keywords were used: *Population*: child/paediatric/pediatric AND balance dysfunction/balance deficits/motor deficits/ instability, *Concepts*: balance assessment/balance tests/balance scales/functional balance test AND balance performance, *Context*: hearing loss/HL/hearing impairment. An example of the search term and strategy used in this study is displayed in Table 1.

Table 1 Example of search strings used in the review

Databases	Limits used	Search strategy
Medline (via Ebsco Host)	1. Language: English 2. Age: 0–18 years	children or adolescents or youth or child or teenager AND hearing loss or deafness or hearing impairment or deaf or hard of hearing AND balance assessment or balance test (((((((((((((ZU "child")) or ((ZU "peadiatric"))) or ((ZU "pediatric"))) or ((ZU "youth & adolescence"))) or ((ZU "children"))) and ((ZU "balance deficit") and (ZU "balance deficits") and (ZU "balance difficulties") and (ZU "balance disorder"))) or ((ZU "balance deficit") or (ZU "balance difficulties") or (ZU "balance disturbance") or (ZU "balance dysfunction"))) and ((ZU "hearing loss"))) or ((ZU "hearing impairment"))) or ((ZU "hl, (hearing loss)"))) and ((ZU "balance test"))) or ((ZU "balance performance"))) or ((ZU "balance assessment"))) and ((ZU "motor deficits"))
Web of Science		((ALL=(children or adolescents or youth or child or teenager)) AND ALL=(hearing loss or deafness or hearing impairment or deaf or hard of hearing)) AND ALL=(balance test or balance tools or balance assessment)

Literature published in Medline (via Ebsco Host), ERIC, Health Source: Nursing/Academic edition, CINAL, Africa wide information, Psych-info, PubMed, Academic search premier, Wiley online, Scopus and Web of Science databases was searched. In addition, a search was conducted on OpenGrey and a manual search through references of included articles was done to account for grey literature. Although it is recommended that literature must not be older than 10 years (Cronin, Ryan, & Coughlan, 2008); for this review, a stipulated time frame was not used due to the novelty of the area of interest.

Data extraction

The data were extracted from the literature search using the draft data charting tool recommended by the JBI (M.D.J. Peters et al., 2021). Figure 1 demonstrates the data extraction process. A search through the above-mentioned databases yielded a total of 704 studies. A total of 320 duplicates were removed, leaving 384 studies for abstract screening. Of these studies, 240 articles were selected for full-text review and 172 articles were removed. Full-text review yielded 68 articles which met the selection criteria.

Results

The findings of this review reflect instruments used in both high-income countries and LMIC [8, 14, 19, 24, 32–95].

In total, 44 different assessment tools were used in the researchers' protocols to examine balance in children with hearing loss (Table 2). These tools evaluated static balance, dynamic balance, functional balance and motor development. A total of 27% of these tests were norm-referenced tests, 64% were criterion referenced tests and 9% could not be identified. The assessment tools that were most commonly used were the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP), Bruininks-Oseretsky Test of Motor Proficiency Second edition (BOT-2), Movement Assessment Battery for Children (2nd edition) and the Single Leg Stance in evaluating motor performance and static balance respectively.

There are a range of low-technology, clinical tools which have been used to assess for balance deficits in children with hearing loss. The researcher further classified assessment tools according to costs as seen in Table 3. Eleven assessment tools were noted to have cost implications and were copyrighted, 22 tests were easily available and required minimal equipment, while eight could not be identified.

Discussion

Recent technological advances have allowed for the quantification of balance, however, some of these assessments are costly and may therefore, be inaccessible in many clinical settings [96]. The objective of this review was to explore clinical balance assessment tools administered to hearing-impaired children between the ages of 3 to 15 years of age. The findings of this review reflect that there is an assortment of balance tools, assessing different aspects of balance function. For the purpose of this review, only the inexpensive and easily available clinical assessment tools (Table 3) will be discussed. Furthermore, the reliability, validity and applicability of these tools will also be discussed.

The literature reviewed in this study reflected that authors [8, 14, 37, 79, 90, 91, 93, 97] utilized the Paediatric Balance Scale (PBS) as part of their balance assessment test battery for children with hearing loss. The PBS is an adaptation of the Berg Balance Scale and it is a criterion-referenced test assessing functional balance in children 2 years – 7 years and older (Franjoine, Darr, Held, Kott, & Young, 2010). It is a valid and reliable balance tool that assesses for functional balance using 14 tasks which are similar to activities of daily living [98]. Within the tasks, the PBS incorporates the conditions similar to the Romberg, Sharpened Romberg, Functional Reach Test and Standing on One Leg test. These tasks can be scored from 0 to 4 where a high score indicates good performance and the test can be completed in approximately 20 min with the aid of easily accessible equipment e.g., chair, bench, stopwatch etc. [99]. The PBS has an interrater reliability of (ICC [3,2] = 0.90–0.92), test-retest (ICC [2,1] = 0.923),

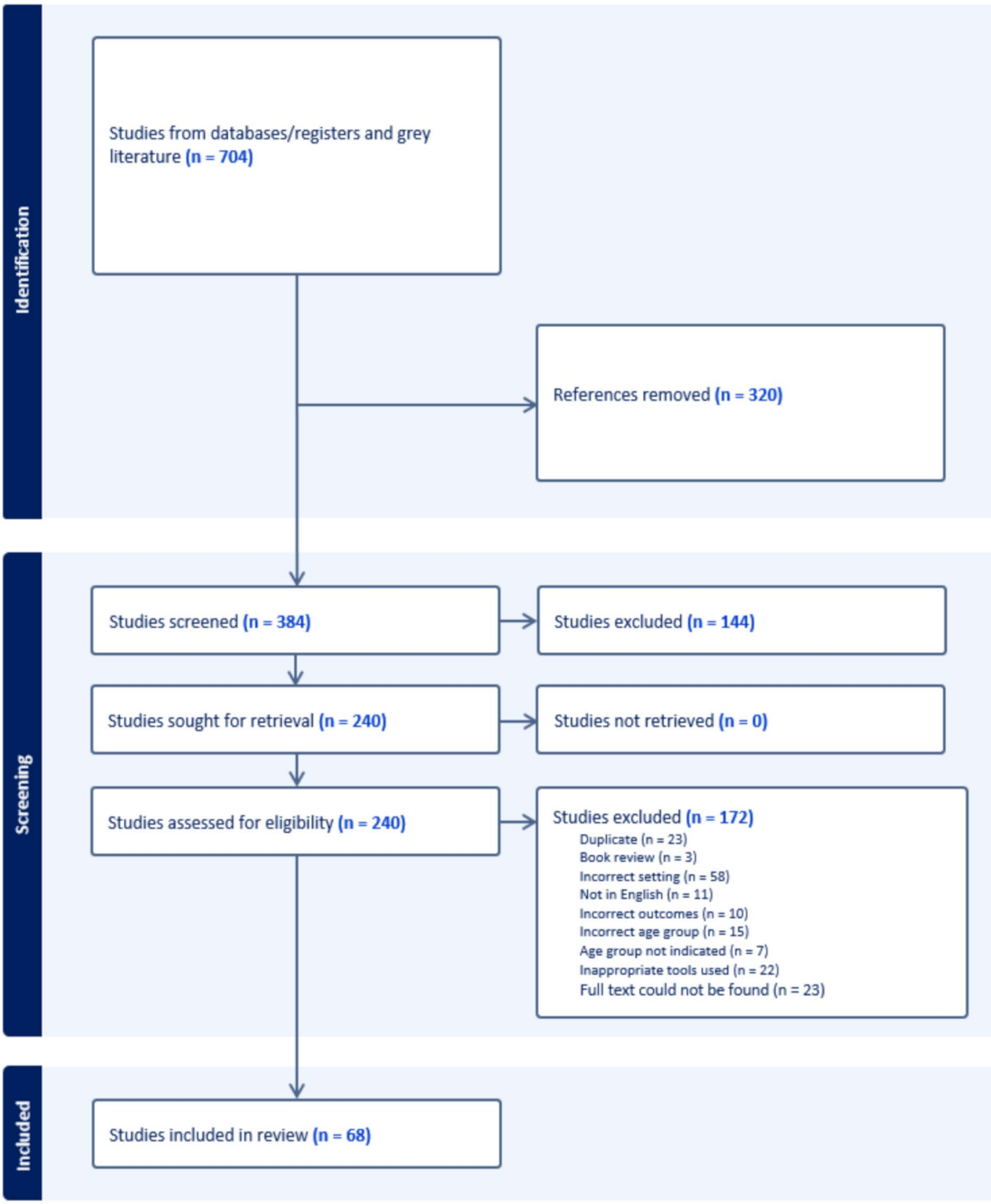

Fig. 1 PRISMA diagram

and intra-rater reliability (ICC [2,1] = 0.895–0.998) allowing for adequately identifying children with balance dysfunction [99]. This review also shows that authors used the Romberg test [24, 50, 59], Sharpened Romberg [50, 93, 100], Functional Reach Test [8, 70, 72, 73, 81, 85, 88], Standing on One Leg test [8, 14, 19, 41, 46, 52, 57, 64, 68, 70, 81, 93, 100, 101], and the Berg Balance Scale [65] from which the PBS is adapted. Thus, in settings where

Table 2 Findings of the scoping review

Study ID	Location	Aim of study	Recruitment of participants	Age	No. participants	Balance test	Balance subtest	Aspect of balance assessed
Cohen et al. (1997)	United States	To determine the presence of balance disorders in young children who had otitis media with effusion (OME)	Clinic	13–57 months	25 (history of OME for 1–35 months)	Peabody Developmental Motor Scales (PDMS)	Reflexes, balance, non-locomotor, locomotor and propulsion	Gross and fine motor skills
Potter & Silverman (1984)	United States	To describe the characteristics of vestibular function and static balance skill in deaf children who had no other known handicaps	School	5–9 years	34 children with deafness	Southern California Sensory Integration tests (SCSIT)	Standing Balance subtests	Static balance
Gayle & Pohlman (1990)	United States	To measure the dynamic, static and rotary balance of deaf and hearing children	-	123 ± 5.9 or 5.6 mo.	40 (20 deaf and 20 normal hearing students)	Lincoln-Oseretsky Motor Development Scale	Item 3	Static balance
Hart et al. (1998)	Not indicated	To investigate the role of chronic otitis media with effusion as a cause of childhood imbalance	Clinic	4.6–6 years	19	Peabody Developmental Motor Scales (PDMS) Bruininks-Oseretsky Test of Motor Proficiency (BOT)	Reflexes, balance, non-locomotion, locomotion, and receipt and propulsion 8 subtests: 4 gross motor subtest, 3 fine motor subtests, and 1 combined gross and fine motor subtest	Gross and fine motor skills
Butterfield (1986)	United States	To examine the influence of age, sex, etiology, and degree of hearing loss on the static and dynamic balance performance of hearing-impaired children and youth	School	3–14 years	132 children with hearing loss	Bruininks-Oseretsky Test of Motor Proficiency (BOT)	Subtest 2- Items 2 and 7	Static and dynamic balance
Wong et al. (2013)	Hong Kong	To investigate the balance performance in a cohort of children with severe to profound grade hearing impairment	Clinic	6–11 years	28 children with HL	Bruininks-Oseretsky Test of Motor Proficiency Second edition (BOT-2) Pediatric Functional Reach Test Pediatric Version of Clinical Test for Sensory Interaction of Balance (P-CTSIB)	Balance subtests	Static and dynamic balance Balance and postural stability Balance through various sensory input

Table 2 (continued)

Study ID	Location	Aim of study	Recruitment of participants	Age	No. participants	Balance test	Balance subtest	Aspect of balance assessed
Fellinger et al. (2015)	Austria	To examine motor performance in a representative sample of children with hearing impairment and to explore possible correlations with mental health such as emotional well-being, peer relation-ships, and externalizing behaviour	School	06–16 years	93 hearing impaired children, 18 were implanted with CI	Zurich Neuromotor Assessment (ZNA)		Motor skills, static balance, and dynamic balance
Wolter (2015)	Toronto, Canada	To determine if children with unilateral sensorineural hearing loss (UHL) demonstrate impaired balance compared with their normal hearing (NH) peers	Clinic	07–18 years	28 (14 children with severe to profound USNHL, 14 NH children)	Bruininks-Oseretsky Test of Motor Proficiency 2nd edition (BOT-2)	Motor skills	Static and dynamic balance
Malek-abadi-zadeh et al. (2016)	Iran	To evaluate the effects of hearing impairment and intellectual disability on children's static and dynamic balance	-	07–12 years	89 (17 severe to profound SNHL, 30 with mild intellectual disability and 42 typically developing children)	Bruininks-Oseretsky Test of Motor Proficiency (BOT)	Balance subtest	Static and dynamic balance
Gronski (2013)	United States	To analyse the literature regarding vestibular function, postural control and balance, and motor skills in children who are d/hh to determine the role for occupational therapy	Literature review	03–18 years	12 articles	Bruininks-Oseretsky Test of Motor Proficiency 2nd edition (BOT-2) Movement Assessment Battery for Children 2nd edition (MABC-2) Koperkoördinations Test für Kinder (KTK) One-leg stand tests		balance and motor deficits
Ven-kadesan & Finita (2010)	India	To summarize inexpensive tools such as TGMD-2, PBS, and P-CTSIB	Literature review	3–11 years	14 articles	Paediatric Balance Scale (PBS) Test of Gross Motor Development Second edition (TGMD-2) Paediatric Clinical Test of Sensory Interaction and Balance (P-CTSIB)		Functional balance Gross motor skills Static balance

Table 2 (continued)

Study ID	Location	Aim of study	Recruitment of participants	Age	No. participants	Balance test	Balance subtest	Aspect of balance assessed
Said (2013)	Egypt	To assess the balance ability in children with sensorineural hearing loss (SNHL)compared with normal-hearing controls using clinical balance subset tests.	Clinic	5–15 years	80 (30 NH children, 50 children with HL- 42 children fitted with bilateral hearing aids, 5 with monaural hearing aids, and 3 children had no hearing aids)	Bruininks-Oseretsky Test of Motor Proficiency 2nd edition (BOT-2) Modified Clinical Test of Sensory Interaction for Balance (mCTSIB) One-leg stand (OLS) Tandem stand	Balance subtests	Static and dynamic balance
Maes et al. (2014)	Belgium	To compare the clinical balance performance of normal-hearing (NH) children with the balance performance of hearing-impaired (HI) children with and without vestibular dysfunction to identify an association between vestibular function and motor performance.	School	3;8mo. – 12;11mo.	36 (children with normal NH and vestibular function, children with HL with normal vestibular function, and HI children with abnormal vestibular function)	Koperkoo ¨rdinationstest fu¨r Kinder (KTK) One-leg Stance with Eyes Closed (OLS EC)	Balance Beam Walking (KTK 1) and One-leg Hopping (KTK 2)	Dynamic balance static balance
Ertugrul et al. (2021)	Turkey	To investigate the postural instability and vestibular functions in children with severe inner ear malformations (IEMs).	Clinic	04–16 years	30 (10 children using with unilateral auditory brainstem implant, 10 children with unilateral cochlear implant, and 10 healthy peers)	Bruininks-Oseretsky Test of Motor Proficiency 2nd edition (BOT-2)	Balance subtest	Static and dynamic balance
Cushing (2008)	Canada	To determine the incidence of static and dynamic balance dysfunction in a group of children with profound sensorineural hearing loss receiving a cochlear implant and to assess the impact of cochlear implant activation on equilibrium.	Clinic	04–17 years	55 (41 children with cochlear implants, 14 normal hearing children)	Bruininks-Oseretsky Test of Motor Proficiency 2nd edition (BOT-2)	Balance subtest	Static and dynamic balance
Janky & Givens (2015)	United States	To 1) determine whether age-related changes in peripheral vestibular tests occur; (2) quantify peripheral vestibular function in children with normal hearing and CCI; and (3) determine whether amount of vestibular loss predicts visual acuity and balance performance	-	6–17 years old	38 (11 children with cochlear implants, 12 children with normal hearing, 15 adult control)	Dynamic Gait Index (DGI) Single-Leg Stance test		Gait Static balance

Table 2 (continued)

Study ID	Location	Aim of study	Recruitment of participants	Age	No. participants	Balance test	Balance subtest	Aspect of balance assessed
Eustaquio et al. (2011)	United States	To determine whether unilateral or bilateral cochlear implantation affects the functional balance of children when compared with children with severe-to-profound bilateral hearing loss without a cochlear implant.	Clinic	04–17 years	64 (12 children with unilateral cochlear implant, 26 with bilateral cochlear implants, and 26 not implanted)	Bruininks-Oseretsky Test of Motor Proficiency second Edition (BOT-2)	Balance subtest	Static and dynamic balance
Uysal et al. (2010)	Turkey	To examine the effect of congenital loss of hearing and sight on gait and balance in children	School	mean age 9 years	60 (20 children with hearing loss, 20 with visually impairment, and 20 controls with no disability)	Southern California Sensory Integration Test (SCSIT)	Standing Balance subtests	Balance and gait
Jafari & Malayeri (2011)	Iran	To specify the percentage of vestibular evoked myogenic potential (VEMP) and an acoustically evoked, short latency negative response (ASNR) recordings and the relation between their presence and static balance ability and postural control of children with profound sensorineural hearing loss (SNHL)	Clinic	06–9.5 years	60 (30 children with hearing loss and 30 normal hearing children)	Bruininks-Oseretsky Test of Motor Proficiency (BOT)		Static and dynamic balance
Melo et al. (2017)	Brazil	To assess the static and dynamic balance performance of students with normal hearing and with sensorineural hearing loss	School	07–18 years	98 (48 children with NH, 48 children with SNHL)	Romberg Romberg-Barré test Fournier test Unterberger test		Static balance and dynamic balance
Lindsey & O'Neal (1976)	United States	To compare balance performance in children with profound hearing loss verses those with normal hearing	School	08–09 years	108 (31 deaf children, 77 NH children)	Bruininks-Oseretsky Tests of Motor Proficiency (BOT) The Meeting Street School Screening Test Cratty's test Touwen Balance beam test	Items 1, 5, 6, 7, 8, 9, 10, 13, 15 Item 14 item 2, 11, 12 item 4	Static and dynamic balance motor behaviour and coordination

Table 2 (continued)

Study ID	Location	Aim of study	Recruitment of participants	Age	No. participants	Balance test	Balance subtest	Aspect of balance assessed
Rajendran et al. (2012)	India	To systematically analyze the available information in the literatures regarding the postural control, motor skills, and health-related quality of life in children with hearing impairment.	Literature review	05–11 years	17 studies	The Southern California Sensory Integration Tests (SCSIT) Körperkoordinations Test Für Kinder (KTK) Bruininks-Oseretsky Tests of Motor Proficiency 2nd edition (BOT-2) Test of Gross Motor Development, Second Edition (TGMD-2) ChAS-T	Standing balance	Static balance dynamic balance static and dynamic motor skills
Fernandes et al. (2015)	India	To identify various management techniques used in clinical practice for balance impairment in children with hearing loss. The secondary objective is to determine the efficacy of these interventions to be implemented in clinical practice	Literature review	0–13 years	3 studies	Test for Gross Motor Development (TGMD)		Gross motor skills
Hartman et al. (2011)	Netherland	To examine motor performance in deaf elementary school children and its association with sports participation	Institute for the deaf	6 to 12 years	42 with hearing impairment	The Movement Assessment Battery for Children (MABC)	3 subtests: manual dexterity (3 items), ball skills (2 items), and static and dynamic balance (3 items)	Motor performance
Livingstone & McPhillips (2011)	Ireland	To examine the effect of partial hearing, including cochlear implantation, on the development of motor skills in children	School	6–12 years	78 (25 children with HL, 53 age-matched comparison group)	The Movement Assessment Battery for Children (MABC)	Manual dexterity, ball skills, and balance	Motor skills
Geddes (1978)	United States	Not indicated	School	04–05 years	11 children who are hard-of-hearing	Geddes Psychomotor Inventory		Motor skills

Table 2 (continued)

Study ID	Location	Aim of study	Recruitment of participants	Age	No. participants	Balance test	Balance subtest	Aspect of balance assessed
Gheysen et al. (2008)	Belgium	The purpose of this study was to investigate the impact of a cochlear implant (CI) on the motor development of deaf children.	School	04–12 years	79 (36 Deaf children- 20 have CI, and NH 43 children)	Movement Assessment Battery for Children (MABC) Körperkoordinations Test Für Kinder (KTK) The one-leg stance		Motor development Gross motor coordination Static balance and postural stability
Lewis et al. (1985)	United States	To assess the effect of a 6-week posture and body awareness activity program on balance		6 to 10 years	16 deaf children	Bruininks-Oseretsky Test of Motor Proficiency (BOT)	Balance subtest	static and dynamic balance
Apeksha (2021)	India	This study aimed to assess the balance function in children with sensorineural hearing loss (SNHL) using different tests to assess vestibulospinal pathway and tests to assess vestibular system and to compare the result obtained with those of children with normal hearing sensitivity	Clinic	06–10 years	30 (15 children with profound SNHL, 15 children with normal hearing)	Romberg test Tandem gait test		Disequilibrium Gait and cerebellar disorders
An et al. (2009)	Korea	The purposes of the present study were to elucidate the age-related changes in single-limb standing balance and sensory compensation for maintaining single-limb standing in profoundly deaf (PD) children, and to compare them with age-matched normal-hearing (NH) children	School	4–14 years	114 (57 deaf children, 57 NH children)	The single-limb standing test (SLS)		Standing balance and postural stability in a static standing position
Siegel et al. (1991)	United States	To compare the scores on a standardized balance test of three age groups of deaf children with those of a sample of normal-hearing children on whom the balance test was standardized	School	4- to 14 years	28 children with hearing impairment	Bruininks-Oseretsky Test of Motor Proficiency (BOT)	balance subtest	Static and dynamic balance

Table 2 (continued)

Study ID	Location	Aim of study	Recruitment of participants	Age	No. participants	Balance test	Balance subtest	Aspect of balance assessed
Holderbaum et al. (1979)	United States	To determine whether or not the Floor Ataxia Test Battery (FATB) is associated with vestibular dysfunction in deaf children	School	mean age of 13 years	31 with hearing loss	Sharpened Romberg with Eyes Closed (SREC) Stand on One Leg with eyes closed Walk on Floor with Eyes Closed (WOFEC) Heath Rail walking Test		Static and dynamic balance
Engel-Yeger et al. (2004)	Israel	To compare balance of children with MEE to that of healthy children and to examine whether a relation exists between balance skills and the degree of muscle strength	Clinic	4.5–7.5	40 (20 children with history of at least 3 episodes of middle ear effusion and 20 healthy childrent	Bruininks - Oseretsky test of Motor Proficiency (BOT)	Balance and strength subtest	Static and dynamic balance
De Kegel et al. (2010)	Belgium	To investigate the construct validity of posturography and clinical balance tests in children with hearing impairments and in children who are developing typically	Centre for childcare	06–12 years	76 (53 typically developing, 23 children with hearing loss)	One-leg stance test Modified Clinical Test of Sensory Interaction of Balance (mCTSIB) Körperkoordinations Test Für Kinder (KTK)	Balance beam walking, one-leg hopping	Static balance Dynamic and static balance Dynamic balance, gross motor coordination
Lima (2017)	Brazil	To analyze deaf children and adolescents prior to and post-practice of capoeira using the Berg Balance Scale (BBS)	-	10–16 years	25 children with hearing loss	Berg Balance Scale (BBS)		Static and dynamic balance
Horak et al. (1988)	Portland	To document the vestibular status and motor proficiency of a heterogeneous group of hearing-impaired children and of a select group of motor-impaired learning-disabled children to determine whether abnormal vestibular function could account for deficits in motor co- ordination	Clinic	7–12 years	89 (44 typically developing children, 30 children with hearing loss, 15 children with learning and coordination disabilities)	Bruininks-Oseretsky test of Motor Proficiency (BOT)	Gross motor subtest	Balance, running speed, bilateral co- ordination, and strength

Table 2 (continued)

Study ID	Location	Aim of study	Recruitment of participants	Age	No. participants	Balance test	Balance subtest	Aspect of balance assessed
Shall (2009)	United States	To valuate saccular function in children with hearing impairments using the Vestibular evoked Myogenic Potential (VEMP)	Parent support groups	4–7 years	33 children with HL	Movement Assessment Battery for Children (MABC)	Manual dexterity, ball skills, and static and dynamic balances	Motor proficiency
De Kegel et al. (2012)	Belgium	To identify the predictive ability of vestibular function test results on motor performance among hearing-impaired children.	School	03–12 years	99 (48 SNHL children, 51 typically developing children)	Movement Assessment Battery for Children Second Edition (MABC-2) Körperkoordinations Test Für Kinder (KTK) One-leg stance (OLS) Modified Clinical Test of Sensory Interaction for Balance (mCTSIB)	Manual dexterity, ball skills abilities, and balance	Motor skills Balance beam walking and one-leg hopping Postural stability Postural stability
Martin et al. (2012)	South Africa	The aims of this study were to determine the prevalence of impairments of motor performance and dynamic visual acuity, and the nature and extent of interaction between these in children with sensorineural hearing loss between the ages of 4 and 14 years.	School	04–14 years	64 (32 children with SNHL, 32 children with normal hearing)	Movement Assessment Battery for Children Second edition (MABC-2)		Motor performance
Patel et al. (2017)	India	To compare overall balance of children with and without hearing impairment.	-	07–15 years	60 (30 children with SNHL and 30 with NH)	One Leg Stance Test Functional Reach Test		Static balance dynamic balance
Hedayatjoo et al. (2020)	Iran	To investigate the effect of balance exercises on balance performance, motor coordination, and attention in children with hearing deficits	Clinic	7 to 12 years old	36 children with severe to profound hearing loss	Bruininks-Oseretsky Test of Motor Proficiency (BOT)	Upper limb coordination, bilateral coordination, and visual-motor control subtests	Motor coordination
Rajendran et al. (2013)	Not indicated	To determine the effectiveness of vestibular-specific neuromuscular training on motor skills, balance and health-related quality of life in children with hearing impairment	School	6–11 years	26 with hearing impairment	Pediatric Functional Reach Test One Leg Standing Test Test of Gross Motor Development 2nd edition (TGMD-2)		Postural stability Static balance Motor skills

Table 2 (continued)

Study ID	Location	Aim of study	Recruitment of participants	Age	No. participants	Balance test	Balance subtest	Aspect of balance assessed
Rajendran et al. (2012)	India	To evaluate the reliability of pediatric reach test in children with hearing impairment	School	6–11 years	65 children with hearing loss	Pediatric Functional Reach Test		Postural stability
Christy et al. (2014)	United States	The purpose of this preliminary study was to deter-mine reliability, sensitivity, specificity, predictive values, likelihood ratios, and cutoff scores for clinical tests of vestibular function	Community	06–12 years	43 (20 children with severe to profound SNHL, 23 typically developing children)	Modified Clinical Test of Sensory Interaction on Balance (mCTSIB)		Balance and postural stability
Cushing et al. (2009)	Canada	Assess vestibular and balance function in meningitis-induced profound sensorineural hearing loss (SNHL)	-	04–17 years	9 children profound SNHL with CI	Bruininsk-Oseretsky Test of Motor Proficiency 2nd edition (BOT-2)	Balance subtest	Static and dynamic balance
Ebrahimi et al. (2017)	Iran	To determine the reliability of static control evaluation with Synapsys Posturography System and to compare the static postural control of deaf children with typically developing children	School	07–12 years	81 (37 typically developing children and 30 children with profound SNHL)	Bruininks-Oseretsky Test of Motor Proficiency (BOT)	Balance	Static balance
Ebrahimi et al. (2016)	Iran	To compare the static and dynamic balance performance of deaf children with and without cochlear implants	School	07–12 years	145 (children with bilateral SNHL- 50 without cochlear implants, 35 with unilateral cochlear implants, and 60 NH peers)	Bruininks-Oseretsky Test of Motor Proficiency (BOT)	Balance	Static and dynamic balance
Oyewumi et al. (2016)	Canada	To determine if bilateral vestibular dysfunction can be predicted by performance on standardized balance tasks in children with sensorineural hearing loss (SNHL) and cochlear implants (CI). 2) To provide clinical recommendations for screening for vestibular impairment in children with SNHL	Clinic	4;8mo. – 18;6mo.	113 (45 children with TBVL, 20 with normal vestibular function)	Bruininks Oseretsky Test of Motor Proficiency second edition (BOT-2)	Balance subtest	Static and dynamic balance
Soylemez et al. (2019)	Turkey	To evaluate the balance skills and falling risk in children with a congenital bilateral profound sensorineural hearing loss (CBPSNHL)		0–18 years	50	Flamingo balance test Tandem stance test One-leg standing test Pediatric Balance Scale (PBS)		Static balance Static balance Static balance Functional balance

Table 2 (continued)

Study ID	Location	Aim of study	Recruitment of participants	Age	No. participants	Balance test	Balance subtest	Aspect of balance assessed
Melo et al. (2018)	Brazil	To compare the balance performance between normal hearing (NH) children and those with SNHL, considering the sex and age range of the sample, and analyze balance performance according to the degrees of hearing loss and etiological factors in the latter group	School	7–18 years	96 (48 NH children and 48 children with SNHL)	Pediatric Balance Scale (PBS)		Static and dynamic balance
Sokolov et al. (2019)	Canada	To determine the prevalence of vestibular end-organ dysfunction in children presenting with profound unilateral sensorineural hearing loss	-	mean age of 8.8 years	20 with unilateral deafness	Bruininks-Oseretsky Test of Motor Proficiency (BOT)	Balance subtest of the	Static and dynamic balance
Karakoc &Mujdeci (2021)	Turkey	To evaluate static, dynamic, functional balance, and mobility as a whole in children with SNHL.	-	6–15 years old	80 (40 with SNHL and 40 with normal-hearing)	Single Stance Test (SLS) Functional Reach Test (FRT) Timed Up and Go Test (TUG) Pediatric Balance Scale (PBS)		Static balance Dynamic balance Mobility and dynamic balance Functional balance
Ayanniyi & Mbada (2014)	Nigeria	The study compared static and dynamic balance of school children with and without hearing loss	Schools	8–17 years	160 (80 children with hearing loss, 80 control)	One Leg Stance Test Functional Reach Test (FRT)		Static balance Dynamic balance
Benjamin et al. (2023)	Canada	This study compared the stability of typically-developing children to children and young adults and with cochleovestibular dysfunction who utilize cochlear implants to hear during balance perturbations and then assessing if the use of an auditory prosthetic aids with balance	Health institution	< 18 years	23 (15 typically developing children, 8 participants with cochleovestibular dysfunction)	Bruininks-Oseretsky Test of Motor Proficiency Second Edition (BOT-2)	Balance subset	Static and dynamic balance

Table 2 (continued)

Study ID	Location	Aim of study	Recruitment of participants	Age	No. participants	Balance test	Balance subtest	Aspect of balance assessed
Chisari et al. (2023)	Australia	The study aim was to explore vestibular function, functional balance and postural control and relationship between these measures in children with SNHL	Clinical setting	5–12 years	22 (11 with SNHL, 11 with normal sound detection)	Bruininks-Oseretsky Test of Motor Proficiency Second Edition (BOT-2) Standing on one leg Balance beam Nintendo Wii Balance Board (WBB)	Standing on a firm surface with eyes open (EO), eyes closed (EC), standing on a foam with eyes open (FEO) and eyes closed (FEC)	Static and dynamic balance Postural stability
Kawati et al. (2023)	Indonesia	This study aimed to investigate the balance in hearing-impaired students	School	8–20 years	59 hearing-impaired children	Stand on one leg Balance test		Static balance Static balance
Çelik et al. (2022)	Turkey	The study aimed to investigate whether the effects of footwear properties on the plantar pressure distribution	School	6–18 years	136 (68 children with hearing impairment, 68 normal hearing children)	Functional Reach Test (FRT) Flamingo Balance Test (FBT)		Dynamic balance Static balance
Ghaffar et al. (2024)	Pakistan	The aim of the study was to determine the prevalence of balance impairment in children with hearing impairments	School	8–15 year	377 children with hearing loss	Standardized Walking Obstacle Course test (SWOC) Timed Up and Go test (TUG)		Functional mobility
Ghosh, Banerjee & Biswas (2022)	India	This study was aimed to evaluate the differences in dynamic balance in school children with various degrees of hearing loss	School	3–16 years	252 children with hearing impairment	Modified Bass Test		Dynamic balance
Hu et al. (2024)	Korea	The study evaluated the effects of Latin dance training on the vestibular function and balance of SNHL children	School	10–18 years	30 children with congenital SNHL	Timed eyes-closed static (ECS) with balance pad Functional reach test (FRT)		Static balance Functional reach test
Janky et al. (2023)		The study aimed to evaluate the effect of hearing loss and vestibular dysfunction on self-concept in children with cochlear implantations and those with normal hearing	Health institution	6–18 years	75 (38 children with normal hearing, 37 children with CI)	Bruininks-Oseretsky Test of Motor Proficiency (BOT-2)	Balance subtest	Static and dynamic balance
Metgud & Topkar (2019)	India	This study aimed to investigate the effects of fine motor exercises with or without balancing exercises on fine motor skills in children with SNHL	School	9–14 year	195 (65 children with hearing loss, 130 children with normal hearing)	Pediatric Balance Scale (PBS)	14 tasks	Functional balance

Table 2 (continued)

Study ID	Location	Aim of study	Recruitment of participants	Age	No. participants	Balance test	Balance subtest	Aspect of balance assessed
Mohamed et al. (2024)	Egypt	The study aim was to assess the efficacy of a vestibular-balance rehabilitation program to minimize or reverse balance disability in children with SNHL	Health institution	4–10 years	45 children with hearing loss	Pediatric balance scale (PBS) Balance Error scoring system (BESS)		Functional balance Evaluation of Vestibulospinal reflex and postural control
Monin et al. (2023)	Switzerland	The aim of this study was to design the GBT test that could objectively measure balance capacities		3–16 year	37 children with hearing loss	Geneva Balance Test (GBT) Modified Bruininks-Oseretsky test of Motor proficiency second edition (mBOT-2)	Balance subtest	Static and dynamic balance
Mujdeci et al. (2021)	Turkey	This study aimed evaluate the effects of age at cochlear implantation on balance in children	Health institution	8–17 years	40 (20 HL with CI before 48months, 20 HL with CI at/ > 48months)	Tandem Romberg (TR) test Single- Stance test (SLS) Pediatric Clinical Test of Sensory Interaction for Balance (P-CTSIB) Pediatric Balance Scale (PBS) Timed Up and Go test (TUG)		

Table 2 (continued)

Study ID	Location	Aim of study	Recruitment of participants	Age	No. participants	Balance test	Balance subtest	Aspect of balance assessed
Zarei et al. (2024)	Iran	The purpose of this review was: a) Compare balance in individuals with hearing impairment and those with NH b) Evaluation of the predominance of each of the sensory systems involved in balance control with increasing age in individuals with HI c) To determine how the visual and proprioception systems function in individuals with HI as compared to individuals with hearing d) To determine whether sports activities influence the balance control e) Comparison of the balance control of individuals with HI who participated in sports and individuals with hearing to determine which balance control group has a better performance	Literature review	5–22 year	24 studies and 27 trials	Movement Assessment Battery for Children (MABC) Bruininks-Oseretsky Test of Motor Proficiency second edition (BOT-2) Bruininks-Oseretsky test of motor proficiency (BOT)		
Singh et al. (2022)	England	The objective of this study was to understand the functional impact of vestibular dysfunction on balance control in children with hearing loss	Literature review	< 21 years	20 studies included	Unterberger (Fukuda) stepping test Romberg Bruininks-Oseretsky test of motor proficiency (BOT) Tandem gait Standing on one foot		
Sinno et al. (2022)		This study aimed to analyse the SVINT results of healthy children vs. children with hearing loss and to correlate it with sensory organization test (SOT) results as a functional balance evaluation tool	Literature review	5–17 years	180 (120 healthy, normal hearing children, 30 hearing-impaired children using HA, 30 hearing-impaired children who use unilateral CIs)	Sensory Organization Test (SOT)		

Table 3 Classification of assessment tools according to cost

	Cost associated	Freely available	Not identified
Test	Peabody Developmental Motor Scales (approx. $193.59) Lincoln-Oseretsky Motor Development Scale (approx. $15- $90) Bruininks-Oseretsky Test of Motor Proficiency (BOTMP) and Second edition (BOT-2) (approx. $954 - $1,060) Zurich Neuromotor Assessment (ZNA) (query via email) Movement Assessment Battery for Children (MABC) and Second Edition (M ABC-2) (approx. $1,971.40) Test of Gross Motor Development Test (TGMD) and (TGMD)-2 (approx. $350) Sensory Organization Test (SOT) (approx. $80000.00) Nintendo Wii Balance Board (WBB) (approx. $100)	Tandem gait test Balance beam test Heath Rail walking Test The Paediatric Balance Scale (PBS) Pediatric/Functional Reach Test One-leg stand test/ Balance Test Modified Clinical Test of Sensory Interaction for Balance (mCTSIB) Dynamic Gait Index (DGI) Romberg test Fournier test Sharpened Romberg/tandem stand Unterberg Walk on Floor Berg Balance Scale (BBS) Flamingo balance test Pediatric Version of Clinical Test for Sensory Interaction of Balance (P-CTSIB) Timed Up and Go Test (TUG) Standardized Walking Obstacle Course test (SWOC) Modified Bass Test Balance Error scoring system (BESS) Geneva Balance Test (GBT)	Cratty's test The Meeting Street School Screening Test ChAS-T Geddes Psychomotor Inventory Touwen test Southern California Sensory Integration Test Koperkoördinationstest für Kinder Timed eyes-closed static (ECS) with balance pad

healthcare practitioners are burdened by high case-loads and have restricted resources, this test could be particularly useful.

The tandem gait test [24, 59] is an assessment procedure used for dynamic postural control [102]. It is a simple test and easy to administer, requiring minimal equipment [103]. It can be conducted in different conditions including eyes open, eyes closed or with dual tasking. This test requires children to walk barefoot along a 3 m line in an alternating heel-to-toe motion, make a turn of 180°, repeat the same action back to the starting line [102]. Four trials are conducted and each trial is timed. The child passes the test if they can walk along the line without stepping over the it, deviating from line or having gait of < 14 s [104]. The tandem gait test has good reliability (intraclass correlation coefficient; ICC [3,1] = 0.86; 95% confidence interval [CI] = 0.73–0.93) [103].

The modified Clinical Test of Sensory Interaction for Balance (mCTSIB) and Pediatric Version of Clinical Test for Sensory Interaction of Balance (P-CTSIB) are modifications of the Clinical Test of Sensory Interaction in Balance (CTSIB) test. These tests were noted in four [19, 64, 68, 105] (mCTSIB) and three [37, 93, 97] (P-CTSIB) studies in this review. The mCTSIB assesses the impact of sensory integration in maintaining balance and postural ability (Lotfi, Javanbakht, Sayaf, & Bakhshi, 2018). The m-CTSIB can be used to evaluate all age groups from 2 years (Horn et al., 2015), while the P-CTSIB shows good reliability for children 4–6 years (Lotfi, Kahlaee, Sayadi, Afshari, & Bakhshi, 2017). It is a criterion reference test that requires minimal equipment that assesses balance in four conditions; eyes open on firm surface, eyes closed on firm surface, eyes open on foam surface and eyes closed on foam surface and each condition is held for 30 s [106]. Three trials are given with performance on each trial timed and recorded. In the P-CTSIB, children are given one-minute rest between each test condition [37]. Maturation is a great factor in these tests. For 6–12year olds, the reliability of the m-CTSIB has good sensitivity (88%) and specificity (85%); and reliability was high (0.78), except for condition 4 (0.56) [105]. For the P-CTSIB for 4–6 years, the interrater reliability was also good (standing duration, antero-posterior sway, and lateral sway = 0.92, 0.77, and 0.84, respectively). The intraclass correlation coefficient (ICC) ranged from 0.70 to 0.92 for standing duration [107].

The Dynamic Gait Index (DGI) [46] is a criterion-based test used to assess postural control and dynamic balance. It measures functionality using 8 items; with a total score of 24, scored from 3 (independent walking) to 0 (severe impairment) [108]. Furthermore, Evkaya (2020) found that the DGI has an internal consistency with a Cronbach's alpha coefficient of 0.969, a test-retest reliability of (ICC = 0.970 Cl (0.915-0990)) and an inter-rater reliability of DGI was excellent (ICC = 0.983 Cl (0.882-0990). These results are applicable for children 6- 14years of age.

The Timed Up and Go Test (TUG) is another measure which can be used to assess dynamic balance in children [109]. In this review, it was utilized by three authors [8, 86, 93]. It is a fairly reliable test of dynamic balance that can be conducted with children as young as 3 years [110]. A standard chair (approx. height of 46 cm) with backrest or armrest can be used [111]. The test requires the child to sit on a chair, get up and walk along a 3 m line, turn around and walk back to the starting position and sit down [112]. The entire process is timed, three trials are conducted and the best of the three is recorded [109, 112]. The TUG is a reliable test with a test-retest, intra-rater, and interrater reliability (intraclass correlation coefficient [ICC] ≥ 0.85) for children between 3–18years of age [109]. The Standardized Walking Obstacle Course test (SWOC) [86] is a similar test to the TUG where a child is required to get up from a sitting position, walk in one direction and then sit. It further consists of three conditions such as walking, walking with a tray and walking with reduced vision (shaded glasses) [113]. It has an intraclass correlation coefficient of 0.99 and with 0.94–0.99 number of steps in children, it has good screening capabilities [114]. Furthermore, this test has showed significant correlation with the TUG ($p = < 0.05$) [115, 116].

Authors in this review also utilized the Modified Bass Test [87] and the Balance Error Scoring System [91]. This is a simple and quick test to conduct, measuring a child's ability to jump from one marked spot to the next without losing balance [117]. Targets are placed on the floor by the examiner in a 2.5 cm x 2 cm pattern, the starting point is also marked and the child is expected to jump to the next target while maintaining a steady position for 5 s. This is done until they jump to all marked targets and they are scored 5 points for accurately landing on the mark and 1 point for each second they are able to hold their balance a higher score indicates good balance [117]. This test is appropriate for assessing static and dynamic balance as it has an ICC of 0.82 [117, 118]. Similarly, the BESS test can be used to assess static balance. With this test, examiners can assess balance in 6 positions which are double leg stance, single leg stance and tandem stance which are done on flat surface and on a foam pad [117]. It is noteworthy that these conditions are similar to that of the P-CTSIB, mCTSIB and the single leg stance test which have been discussed above. Time limit is kept and errors such as touching down with opposite foot, excessive hip movement, moving out of test position and taking a step, stumbling or falling [119]. Less errors indicate better static balance [117]. This measure has moderate to good reliability and can be used by clinicians who do have access to advanced balance assessments [120].

Last, the development of the new Geneva Balance Test (GBT) [92] assists in the screening for balance deficits in very young children. This test utilizes two conditions: walking at normal pace on a foam mat in bright condition, and walking at normal pace on a foam mat in dim light condition. Each condition is repeated 3 times, a deviation from the midline is observed and a score from 0 to 9 is given where the maximum score is 18. The lower the score, the better the balance performance. This test is differentiate between children with bilateral vestibulopathy against the control, thus could be useful in quantifying balance deficits in children [92].

The balance assessment tools discussed in this review were primarily designed for adults; however, researchers have made strides to develop normative data applicable for children of different ages. The findings of this review reflect the heterogenous nature of balance assessments available, thus, allowing clinicians the opportunity to select the appropriate tool to use based on the child's age and aspect of balance they would like to assess. The tools (DGI, TUG, m-CTSIB) are also clinically recommended by VEDGE Task Force [121] as tools which can be used to assess balance function; and literature supports the clinical utility in children [122, 123]. Furthermore, due to limited cost implications and low-technological nature of these tools, they could be easily adopted into clinical practice by professionals from different contexts and disciplines. The early identification of balance deficits in children with hearing loss can have far reaching effects, allowing for early intervention and subsequent improvement in the child's quality of life. Ultimately, making the integration of balance assessments across a continuum of care for children with hearing loss feasible.

Limitations

In this review, the quality of the studies included was not assessed. Although this may not be typical of a scoping review, it can be seen as a limitation as poorly designed studies have not been identified. The analysis of this review was based on balance assessments in children with hearing loss, thus, it may be important to consider the impact of balance impairment in children and the related interventions. A further limitation to this scoping review was the inclusion of studies written in English only, thus, limiting the extent to which the literature could be explored in other languages. As recommendation, future research in this field could provide sufficient data through systemic reviews or meta-analyses to inform the development of a standard paediatric balance assessment battery.

Conclusion

The finding of this review demonstrates a robustness in clinical balance assessments used to assess children with hearing loss. Tests such as the Tandem gait test, Paediatric Balance Scale, Modified/ Pediatric Clinical Test of Sensory Interaction for Balance (mCTSIB/PCTSIB), Dynamic Gait Index (DGI) or Timed Up and Go Test (TUG) can be used to evaluate different aspects of balance which can be vital for the identification of balance dysfunctions.

Balance dysfunction plays a detrimental role in childhood development and may contribute to global developmental delay as well as a delay in cognitive development [124]. Therefore, assessment and management of such dysfunctions becomes imperative. The abovementioned instruments that are reliable, quick and easy to administer and can be suitable for any clinical context. More importantly, these tools may be appropriate for use in primary healthcare settings as they require minimal equipment and are easily accessible. However, there is room to further explore paediatric balance assessment tools in both research and clinical practice to aid in the development of a standardized protocol for balance assessment in children with hearing loss. This could inform policy makers and relevant stakeholders in healthcare institutions about the need to review current practices and protocols regarding the management of children with hearing loss.

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Competing interests
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References

1. Morita H, Kaji H, Ueta Y, Abe C. Understanding vestibular-related physiological functions could provide clues on adapting to a new gravitational environment. J Physiol Sci. 2020;70(1):17.
2. Melo RS, Lemos A, Wiesiolek CC, Soares LG, Raposo MC, Lambertz D et al. Postural sway velocity of deaf children with and without vestibular dysfunction. Sens [Internet]. 2024; 24(12).
3. Varedi M, Lu L, Phillips NS, Partin RE, Brinkman TM, Armstrong GT, et al. Balance impairment in survivors of pediatric brain cancers: risk factors and associated physical limitations. J Cancer Surviv. 2021;15(2):311–24.
4. Horowitz G, Ungar OJ, Levit Y, Himmelfarb M, Handzel O. The impact of conductive hearing loss on balance. Clin Otolaryngol. 2020;45(1):106–10.
5. Walicka-Cupryś K, Przygoda Ł, Czenczek E, Truszczyńska A, Drzał-Grabiec J, Zbigniew T, et al. Balance assessment in hearing-impaired children. Res Dev Disabil. 2014;35(11):2728–34.
6. Vitkovic J, Le C, Lee SL, Clark RA. The contribution of hearing and hearing loss to balance control. Audiol Neurootol. 2016;21(4):195–202.
7. Sokolov M, Gordon KA, Polonenko M, Susan I, Blaser SI, Papsin BC, Cushing SL. Vestibular and balance function is often impaired in children with profound unilateral sensorineural hearing loss. Hear Res. 2019;372:52–61.
8. Karakoc K, Mujdeci B. Evaluation of balance in children with sensorineural hearing loss according to age. Am J Otolaryngol. 2021;42(1):102830.
9. Mulwafu W, Kuper H, Ensink RJ. Prevalence and causes of hearing impairment in Africa. Trop Med Int Health. 2016;21(2):158–65.
10. Hazen M, Cushing LS. Implications of concurrent vestibular dysfunction in pediatric hearing loss. Curr Otorhinolaryngol Rep. 2020;8:267–75.
11. Yassin O, Elshafey M, Hamdy B, Gamal R, Abdelazeim F. Comprehensive evaluation of vestibular dysfunction in deaf children. J Crit Reviews. 2020;7(18):3586–94.
12. Ionescu E, Reynard P, Gouleme N, Becaud C, Spruyt K, Ortega-Solis J, et al. How sacculo-collic function assessed by cervical vestibular evoked myogenic potentials correlates with the quality of postural control in hearing impaired children? Int J Pediatr Otorhinolaryngol. 2020;130:109840.
13. Antoine MW, Vijayakumar S, McKeehan N, Jones SM, Hebert JM. The severity of vestibular dysfunction in deafness as a determinant of comorbid hyperactivity or anxiety. J Neurosci. 2017;37(20):5144–54.
14. Soylemeza E, Ertugrulb S, Doganc E. Assessment of balance skills and falling risk in children with congenital bilateral profound sensorineural hearing loss. Int J Pediatr Otorhinolaryngol. 2019;116:75–8.
15. Grivna M, Al-Marzouqi HM, Al-Ali MR, Al-Saadi NN, Abu-Zidan FM. Pediatric falls from windows and balconies: incidents and risk factors as reported by newspapers in the united Arab Emirates. World J Emerg Surg. 2017;12(1):45.
16. Lack V, Fru PN, Van Rensburg C, Van Rensburg K, Loveland JA. The epidemiology of traumatic brain injuries sustained by children under 10 years of age presenting to a tertiary hospital in Soweto, South Africa. South Afr Med J. 2021;111(Electronic):2078–5135.
17. Tupetz A, Friedman K, Zhao D, Liao H, Isenburg MV, Keating EM, et al. Prevention of childhood unintentional injuries in low- and middle-income countries: A systematic review. PLoS ONE. 2021;15(12):e0243464.
18. Kelly A, Liu Z, Leonard S, Toner F, Adams M, Toner J. Balance in children following cochlear implantation. Cochlear Implant Int. 2017.
19. Said EAF. Clinical balance tests for evaluation of balance dysfunction in children with sensorineural hearing loss. Egypt J Otolaryngol. 2013;29(3):189–201.
20. Zhou G, Kenna MA, Stevens K, Greg Licameli G. Assessment of saccular function in children with sensorineural hearing loss. Arch Otolaryngol Head Neck Surg. 2009;135(1):40–4.
21. Martens S, Dhooge I, Dhondt C, Leyssens L, Sucaet M, Vanaudenaerde S, et al. Vestibular infant Screening - Flanders: the implementation of a standard vestibular screening protocol for hearing-impaired children in Flanders. Int J Pediatr Otorhinolaryngol. 2019;120(Electronic):1872–8464.
22. Božanić Urbančič N, Vozel D, Kordiš Š, Hribar M, Urbančič J, Battelino S. Indicators of pediatric peripheral vestibular disorder: A retrospective study in a tertiary referral center. Int J Pediatr Otorhinolaryngol. 2022;159:111221.
23. Martens S, Dhooge I, Dhondt C, Vanaudenaerde S, Sucaet M, Rombaut L, et al. Pediatric vestibular assessment: clinical framework. Ear Hear. 2023;44(Electronic):1538–4667.
24. Singh A, Heet H, Guggenheim DS, Lim M, Garg B, Bao M, et al. A systematic review on the association between vestibular dysfunction and balance performance in children with hearing loss. Ear Hear. 2022;43(3):712.
25. Seedat T, Khoza-Shangase K, Sebothoma B. Vestibular assessment and management in adults: current practice by South African audiologists. Hear Balance Communication. 2018;16:1–13.
26. Rajendran V, Roy FG. An overview of motor skill performance and balance in hearing impaired children. Ital J Pediatr 2011;37(33).
27. Callahan AJ, Lass NJ, Reed S, Willis M. Pediatric vestibular evaluation/balance assessment: audiologists' perceived skills and clinical practices. Audiol Today. 2012;24(5):28–37.
28. Martens S, Dhooge I, Dhondt C, Vanaudenaerde S, Sucaet M, Rombaut L et al. Vestibular infant screening (VIS)-Flanders: results after 1.5 years of vestibular screening in hearing-impaired children. Sci Rep. 2020;10(2045–2322 (Electronic)):21011.
29. Munn Z, Peters MDJ, Stern C, Tufanaru C, McArthur A, Aromataris E. Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. BMC Med Res Methodol. 2018;18(1):143.
30. Joint Committee on Infant Hearing. Year 2019 position statement: principles and guidelines for early hearing detection and intervention programs. J Early Hear Detect Intervention. 2019;4:1–44.
31. O'Reilly R, Grindle C, Zwicky EF, Morlet T. Development of the vestibular system and balance function: differential diagnosis in the pediatric population. Otolaryngol Clin North Am. 2011;44(2):251–.– 71, vii.
32. Cohen H, Friedman EM, Lai D, Pellicer M, Duncan N, Sulek M et al. Balance in children with otitis media with effusion. 1997.
33. Potter CN, Silverman LN. Characteristics of vestibular function and static balance skills in deaf children. Phys Ther. 1984;64:1071–5.
34. Gayle GW, Pohlman RL, COMPARATIVE STUDY O F T H E DYNAMIC STATIC. A N D ROTARY BALANCE O F DEAF AND HEARING CHILDREN '. 1990.
35. Hart MC, Nichols DS, Butler EM, Barin K. Childhood imbalance and chronic otitis media with effusion: effect of tympanostomy tube insertion on standardized tests of balance and locomotion. Laryngoscope. 1998;108:665–70.
36. Butterfield SA, Ersing WF. Influence of age, sex, etiology, and hearing loss on balance performance by deaf children. Percept Mot Skills. 1986;62(2):659–63.

37. Wong TPS, Leung EYW, Poon CYC, Leung CYF, Lau BPH. Balance performance in children with unilateral and bilateral severe-to-profound-grade hearing impairment. Hong Kong Physiother J. 2013;31(2):81–7.
38. Fellinger MJ, Holzinger D, Aigner M, Beitel C, Fellinger J. Motor performance and correlates of mental health in children who are deaf or hard of hearing. Dev Med Child Neurol. 2015;57(10):942–7.
39. Wolter NE, Gordon KA, Papsin BC, Cushing SL. Vestibular and Balance Impairment Contributes to Cochlear Implant Failure in Children. Otology & neurotology: official publication of the American Otological Society, American Neurotology Society [and] European Academy of Otology and Neurotology. 2015;36(6):1029-34.
40. Malekabadizadeh Z, Barati A, Khorashadizadeh M. The effect of hearing impairment and intellectual disability on children's static and dynamic balance. 2016.
41. Gronski M. Balance and motor deficits and the role of occupational therapy in children who are deaf and hard of hearing: A critical appraisal of the topic. J Occup Therapy Schools Early Intervention. 2013;6(4):356–71.
42. Venkadesan R, Finita GR. Motor development and postural control evaluation of children with sensorineural hearing loss: A review of three inexpensive assessment tools-PBS, TGMD-2, and P-CTSIB. Iran J Child Neurol. 2010;4(4):7–12.
43. Maes L, De Kegel A, Van Waelvelde H, Dhooge I. Association between vestibular function and motor performance in hearing-impaired children. Otology Neurotology. 2014;35(10):e343–7.
44. Ertugrul G, Sennaroglu G, Karakaya J, Sennaroglu L. Postural instability in children with severe inner ear malformations: characteristics of vestibular and balance function. Int J Audiol. 2021;60(2):115–22.
45. Cushing SL, Chia R, James AL, Papsin BC, Gordon KA. A test of static and dynamic balance function in children with cochlear implants. ARCHIVES OF OTOLARYNGOLOGY-HEAD & NECK SURGERY. 2008;134(1):34– 8.
46. Janky KL, Givens D, Vestibular. Visual acuity, and balance outcomes in children with cochlear implants: A preliminary report. Ear Hear. 2015;36(6):E364–72.
47. Eustaquio ME, Berryhill W, Wolfe JA, Saunders JE. Balance in children with bilateral cochlear implants. OTOLOGY NEUROTOLOGY. 2011;32(3):424–7.
48. Uysal SA, Erden Z, Akbayrak T, Demirturk F, COMPARISON OF BALANCE, AND GAIT IN VISUALLY OR HEARING IMPAIRED CHILDREN. Percept Mot Skills. 2010;111(1):71–80.
49. Jafari Z, Malayeri SA. The effect of saccular function on static balance ability of profound hearing-impaired children. Int J Pediatr Otorhinolaryngol. 2011;75(7):919–24.
50. Melo RD, Marinho SED, Freire MEA, Souza RA, Damasceno HAM, Raposo MCF. Static and dynamic balance of children and adolescents with sensorineural hearing loss. EINSTEIN-SAO PAULO. 2017;15(3):262–8.
51. Lindsey D, O'Neal J. Static and dynamic balance skills of eight year old deaf and hearing children. 1976;121:49.
52. Rajendran V, Roy FG, Jeevanantham D. Postural control, motor skills, and health-related quality of life in children with hearing impairment: a systematic review. European archives of oto-rhino-laryngology: official journal of the European federation of Oto-Rhino-Laryngological societies (EUFOS): affiliated with the German society for Oto-Rhino-Laryngology -. Head Neck Surg. 2012;269(4):1063–71.
53. Fernandes R, Hariprasad S, Kumar VK. Physical therapy management for balance deficits in children with hearing impairments: A systematic review. J Paediatr Child Health. 2015;51(Electronic):1440–754.
54. Hartman E, Houwen S, Visscher C. Motor skill performance and sports participation in deaf elementary school children. Adapted Phys Activity Q. 2011;28(2):132–45.
55. Livingstone N, McPhillips M. Motor skill deficits in children with partial hearing. Dev Med Child Neurol. 2011;53(9):836–42.
56. Geddes D. Motor development profiles of preschool deaf and hard-of-hearing children. Percept Mot Skills. 1978;46(1):291–4.
57. Gheysen F, Loots G, Van Fau - H, Van Waelvelde H. Motor development of deaf children with and without cochlear implants. J Deaf Stud Deaf Educ. 2008;13(Print):1081–4159.
58. Lewis S, et al. Development of an exercise program to improve the static and dynamic balance of profoundly Hearing-Impaired children. Am Ann Deaf. 1985;130(4):278–81.
59. Apeksha K, Singh S, Rathnamala M, Varalakshmi S, Preethu DJ, Kavya V, et al. Balance assessment of children with sensorineural hearing loss. Indian J Otolaryngol Head Neck Surgery: Official Publication Association Otolaryngologists India. 2021;73(1):12–7.
60. An M-h, Yi C-h, Jeon H-s, Park S-y. Age-related changes of single-limb standing balance in children with and without deafness. Int J Pediatr Otorhinolaryngol. 2009;73(11):1539–44.
61. Siegel JC, Marchetti M, Tecklin JS. Age-related balance changes in hearing-impaired children. Phys Ther. 1991;71(3):183–9.
62. Holderbaum FMI, et al. A study of otoneurologic and balance tests with deaf children. Am Ann Deaf. 1979;124(6):753–9.
63. Engel-Yeger B, Golz A, Parush S. Impact of middle ear effusion on balance performance in children. Disabil Rehabilitation. 2004;26(2):97–102.
64. De Kegel A, Dhooge I, Peersman W, Rijckaert J, Baetens T, Cambier D, et al. Construct validity of the assessment of balance in children who are developing typically and in children with hearing impairments. Phys Ther. 2010;90(12):1783–94.
65. Lima R. Balance assessment in deaf children and teenagers prior to and post capoeira practice through the Berg balance scale. Int Tinnitus J. 2017;21(2):77–82.
66. Horak FB, Shumway-Cook A, Crowe TK, Black FO. Vestibular function and motor proficiency of children with impaired hearing, or with learning disability and motor impairments. Dev Med Child Neurol. 1988;30(1):64–79.
67. Shall MS. The importance of saccular function to motor development in children with hearing impairments. Int J Otolaryngol. 2009;2009:1–5.
68. De Kegel A, Maes L, Baetens T, Dhooge I, Van Waelvelde H. The influence of a vestibular dysfunction on the motor development of hearing-impaired children. Laryngoscope. 2012;122(12):2837–43.
69. Martin W, Jelsma J, Rogers C. Motor proficiency and dynamic visual acuity in children with bilateral sensorineural hearing loss. Int J Pediatr Otorhinolaryngol. 2012;76(10):1520–5.
70. Patel H, Malawade M, Butte-Patil S, Khairnar P, Gawade S, Student I. Comparison of balance in children with and without hearing impairment. 2017.
71. Hedayatjoo M, Rezaee M, Alizadeh Zarei M, Mirzakhany N, Nazeri A, Akbarzadeh Baghban A, et al. Effect of balance training on balance performance, motor coordination, and attention in children with hearing deficits. Arch Neurosci. 2020;7(1):e84869.
72. Rajendran V, Roy FG, Jeevanantham D. A preliminary randomized controlled study on the effectiveness of vestibular-specific neuromuscular training in children with hearing impairment. Clin Rehabil. 2013;27(5):459–67.
73. Rajendran V, Roy FG, Jeevanantham D. Reliability of pediatric reach test in children with hearing impairment. Int J Pediatr Otorhinolaryngol. 2012;76(6):901–5.
74. Christy JB, Payne J, Azuero A, Formby C. Reliability and diagnostic accuracy of clinical tests of vestibular function for children. Pediatr Phys Ther. 2014;26(2).
75. Cushing SL, Papsin BC, Rutka JA, James AL, Blaser SL, Gordon KA. Vestibular end-organ and balance deficits after meningitis and cochlear implantation in children correlate poorly with functional outcome. Otol Neurotol. 2009;30(4):488–95.
76. Ebrahimi AA, Jamshidi AA, Movallali G, Rahgozar M, Haghgoo HA. The effect of vestibular rehabilitation therapy program on sensory organization of deaf children with bilateral vestibular dysfunction. Acta Med Iran. 2017;55(11):683–9.
77. Ebrahimi AA, Movallali G, Jamshidi AA, Haghgoo HA, Rahgozar M. Balance performance of deaf children with and without cochlear implants. Acta Med Iran. 2016;54(11):737–42.
78. Oyewumi M, Wolter NE, Heon E, Gordon KA, Papsin BC, Cushing SL. Using balance function to screen for vestibular impairment in children with sensorineural hearing loss and cochlear implants. Otol Neurotol. 2016;37(7):926–32.
79. Melo LA, Raposo MCF, Belian RB, Ferraz KM. Balance performance of children and adolescents with sensorineural hearing loss: repercussions of hearing loss degrees and etiological factors. Int J Pediatr Otorhinolaryngol. 2018;110:16–21.
80. Sokolov M, Gordon KA, Polonenko M, Blaser SI, Papsin BC, Cushing SL. Vestibular and balance function is often impaired in children with profound unilateral sensorineural hearing loss. Hear Res. 2019;372:52–61.
81. Ayanniyi O, Adepoju F, Mbada C. Static and dynamic balance in school children with and without hearing impairment. J Experimental Integr Med. 2014;4:245.
82. Benjamin RS, Cushing SL, Blakeman AW, Campos JL, Papsin BC, Gordon KA. Evaluating the use of a balance prosthesis during balance perturbations in children and young adults with cochleovestibular dysfunction. Sci Rep. 2023;13(1):9721.
83. Chisari D, Vitkovic J, Clark R, Rance G. Vestibular function and balance performance in children with sensorineural hearing loss. Int J Audiol. 2023:1–9.

84. Ekawati FF, Rahayu TW, Ismaryati I, Satyawan B, Meli Andani A. Balance assessment in students with hearing impairment. Jurnal SPORTIF: Jurnal Penelitian Pembelajaran. 2023;9(3):437–46.
85. Çelik SE, Bek N, Özcebe LH, Kocaman H, THE EFFECTS OF SHOE, SUITABILITY ON PLANTAR PRESSURE DISTRIBUTION AND BALANCE PARAMETERS IN CHILDREN WITH HEARING IMPAIRMENT. Turkish J Physiotherapy Rehabilitation. 2022;33(2):54–62.
86. Ghaffar E, huda N, Fatima S, Fatima Q, Haider M, Ain N, et al. Prevalence of balance impairment in children with hearing impairment: balance issues in hearing-Impaired children. J Health Rehabilitation Res. 2024;4:1–8.
87. Ghosh S, bannetjee s, Biswas R. A study on the dynamic balance of schoolchildren in India with varying degrees of hearing impairments. J Phys Educ Sport. 2022;22:1177–89.
88. Hu F, Qiu X, Wu X, Wu X, Li H, Kim S. Effects of dance sports exercise on vestibular function and balance of children with sensorineural hearing loss; a randomized quasi-experimental trial. Front Pead. 2024;12.
89. Janky KL, Patterson J, Thomas M, Al-Salim S, Robinson S. The effects of vestibular dysfunction on balance and self-concept in children with cochlear implants. Int J Pediatr Otorhinolaryngol. 2023;171:111642.
90. Metgud DC, Topkar P. Balance and agility testing in normal and Hearing-Impaired children: A Case–Control study. Indian J Phys Therapy Res. 2019;1(1).
91. Mohamed ST, Hazzaa N, Abdel Rahman T, Ezz Eldin DM, Elhusseiny AM. Efficacy of vestibular rehabilitation program in children with balance disorders and sensorineural hearing loss. Int J Pediatr Otorhinolaryngol. 2024;179:111931.
92. Monin E, Bahim C, Baussand L, Cugnot J-F, Ranieri M, Guinand N et al. Development of a new clinical tool to evaluate the balance abilities of children with bilateral vestibular loss: the Geneva balance test. Front Neurol. 2023;14.
93. Mujdeci B, Önder S, Alluşoğlu S, Boynuegri S, Kum O, Atan D. The effects of age at cochlear implantation on balance in children: A pilot study. Int J Artif Organs. 2020;44(6):440–5.
94. Zarei H, Norasteh AA, Lieberman LJ, Ertel MW, Brian A. Balance control in individuals with hearing impairment: A systematic review and Meta-Analysis. Audiol Neurotology. 2023;29(1):30–48.
95. Sinno S, Najem F, Dumas G, Abouchacra KS, Mallinson A, Perrin P. Correlation of SVINT and sensory organization test in children with hearing loss. Audiol Res [Internet]. 2022; 12(3):[316–26 pp.].
96. Ghai S, Hakim M, Dannenbaum E, Lamontagne A. Prevalence of vestibular dysfunction in children with neurological disabilities: A systematic review. Front Neurol. 2019;10:1294.
97. Venkadesan R, Fitina GR. Motor development and postural control evaluation of children with sensorineural hearing loss: A review of three inexpensive assessment tools-PBS, TGMD-2, and P-CTSIB. Iran J Child Neurol. 2010;4:7–12.
98. Wardani NK, Kusumawardani MK, Mayangsari JA, Wulan S. Correlation between one leg stand test and paediatric balance scale in children aged 7–12 years. Sri Lanka J Child Health. 2022;51(2):204–8.
99. Franjoine MR, Darr N, Held SL, Kott K, Young BL. The performance of children developing typically on the pediatric balance scale. Pediatr Phys Ther. 2010;22(4):350–9.
100. Holderbaum Fm Fau -, Ritz S, Ritz S, Fau - Hassanein KM, Hassanein Km Fau -, Goetzinger CP, Goetzinger CP. A study of otoneurologic and balance tests with deaf children. Am Ann Deaf. 1979;124:753–9. (0002-726X (Print)).
101. Maes L, De Kegel A, Van Waelvelde H, De Leenheer E, Van Hoecke H, Goderis J, et al. Comparison of the motor performance and vestibular function in infants with a congenital cytomegalovirus infection or a connexin 26 mutation: a preliminary study. Ear Hear. 2017;38(1):e49–56.
102. Howell DR, Brilliant AN, Meehan WP. 3rd. Tandem gait Test-Retest reliability among healthy child and adolescent athletes. Ournal Athletic Train. 2019;54:1254–9. 1938-162X (Electronic).
103. Galea OA, Bristow HD, Chisholm SM, Mersch ME, Nullmeyer J, Reid CR, et al. Single and dual tandem gait assessment post concussion: what performance time is clinically relevant across adult ages and what can influence results? Musculoskelet Sci Pract. 2019;42:166–72.
104. Oldham JR, DIFABIO MS, KAMINSKI TW, DEWOLF RM, HOWELL DR. Efficacy of tandem gait to identify impaired postural control after concussion. Med Sci Sports Exerc. 2018;50(6):1162–8.
105. Christy JB, Payne J, Azuero A, Formby C. Reliability and diagnostic accuracy of clinical tests of vestibular function for children. Pediatr Phys Ther. 2014;26(2):180–9.
106. Van Hecke R, Deconinck FJA, Wiersema JR, Clauws C, Danneels M, Dhooge I et al. Balanced Growth project: A protocol of a single-centre observational study on the involvement of the vestibular system in a child's motor and cognitive development. BMJ Open. 2021;11(6).
107. Yones L, Kahlaee AH, Sayadi N, Jalilzadeh Afshari P, Bakhshi E. Test-retest reliability of the pediatric clinical test of sensory interaction for balance in 4–6 years old children. Auditory Vestib Res. 2017;26(4).
108. Evkaya A, Karadag-Saygi E, Karali Bingul D, Giray E. Validity and reliability of the dynamic gait index in children with hemiplegic cerebral palsy. Gait Posture. 2020;75:28–33.
109. Verbecque E, Schepens K, Theré J, Schepens B, Klingels K, Hallemans A. The timed up and go test in children: does protocol choice matter?? A systematic review. Pediatr Phys Ther. 2019;31(1):22–31.
110. Williams E, Carroll N, Reddihough SG, Phillips DS, Galea BA. Investigation of the timed 'up & go' test in children. Dev Med Child Neurol. 2005;47:518–24.
111. Nicolini-Panisson RD, Donadio MV. Timed up & go test in children and adolescents. Revista Paulista De Pediatria: Orgao Oficial Da Sociedade De Pediatria De Sao Paulo. 2013;31:377–83. (1984–0462 (Electronic)).
112. Nicolini-Panisson RD, Donadio MV. Normative values for the timed 'up and go' test in children and adolescents and validation for individuals with down syndrome. Dev Med Child Neurol. 2014;56(5):490–7.
113. Kott KM, Held SL, Giles EF, Franjoine MR. Predictors of standardized walking obstacle course outcome measures in children with and without developmental disabilities. Pediatr Phys Ther. 2011;23(4).
114. Kott KM, Held S, Franjoine MR. Reference data for performances on the standardized walking obstacle course in children developing typically. Gait Posture. 2016;49:398–401.
115. Held SL, Kott KM, Young BL. Standardized walking obstacle course (SWOC): reliability and validity of a new functional measurement tool for children. Pediatr Phys Ther. 2006;18(1).
116. Ng S, Chan S, Chan A, Chung H, Lee N, Ngan A et al. Reliability and concurrent validity of standardized walking obstacle course test in people with stroke. J Rehabil Med. 2017;49.
117. Ambegaonkar J, Caswell S, Winchester J, Shimokochi Y, Cortes N, Caswell A. Balance comparisons between female dancers and active nondancers. Res Q Exerc Sport. 2013;84:24–9.
118. Tsigilis N, Zachopoulou E, Mavridis T. Evaluation of the specificity of selected dynamic balance tests. Percept Mot Skills. 2001;92(3):827–33.
119. Jaffri A, Newman T, Smith B, Miller S. The dynamic leap and balance test (DLBT): A test-Retest reliability study. Int J Sports Phys Therapy. 2017;12:512–9.
120. Bell DR, Guskiewicz KM, Clark MA, Padua DA. Systematic review of the balance error scoring system. Sports Health. 2011;3(3):287–95.
121. Academy of Neurologic Physical Therapy, Vestibular EDGE, Roseville,:. ACADEMY OF NEUROLOGIC PHYSICAL THERAPY 2018 [Available from: https://www.neuropt.org/practice-resources/neurology-section-outcome-measures-recommendations/vestibular-disorders
122. Sember V, Grošelj J, Pajek MA-O. Balance tests in Pre-Adolescent children: retest reliability, construct validity, and relative ability. LID– 10.3390/ijerph17155474 [doi] LID– 5474. Int J Environ Res Public Health. 2020;17:1660–4601. (Electronic)):5474.
123. Sæther R, Helbostad J, Riphagen I, Vik T. Clinical tools to assess balance in children and adults with cerebral palsy: A systematic review. Dev Med Child Neurol. 2013;55.
124. Dasgupta S, Mandala M, Salerni L, Crunkhorn R, Ratnayake S. Dizziness and balance problems in children. Curr Treat Options Neurol. 2020;22(3):8.

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