


College of Health Sciences

School of Medicine

Department of Medical Physiology

# Static and Dynamic Balance Performance and Associated Factors in Normal and Hearing-Impaired Schoolchildren in Addis Ababa Public Schools

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## Approval Sheet

This thesis by Haimanot Andualem Ayalsew, was accepted in its present form by the board of examiners, satisfying the thesis requirement for the degree of Master of Science in Medical Physiology.

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## Declaration

I declare that "Assessments of Static and Dynamic Balance Performance and Associated Factors in Normal and Hearing-Impaired Schoolchildren in Addis Ababa Public Schools, Ethiopia, 2024" is my work and that all the resources that I have used or quoted have been indicated and acknowledged through complete resources. This work has not been undertaken or submitted to any other institution.

Principle Investigator

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**Acronyms and Abbreviations**

| | |
|---|---|
| **dB** | Decibel |
| **FRT** | Functional Reach Test |
| **HA** | Hearing Aid |
| **HI** | Hearing Impairment |
| **Hz** | Hertz |
| **PBS** | Pediatric Balance Scale |
| **SCC** | Semi Circular Canal |
| **SLS** | Single Leg Stance |
| **SLSEC** | Single Leg Stance Eyes Closed |
| **SLSEO** | Single Leg Stance Eyes Open |
| **SNHL** | Sensory Neural Hearing Loss |
| **WHO** | World Health Organization |

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## Abstract

**Background:** Maintaining balance is crucial for everyday activities, motor development, sports, and overall well-being. It manifests in static and dynamic forms. The vestibular system plays a vital role in the maintenance of this balance. Hearing loss, infection and other problem-induced vestibular system impairments among children cause great burdens. However, balance assessment is not routinely conducted in children with and without hearing impairments.

**Objective**: This study assessed static and dynamic balance performance and its associated factors among schoolchildren with and without hearing impairments in Addis Ababa public schools.

**Materials and Methods**: A comparative cross-sectional study design was used to evaluate the static and dynamic balance performance of 148 (74 hearing-impaired and 74 normal hearing) children aged 7 to 18 years. The study was conducted from September 1, 2023, to May 30, 2024. Single leg stance (eyes open/closed), functional reach, and pediatric balance scale tests were used to assess balance performance. The data were entered and analyzed using SPSS (version 27) software. Independent t-tests, Pearson's correlation, and regression analysis were used, and a p-value less than 0.05 was considered statistically significant.

**Results**: Compared with those of normal hearing peers, the single-leg stance eyes open (30.6±15.8 vs.47.6±12.2 sec, $p<0.001$), eyes closed (4.2±4.1 vs.15.4±7.9 sec, $p<0.001$), functional reach test (22.2±4.3 vs. 26.3±6.6 cm, $p<0.001$), and pediatric balance scale (54.4±1.2 vs. 55.8±0.5, $p<0.001$) scores of hearing-impaired children were significantly lower. The single-leg stance eyes open (29.2±15.8 vs.45.5±12.6 sec, $p<0.001$), eyes closed (5.4±5.24 vs.14.2±7.5 sec, $p<0.001$), functional reach test (21.8±4.1 vs.25.7±6.3 cm, $p<0.002$), and pediatric balance scale (54.5±1.2 vs.55.8±0.5, $P<0.001$) scores of males with hearing-impairments were significantly lower than the same sex with normal hearing. The single-leg stance eyes open (32.0±15.9 vs. 49.7±11.5 sec, $P<0.001$), eyes closed (3.2±2.0 vs. 16.6±8.4 sec, $P<0.001$), pediatric balance scale (54.3±1.1 vs. 55.9±0.5, $P<0.001$), and functional reach test (22.6±4.5 vs. 26.9±6.9 cm, $P <0.003$) scores of females with hearing impairments were also significantly lower than the same sex of normal hearing.

**Conclusion:** Compared with normal-hearing peers of the same sex, children with hearing impairments showed lower static and dynamic balance performance. Routine balance screening and balance training programs for children with hearing impairments are needed.



**Keywords:** Static, Dynamic, Balance performance, Hearing-impaired, Children.

# 1. Introduction

## 1.1 Background

Hearing is a vital sense that allows humans to perceive vibrations as sounds, playing a crucial role in social interaction and learning abilities [1]. The ear, which is essential for normal hearing consists of three parts: the outer ear, middle ear, and inner ear. The inner ear is further divided into the vestibular labyrinth and the cochlea [2]. The outer ear collects sound, which then travels to the middle ear after hitting and vibrating the tympanic membrane. These vibrations are amplified by the ossicles in the middle ear and sent to the cochlea. The organ of corti then converts these vibrations into electrical signals, which sent to the brain through the vestibulocochlear nerve [2].

Hearing impairment is defined as an inability to hear up to 20 decibels in both ears [3]. This happens when the auditory system is not working in the usual way [4]. It can range from mild to profound and may affect one or both ears [3,4]. Congenital factors, chronic middle ear infections, higher noise exposure, aging, and ototoxic drugs are some of the risk factors for hearing loss [3,4]. Hearing loss is the most common sensory deficit and one of the leading causes of disability worldwide [5,6]. Globally, 1.5 billion people suffer from hearing impairments, of which approximately 34 million are children, and 60% of cases are preventable [3].

Hearing impairments have profound impacts, leading to communication difficulties, delayed language development, social isolation, and frustration [3,4]. This, in turn, can adversely affect academic performance and limit employment opportunities, especially for children in developing countries, who often lack access to proper schooling and affect day-to-day activities [3]. According to a study, hearing impairments are accompanied by vestibular and balance defects [7].

The vestibular system is composed of complex structures and neural pathways essential for maintaining balance [2,8]. The system includes three semicircular canals, which manage angular acceleration and head rotation across various planes, and two otolith organs (utricle and saccule), which detect linear acceleration [2,8–10].

Balance is a key skill that is essential for individuals and serves as a fundamental aspect of day-to-day activities. Postural control involves the complex ability to maintain, achieve, or restore equilibrium whether one is stationary, in motion, or transitioning between the two states [11]. It involves maintaining equilibrium by keeping the center of gravity within the base of support. It

relies on input from the visual, vestibular, and somatosensory systems. It can be static (nonmoving) or dynamic (moving). The vestibular system is essential for maintaining this balance [7,11,12].

Owing to the close anatomical and functional relationship between the vestibular and auditory systems, children with hearing impairments face the risk of vestibular dysfunction [13]. Hearing impairments during childhood are directly linked to delays in motor development, affecting balance, postural control, and coordination between limbs [14]. Certain congenital or acquired hearing deficits can affect the vestibular nerve, CN-VIII [15].

Vestibular loss can impair motor development in children and negatively affect quality of life. When the vestibular system is compromised, maintaining balance becomes challenging, particularly in individuals with sensory neural hearing loss [6,7,12]. Delays in motor development can affect the ability of children to participate in adequate levels of motor skills, which can result in an inability to perform physical activities [16]. Another study indicated that vestibular dysfunction is a frequent finding in the otoneurological evaluation of children with sensory neural hearing loss [12].

Researchers have shown that deaf or hearing-impaired school-aged children have poor balance performance [12,15,17]. The incorporation of balance assessment is important for the early detection of a problem, the preparation of guidelines, and the execution of appropriate interventions. However, routine screening usually is not included in the assessment of balance and motor function unless evident orthopedic issues arise [18].

In Ethiopia, public schools serve diverse populations, including children with hearing impairments. However, no research on balance performance among schoolchildren with and without hearing impairments has been conducted. Moreover, there is no screening for balance issues in hearing-impaired children. Therefore, this study aimed to assess the static and dynamic balance performance of normal and hearing-impaired schoolchildren, and the factors affecting balance.

### 1.2 Statement of the Problem

Maintaining balance is crucial for everyday activities, motor development, sports, and overall well-being [16]. However, hearing loss during childhood is directly associated with delays in motor development, particularly in areas such as balance, postural control, and limb coordination [14]. Severe or profound hearing loss often results in vestibular deficits in 30 to 85% of cases [15]. Furthermore, the vestibular dysfunction of 20 to 70% of children with hearing loss is attributed to these deficits [13]. Beyond vestibular involvement, children with congenital hearing impairments with normal vestibular function develop head control and begin walking independently later than typically developing children did [19]. This finding suggests that a hearing deficit alone can prolong the timeline for motor development in children with congenital or early-acquired SNHL, even when vestibular function is normal [19]. These impairments affect various aspects of child development, including coordination, speed of movement, and static and dynamic balance reactions [15].

Balance is crucial for a child's neuromotor development, influencing all interactions with their environment during daily activities and play. Children with sensorineural hearing loss frequently face delays in neuro-motor development and motor skill issues [20]. As a result, they often struggle with maintaining their head, sitting, and bipedal positions, and they exhibit impaired balance skills, which increases their risk of falls and injuries [15]. Falls are a leading cause of injuries in children and can occur for several reasons. Due to impaired vestibular function and delayed motor development, children with hearing loss fall more frequently [13]. Higher degrees of hearing loss are associated with increased odds of falling [8]. Compared with their healthy peers, children with sensorineural hearing loss exhibit significantly worse static and dynamic balance skills [13,21].

Children with hearing difficulties experience dizziness and balance problems at a much higher rate (20.9%) than children without hearing difficulties (4.9%). Hearing difficulties significantly increase the risk of dizziness and balance problems with an odds ratio of 4.8 [22]. Balance disorders present significant social challenges [21] that impact children's neurodevelopmental stages, and daily activities, and lead to psychoneurological, affective, and behavioral disturbances [23]. Children with these disorders often experience imbalance, dizziness, and gait disturbances, which interfere with activities such as riding a bicycle, skipping a rope, and playing on playground

equipment [12]. These challenges hinder the development of age-appropriate motor skills, creating obstacles to physical and social growth [20].

Emerging research indicates that the vestibular system is not only crucial for balance but also plays a significant role in consciousness. Malfunctions in this system can lead to cognitive impairments affecting spatial memory, learning, and navigation [8]. Furthermore, disruptions in vestibular function can result in symptoms, including dizziness, vision issues, nausea, fatigue, and difficulty concentrating. These disturbances can cause widespread and profound impacts on daily life [20]. However, identifying balance disorders in children poses considerable challenges, as they may not be able to describe their symptoms and often appear clumsy instead [18]. Measuring postural stability as early as possible is crucial [21].

### 1.3 Significance of the Study

The study's findings could help stakeholders, including program planners, healthcare workers, education bureaus, and sport teachers to develop screening and early treatment protocols to reduce the risk of falls among normal and hearing-impaired schoolchildren. This would also empower families to better care for their children's safety and well-being.

Moreover, this study will facilitate collaboration among audiologists, physiotherapists, educators, and policymakers. It is also important in promoting a multidisciplinary approach to address the complex needs of hearing-impaired children and enhance their quality of life. By creating awareness and adding substantial value to the existing literature, it fills a critical gap and provides profound insights into the impact of hearing status on balance. It serves as a baseline for future researchers dedicated to this area.

## 2. Literature Review

### 2.1 Hearing and Hearing Loss

Hearing is vital for social interaction and learning and is dependent on the proper functioning of the ear [2]. The human ear is structurally and functionally divided into three parts. First, the outer part, containing the pinna and auditory canal, passes sound vibrations to the tympanic membrane, which separates the outer and middle ears. The middle ear contains the three ossicles (malleus, incus, and stapes) receive these vibrations and amplifies them. The inner ear contains (the cochlea, vestibular apparatus and nerves), and as the vibration continues, it travels into the inner ear: it reaches the spiral-shaped cochlea, the primary organ of hearing. Within the cochlea, hair cells (stereocilia) found in the organ of the Corti have hair-like projections. The rhythmic movement of these stereocilia opens mechanotransduction channels, converting mechanical vibrations into nerve signals that are sent to the brain. In this way, these vibrations are converted into understandable sounds [2,4].

Hearing impairments refer to the inability to hear sounds less than 20 decibels in both ears [3]. This condition can arise from issues in any part of the auditory system, with the severity ranging from mild to profound [4]. There are three main types of hearing loss. Conductive hearing loss occurs when sounds are obstructed from passing through the outer or middle ear. SNHL results from problems within the inner ear or the hearing nerve, affecting the way sound signals are processed. Mixed hearing loss is a combination of both conductive hearing loss and sensorineural hearing loss, affecting multiple parts of the auditory system [3,4].

Hearing loss in children can be either congenital or acquired. Congenital hearing loss is present at birth and can be hereditary or due to other factors during pregnancy or birth. Genetic factors are responsible for more than 50% of congenital hearing loss cases. Nonhereditary causes include intrauterine infections such as rubella, cytomegalovirus, and herpes simplex virus, as well as complications related to the Rh factor in the blood, prematurity, maternal diabetes, and anoxia (lack of oxygen) at birth [1,4]. Acquired hearing loss appears after birth and can occur at any time due to various factors. These include ear infections (otitis media), meningitis, measles, chickenpox, influenza, mumps, and the use of ototoxic drugs. Additionally, head injuries and loud noise exposure can contribute to hearing loss. These factors can impact hearing at any point in a child's life, leading to varying degrees of hearing impairment [1,4].

It is the most common sensory deficit in humans and one of the leading causes of disability worldwide [5,6]. Globally, it affects over 1.5 billion people, with approximately 34 million affected children, 60% of whom are preventable [3]. At the other end of the lifespan, approximately 30% of people over 60 years of age have hearing loss [3]. In sub-Saharan Africa, the prevalence of hearing impairments is notably greater than in wealthier regions. WHO estimates show a 15.7% vs. 4.9% prevalence in adults (>15 years), whereas for children (5–14 years), the prevalence is 1.9% vs. 0.4% in sub-Saharan Africa and in high-income countries, respectively [24]. In Ethiopia, a study conducted at Mekelle reported that 7% of schoolchildren had hearing loss (>20 dB) in at least one ear [25]. Another study targeting children aged 0–14 years reported a 2.7% disability rate, and hearing impairments stood out as the predominant disability, affecting 71.2% of the population [26]. A study in Addis Ababa Elementary School reported a higher prevalence of hearing impairments (34%) than global and regional estimates by the WHO [5].

Hearing loss has profound impacts, including communication difficulties, delayed language development, social isolation, and frustration [3,4]. These challenges can negatively affect academic performance and limit employment opportunities, particularly in developing countries where access to proper schooling is often lacking. Deafness can also impact cognitive, emotional, social, and neuromotor development, with children often showing significant deficits in motor skills, especially balance [27].

Moreover, hearing loss affects various everyday activities beyond communication and social interactions. Many hearing loss conditions are accompanied by vestibular defects, which are crucial for balance and mobility [7]. Children with hearing impairments are at risk of vestibular dysfunction due to the close anatomical and functional relationship between the vestibular and auditory systems; diseases affecting the auditory system can also affect the vestibular system, and certain congenital or acquired hearing deficits may impact the vestibular branch of cranial nerve VIII [13,15].

## 2.2 Vestibular System

The vestibular system is a complex sensory organization that involves communication between the peripheral vestibular apparatus, ocular system, postural muscles, brainstem, cerebellum, and cortex [9]. It consists of both central and peripheral components. The centrally located vestibular system includes neural pathways in the brain that process input from the peripheral system in the inner ear and send signals that enable reflexive responses [8].

The peripheral vestibular system, located in the inner ear, consists of both a bony and a membranous labyrinth. The bony labyrinth includes the cochlea, vestibule, and semicircular canals, all of which are filled with perilymph. Within this structure, the membranous labyrinth is suspended, containing the sensory epithelium and components of the vestibular apparatus with endolymph flowing through it [9]. The endolymph within the membranous labyrinth envelops the sensory epithelium and interacts with hair cells in the vestibular apparatus, providing a high potassium gradient that facilitates the depolarization of hair cells and the transmission of afferent nerve signals [8].

The vestibular apparatus is a complex system comprising five organs: the utricle, the saccule, and the lateral, superior, and posterior semicircular ducts. The utricle and saccule, parts of the static labyrinth, detect head orientation in space by responding to linear acceleration, gravitational forces, and head tilting. Each contains a sensory neuroepithelium called the macula, where sensory hair cells project into a gelatinous material embedded with calcium carbonate crystals (otoconia). This structure provides inertial mass. Motion toward kinocilia causes excitation, whereas motion away leads to inhibition. Utricular excitation occurs during horizontal linear acceleration or static head tilt, while saccular excitation occurs during vertical linear acceleration [9,28]. The semicircular canals form the kinetic labyrinth, which senses angular acceleration or head rotation. These canals are oriented at right angles to each other. The semicircular canals (SCCs) enlarge at one end to form the ampulla, which contains the cupula, a gelatinous barrier housing sensory hair cells. These hair cells have kinocilia and stereocilia seated in the crista-ampullaris, the sensory organ for angular rotation. Motion of the endolymph causes deflection of the stereocilia, opening or closing the transduction channels of hair cells, and altering their membrane potential. Deflection toward the kinocilia results in excitation (depolarization), whereas deflection away leads to inhibition [9,28].

All human activities require control, stability, and balance. Primary motor skills such as walking, standing, and sitting rely on effective posture control [29]. The ability to maintain a state of equilibrium is a critical element of movement that facilitates functional skills by ensuring proper orientation and alignment of the body in space [6,7,29,30]. This ability is vital for children's daily activities, encompassing the capacity to maintain, achieve, or restore bodily equilibrium whether stationary, preparing to move, in motion, or halting movement [31]. From birth to our elderly years, our sense of balance plays a crucial role in maintaining well-being and ensuring survival. Notably, the sensory systems responsible for balance are fully developed at birth [10].

In daily life, individuals display two types of balance: static and dynamic. Static balance refers to the ability to maintain equilibrium while stationary, whereas dynamic balance involves maintaining total body balance while in motion [12,29]. Both types of postural control are essential motor abilities necessary for performing various functional activities, including both locomotor and manipulative skills. Functional balance in children is characterized as the ability to uphold the center of mass concerning the base of support while engaging in routine childhood activities, whether during daily living, school-related tasks, or play [22].

This regulation of body balance is orchestrated through the integration of sensory input from three systems: visual, somatosensory, and vestibular. These inputs are coordinated by the central nervous system to generate motor responses that keep the body balanced [31,32]. The vestibular system, located in the inner ear, detects the position and movement of the head in space, enabling the coordination of eye movements, posture, and equilibrium. It accomplishes this by sending afferent nerve signals from its individual components [8]. This information is processed by vestibular centers in the brain, allowing the body to maintain balance, proper spatial orientation during movement, and correct processing of visual images during motion [9].

However, disruptions in any of these sensory systems can potentially destabilize body balance [31]. If the vestibular, visual, and somatosensory systems do not work in concert, dizziness, falls, and gait disturbances are observed [12]. Dysfunction of the vestibular system can manifest symptomatically as vertigo, nausea, vomiting, visual disturbance, hearing changes, and various cognitive deficits. The relationship between the vestibular system and cognition is not well understood, but many patients with vestibular dysfunction exhibit impairments in spatial navigation, learning, memory, and object recognition [8].

Vestibular disorders in childhood are more common than previous thought and can affect the development of neuromotor skills, particularly sensory integration involving the vestibular system. Children with these disorders may experience symptoms such as imbalance, dizziness, and gait disturbances, leading to difficulties in activities such as riding a bicycle, skipping rope, or playing on playground equipment. These challenges hinder the acquisition of age-appropriate motor skills [12].

The observed balance deficits in children with hearing impairments are attributed to the proximity of the vestibular system to the cochlea. Both the cochlea and the vestibular receptors, including the semicircular canals and otolith organs, are anatomically and phylogenetically related, sharing the continuous membranous labyrinth of the inner ear and operating through similar receptor cells [28]. Consequently, abnormalities or diseases affecting the inner ear are likely to impact both hearing and balance [33]. Children with inner ear injuries might have concurrent vestibular problems alongside sensorineural hearing loss. Studies highlight the common occurrence of vestibular dysfunction in the otoneurological assessment of children with sensorineural hearing loss [12]. Vestibular dysfunction occur in 20 to 70% of children with hearing loss [13].

### 2.3 Prevalence of Balance Disorders in Children

Studies in the scientific domain present highly variable prevalence rates for balance disorders in children and adolescents, ranging from as low as 0.4% to as high as 15% (Redaelli and Balzanelli, 2022). Additionally, estimates for dizziness and balance problems in children fall between 5% and 18% [22]. Published epidemiological data underscore this variability, with prevalence rates approaching 10% in clinical studies [23]. In the United States, 5.3% of children (3.3 million) experience these issues, with higher rates in females (5.7%) than in males (5.0%). The prevalence increases with age, from 4.1% at ages 3-5 years to 7.5% at ages 15-17 years [22].

In terms of sensory issues, children with difficulty hearing had a higher prevalence of balance problems (20.9%) than those without hearing difficulty (4.9%). Notably, hearing difficulty increases the risk of dizziness and balance problems, with an odds ratio of 4.8 [22].

### 2.4 Effects of Hearing Loss and Hearing Aids Usage on Balance

While research often focuses on how hearing affects communication and social interactions, it also plays a crucial role in spatial awareness, object perception, and movement coordination, particularly in activities influencing balance and mobility [7].

Hearing-impaired schoolchildren may experience inadequate sensory organization due to damage to the vestibular system and associated nerves. Since the sensory system for balance includes the visual, auditory, and somatosensory systems [20], these children might experience broader issues with balance and coordination problem. When the brain receives limited information from the auditory system, the perception of body position may be impaired, resulting in postural instability [15]. Hearing provides spatial acoustic information essential for maintaining postural balance [35]. Subjects with normal hearing use auditory cues to improve postural sway. However, this ability diminishes with hearing loss but can be restored with hearing aids [36]. Consequently, individuals with conductive hearing loss experience balance disturbances [35].

The benefits of hearing aids (HAs) for balance improvement remain uncertain, although some studies suggest enhanced balance in patients using HAs. It is speculated that hearing aids might improve static, dynamic, or subjective perceptions of balance function in individuals with hearing loss [37]. The ability to use sound cues for postural control is diminished with hearing loss but restored with hearing aids [36].

Both the cochlea and the vestibular receptors, including the semicircular canals and otolith organs, are anatomically and phylogenetically related, sharing the continuous membranous labyrinth of the inner ear and operating through similar receptor cells. Consequently, abnormalities or diseases affecting the inner ear are likely to impact both hearing and balance [28,33]. Damage to the cochlea, regardless of the cause, can negatively affect the vestibular organs [38]. This strong relationship is evident in the high prevalence of vestibular disorders among children with sensorineural hearing loss [39]. Injury to the vestibular organs can lead to balance and motor development disorders [40], and greater balance instability is directly correlated with the severity of sensorineural hearing loss [30].

Studies revealed common vestibular dysfunction and structural changes in the labyrinths of children with sensorineural hearing loss [12,41]. Deaf or hearing-impaired school-aged children

have poorer balance and motor skills than their typically developing peers [16,32,42]. Specifically, children with sensorineural hearing loss demonstrate inferior postural control compared to their typically developing counterparts of the same gender and age [32,42].

In terms of the degree hearing loss, individuals in the mild group demonstrated notably superior balance performance compared with those in the profound, severe, and moderately severe groups [30]. Similarly, those in the moderate group were significantly better than those in the profound, severe, and moderately severe groups were. Additionally, moderate to severely impaired hearing in the moderately severe group displayed significantly better static balance than did that in the profound and severe groups ([30,43]. Furthermore, there is a notable association between higher degrees of hearing loss and increased odds of falling, with a 1.4x increased likelihood of falling for every 10 dB increase in hearing loss [7].

Children with acquired causes of hearing impairment often have higher abnormal scores on clinical balance tests compared to those with other etiologies [44]. Additionally, children whose hearing loss results from prematurity or postnatal meningitis exhibit poorer balance performance than those with other causes [32].

### 2.5 Effects of Age, Sex, Anthropometry, and Physical Activity on Balance

Balance development begins in infancy with the acquisition of head and trunk control. Milestones such as walking, running, and jumping are attained during the toddler and preschool years [16]. Typically, infants start mastering standing and then walking between 10 and 18 months. Preschoolers continue to refine their locomotion and motor skills, heavily relying on balance, stability, and postural control. By approximately 6 to 7 years of age, children begin to exhibit an adult-like balance [45].

Infants and young children (4 months to 2 years old) rely on the visual system to maintain balance. Between the ages of 3 and 6 years, they start to integrate somatosensory information [43]. From 6 to 8 years, there is a transition in postural behavior organization due to the maturation of the somatosensory and vestibular systems, with vision becoming less dominant compared to other systems. Finally, by 7 to 10 years of age, children can resolve sensory conflicts and effectively use the vestibular system alongside other sensory systems [43].

Children's postural stability improves with age [21], as evidenced by clinical balance tests; the youngest children in the hearing-impaired group consistently achieved lower scores than those in older age groups. Notably, the most significant differences were observed during tests performed with eyes closed, indicating greater balance maintenance difficulty, especially in younger children with hearing impairments [44]. Children with SNHL exhibited lower balance performance than did their normal-hearing counterparts in static balance tests (SLS with eyes open and closed), in PBS, and in FRT in all age groups [46]. Another study indicated that children with hearing impairments scored lower on various clinical balance tests across all age groups [44].

The findings of Said [44] revealed that children with hearing impairments had lower success rates in different balance skill tests than did children with normal hearing of the same sex. Another study, suggested that children with sensorineural hearing loss have poorer postural control skills than their normal-hearing counterparts of the same sex did [42]. Similarly, a research has indicated that children with SNHL exhibit greater balance instability than their NH peers of similar sex [30]. The static balance of girls was significantly greater than boys when all degrees of hearing loss were combined. The static balance increases with decreasing hearing loss when both sexes are combined and when both sexes are considered separately [11,32].

Physical delays (e.g., balancing, postural control, and coordination between limbs) associated with deaf or hearing impaired children combined with social and emotional delays may reduce children's participation in physical activity [16]. Engaging in sports and recreational activities appears to offer promising avenues for enhancing the balance and gait of children and adolescents with sensorineural hearing loss [31]. This is supported by findings indicating that children who participated in sports classes demonstrated improved body balance [21]. Acknowledging the need for increasing levels of recommended physical activity and improving accessible assessments for children who are deaf or hearing-impaired may improve levels of physical activity [16]. Balance exercises have been shown to enhance the postural control of children diagnosed with sensorineural hearing loss [47]. Given these findings, balance training programs are recommended for children with hearing impairment exhibiting movement and stability deficits [17].

Additionally, associations have been found between excess body weight and below-normal values in certain balance conditions, indicating the interference of anthropometric indicators in children's postural balance [48]. Children with disabilities, including children who are deaf and hearing impaired tend to be less

physically active, substantially fit, and have a greater average body weight than their typically developing peers [16]. The study revealed a positive impact of greater body height on postural stability [41].

### 2.6 Static and Dynamic Balance of Normal and Hearing-Impaired Children

Static balance is the ability to stay steady while holding a position, such as standing on one leg briefly. In children, vestibular issues may present during tasks like the one-leg stance test. Dynamic balance is about keeping stable while moving, such as while walking or running. Children need good balance for different activities and environments [16].

Researchers have reported that, compared with their typically developing peers, children with hearing impairments exhibit differences in static balance [16]. Similarly, a previous study revealed that students with hearing loss exhibited significantly lower static balance than normal-hearing peers did [12]. Moreover, children with severe and profound SNHL demonstrate static balance instabilities compared with children with normal hearing [30]. Another study demonstrated that static balance abilities were significantly poorer in children with hearing impairments than in normal-hearing peers [44]. In contrast, one study revealed that hearing-impaired children demonstrated superior static balance parameter values than their peers with normal hearing [15].

A pervious study revealed that normal hearing children demonstrated greater balance according to the FRT than did children with hearing impairments [27]. Similarly, in a previous study [12], students with hearing loss exhibited lower dynamic balance performance than did those with normal hearing. Another study revealed that dynamic balance abilities are significantly poorer in children with hearing impairments than in their normal hearing peers [44]. Similarly, [38] demonstrated that deaf children achieved significantly lower equilibrium scores than did the control group. However, another study did not find significant differences in dynamic balance between hearing impaired and normal hearing children [17,49].

### 2.7 Conceptual Framework of the Study

The framework of this study is adopted from previous studies [16,17,30,36,41,42]. Factors expected to affect static and dynamic balance either negatively or positively represented in this framework (**Figure 1**).

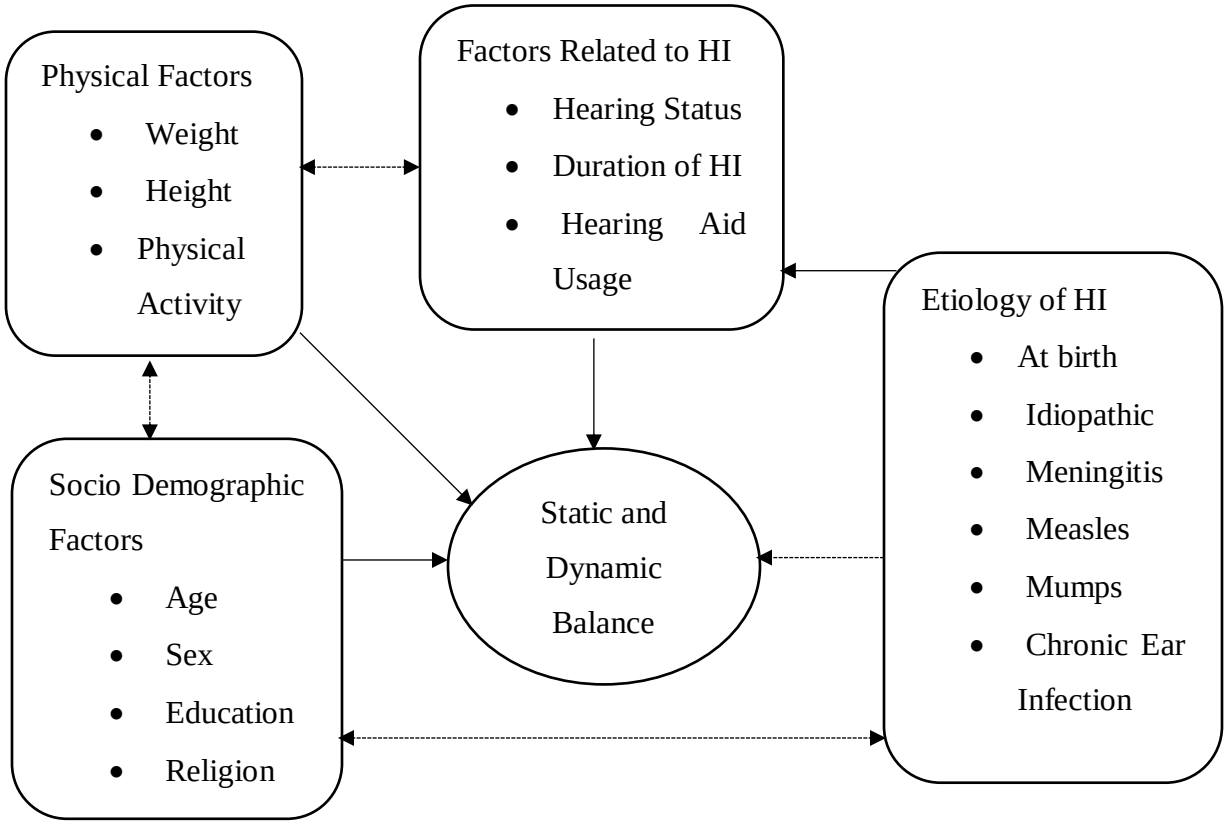



**Figure 1: Conceptual framework**:

## 3. Hypotheses

Hypothesis 1: There is a significant difference in static balance performance between schoolchildren with hearing impairments and those with normal hearing

Hypothesis 2: There is a significant difference in dynamic balance performance between schoolchildren with hearing impairments and those with normal hearing

Hypothesis 3: There is a correlation between static and dynamic balance performance in normal and hearing-impaired schoolchildren

# 4. Objectives

## 4.1 General Objective

To assess static and dynamic balance performance and associated factors among normal and hearing-impaired schoolchildren in Addis Ababa public schools

## 4.2 Specific Objectives

To assess the static balance performance of normal and hearing-impaired schoolchildren

To assess the dynamic balance performance of normal and hearing-impaired schoolchildren

To determine the correlation between static and dynamic balance performance in normal and hearing-impaired schoolchildren

To determine the factors affecting the static and dynamic balance performance of normal and hearing-impaired schoolchildren

# 5. Materials and Methods

## 5.1 Study Area

The research was conducted in Addis Ababa; it is the capital city of Ethiopia and is located at an elevation of 2355 meters above sea level. The city is divided into 11 sub-cities and 100 kebeles with an estimated population of 5,703,628 [50]. The city has 444 government schools, as identified by the Addis Ababa Education Bureau (AAEB) and Splash. This educational landscape comprises 36% (160) preschools, 48% (213) primary schools, 13% (58) secondary schools, and 3% (13) preparatory schools (grades 11-12) (Michael et.al, 2018). According to the Addis Ababa City Administration Education Bureau's report, approximately 12 public schools provide inclusive education for students with normal hearing and hearing impairments in the city. Menelik-II schools, the first modern school in Ethiopia opened in 1908, are the sole institution offering both primary and secondary inclusive education and Alpha special schools for the deaf; provide education from KG1 up to Grade 8 for hearing-impairments, established in 1958 EC. These schools were our study sites.

## 5.2 Study Design and Period

A comparative multicenter cross-sectional study was conducted from September 1, 2023, to May 30, 2024.

## 5.3 Population

### 5.3.1 Source Population

All the schoolchildren, both with normal hearing and hearing-impairments, attended the selected primary and secondary public schools in Addis Ababa.

### 5.3.2 Study Population

Schoolchildren with normal hearing and those with hearing-impairments who met the inclusion criteria at selected primary and secondary public schools in Addis Ababa during the data collection period.

### 5.3.3 Study Participants

Schoolchildren with normal hearing and those with hearing-impairments who were randomly selected and had consent forms. Hearing-impaired schoolchildren were recruited from the Alpha Special Deaf School and Menelik-II Primary and Secondary Schools, whereas children with normal hearing were recruited from Menelik-II primary and secondary schools.

## 5.4 Eligibility Criteria

### 5.4.1 Inclusion Criteria

Schoolchildren who were both normal and hearing impaired, aged between 7 and 18 years, and whose parents consented and agreed with the students who attended the selected public school during the data collection period to participate in this study were included in the study.

### 5.4.2 Exclusion Criteria

Children with known neurological problems, orthopedic conditions, identified visual issues, a history of head injuries and students' systemic diseases (e.g., diabetes mellitus, heart and renal problems) and those with mental retardation were excluded from this study. Children with a history of alcohol and drug consumption were not included in the study.

### 5.5 Sample Size Determination and Sampling Technique

#### 5.5.1 Sample Size Determination

To determine the appropriate sample size for the study, we utilized a confidence level of 95% corresponding to a critical value ($za/2$ = 1.96), and a power of 80% ($z\beta$= 0.84). We based our prevalence rates on previous research [22], which reported a 4.9% prevalence of balance disorders in individuals with normal hearing (p1= 0.049) and a 20.9% prevalence in individuals with hearing impairments (p2= 0.209). Given the 1:1 ratio of participants with normal hearing to those with hearing impairments, we calculated the required sample size using the double population proportion formula:

$$\mathbf{n} = \frac{\left(\mathbf{Z}_{\{\frac{\alpha}{2}\}} + \mathbf{Z}_{\{\beta\}}\right)^{\mathbf{2}} . (\mathbf{p1}(\mathbf{1} - \mathbf{p1}) + \mathbf{p2}(\mathbf{1} - \mathbf{p2}))}{(\mathbf{p1} - \mathbf{p2})^{\mathbf{2}}}$$

$$\boldsymbol{n}1 = \frac{(1.96 + 0.84)^2 . \left(0.049(1 - 0.049) + 0.209(1 - 0.209)\right)}{(0.049 - 0.209)^2}$$

.

$$\text{n1} = \frac{7.84 . (0.05+0.17)}{(0.16)^2} = \frac{\mathbf{1.7248}}{\mathbf{0.025}}$$

n1 = 68.9 n1≈ 69

Where:

Zα/2: value for the desired CL (1.96 for 95% confidence)

• Zβ: value for the desired power (0.84 for 80% power)

• p1: proportion (0.049 prevalence of balance disorder in normal hearing)

• p2: proportion (0.209 prevalence of balance disorder in hearing impaired)

• n: sample size per group

Therefore, the calculated sample size was 138 (69 samples per group), and considering a 10% nonresponse rate, the final sample size was adjusted to a total sample size of 152 (76 participants per group).

### 5.5.2 Sampling Technique and Sampling Procedures

The total number of students with normal hearing and hearing impairments in the selected public schools was obtained before data collection from the Addis Ababa Education Bureau and from schools. Students who subsequently fulfilled the inclusion criteria were randomly selected via the lottery method. The random selections took place in the classroom in the presence of all the students, a sign language teacher, a school clinic nurse and the researcher.

To ensure fair representation, the number of study participants from each class was determined using the proportional allocation formula. This approach ensured an equal distribution of 152 study participants across all grades, from grade 1 to grade 12. Each grade included approximately 12 children, with six with normal hearing and six with hearing impairments (**Figure 2**).

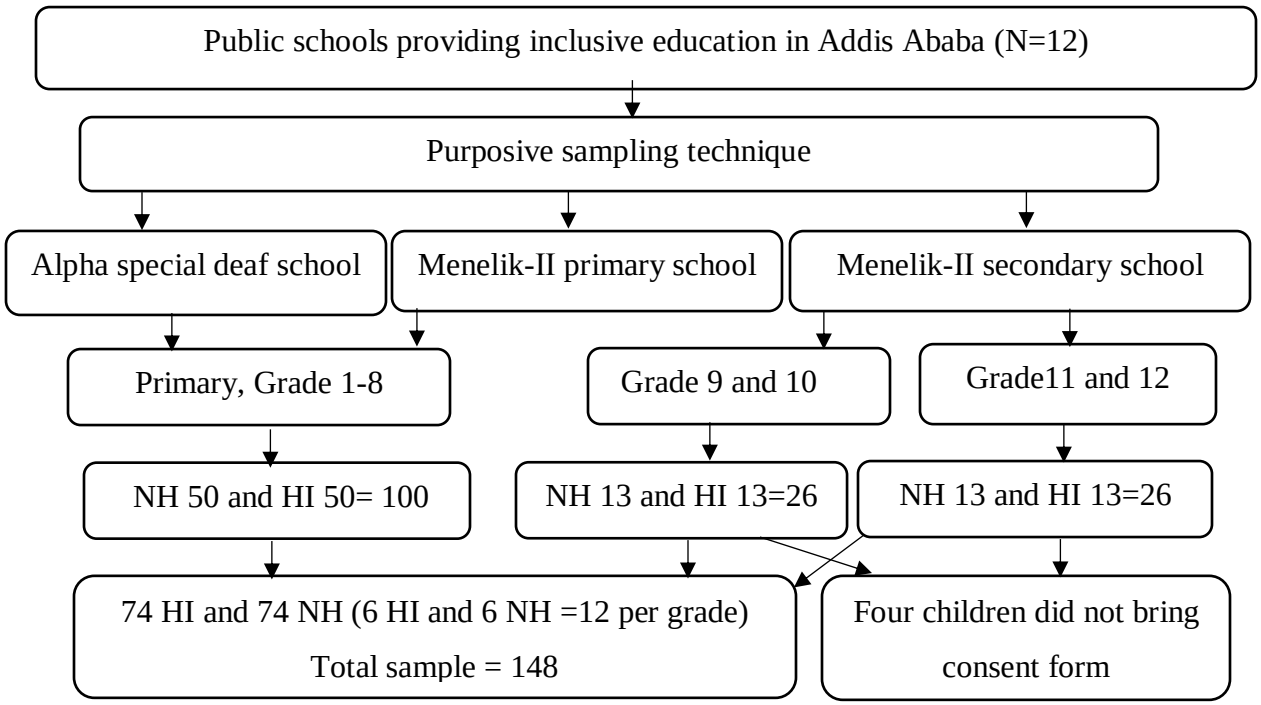



**Figure 2: Sampling Procedure**.

### 5.6 Study Variables

#### 5.6.1 Dependent Variable

Static and dynamic balance performance

#### 5.6.2 Independent Variables

Sociodemographic characteristics (age, sex, educational status, and religion), hearing status, utilization of hearing aids, weight, height, physical activity, and the etiology of hearing impairments were the predictor variables.

### 5.7 Operational Definition

**Hearing loss**: A person who is unable to hear thresholds of <20 dB or better in both ears [3].

**Deafness**: Profound hearing loss, which implies very little or no hearing [3].

**Conductive hearing loss**: Hearing loss is attributed to problems in the outer or middle ear [4].

**Sensory neural hearing loss**: is caused by problems of the inner ear or hearing nerve [4].

**Mixed hearing loss**: Includes both a conductive and a sensory neural hearing loss [4].

**No impairment**: Hearing sounds with less than 20 dB [3].

**Mild hearing loss**: Able to hear sounds at 20–34 dB [3].

**Moderate hearing loss**: Able to hear sounds at 35–49 dB [3].

**Moderately severe hearing loss**: Able to hear sounds at 50–64 dB [3].

**Severe hearing loss**: Able to hear sounds at 65–79 dB [3].

**Profound hearing impairment**: Able to hear sounds at 80–94 dB [3].

**Complete or total hearing loss**: Able to hear sounds at 95 dB or greater [3,52].

**Dominant arm/leg:** An arm that a child uses for writing, eating or throwing, and a leg that is used to kick a ball [17].

**Static balance**: Ability to hold our body in a specific position and posture [12,17]

**Single leg stance (SLS) test**: This test is used to assess static postural and balance control [17,53]. A duration of ≥30 seconds is considered normal, 15–29 seconds is classified as mild, and <15 seconds is categorized as moderate to severe [54].

**Dynamic balance**: Ability to maintain balance while one's body is moving and walking [12,17].

**Functional reach test (FRT**): This test is used to assess dynamic balance by measuring the maximal forward reach over a fixed base of support [17,53,55]. For children aged 7 years and above, normal FRT values are 19.5 cm and higher [43].

**Pediatric balance scale (PBS)**: This scale is a reliable functional balance measurement in children and has been demonstrated to have good test-retest and interpreter reliability when used with school-age children to measure balance [29,46,56,57].

### 5.8 Data Collection Tools

The structured Amharic version questionnaire was used to gather data on sociodemographic characteristics and existing medical conditions. It was availed for parents to fill out at home and send it back. The responses were subsequently translated back into English and then entered into the Kobo Toolbox.

Anthropometric measurements were also performed. Height was measured using a stadiometer and weight was measured via a digital weighing scale. Static balance was assessed using the single leg stance (eye open and closed) test, whereas dynamic balance was assessed using the functional reach test, and functional balance was evaluated via the pediatric balance scale. Additionally, an audiometer was employed to evaluate hearing status.

### 5.9 Data Collection Procedure

After the instructions were delivered to the normal-hearing children verbally by the researcher and school nurse and in sign language to hearing-impaired children by the school's sign language teacher. To ensure clarity, children were asked if they understood the assessment procedures, and any uncertainties were addressed by repeating the instructions until all questions were resolved, ensuring a smooth and effective start of the assessments.

The trained school nurses then entered sociodemographic data, which had been completed by the children's families, into the Kobo Toolbox. They proceeded with anthropometric measurements and balance assessments. Simultaneously, a trained school audiometrist evaluated the children's hearing status, with the PI overseeing the entire process.

#### 5.9.1 Anthropometry Measurements

The participants' height was measured with a stadiometer and their weight was measured with a digital scale, with the participants in barefoot and in light clothing. Height was recorded in centimeters, and weight was recorded in grams [17].

### 5.9.2 Hearing Assessments

A trained school audiometrist, who is also a sign language teacher, conducted the hearing assessments in a quiet room using a Micro-Mate 304 screening audiometer (Denmark). Pure tone audiometry was performed at frequencies of 250, 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz [30]. The children were instructed to raise their hands each time they heard a beep, and to lower their hands when the beep ceased. During the procedure, headphones were worn. A child who responded to all tones in both ears was marked as a 'pass,' whereas a child who failed to respond to any of the tones was marked as a 'fail, and its value was recorded [5]. The World Health Organization criteria were employed to determine the degree of hearing loss as follows: normal (<20 dB), mild (20-34 dB), moderate (35-49 dB), moderately severe (50-64 dB), severe (65-79 dB), profound (80-94 dB), and complete deafness (≥95 dB) [52,58].

### 5.9.3 Static Balance Assessment

Single-leg stance test: This test is a widely used clinical tool for assessing static balance [17,44,59]. In this study, a standardized protocol was followed. Children were instructed to stand on their dominant leg for as long as possible during each trial. The opposite leg was bent at the knee, with the sole of the raised foot positioned at the knee level of the standing leg. Timing with a stopwatch began once the subject achieved a stable position with the non-dominant leg raised. They stood barefoot, placed their hands on their hips, and looked straight ahead [17,44,59].

Imbalance was defined, and the test was stopped if the child placed the lifted foot on the floor, removed either hand from their hips to regain balance, hopped, opened their eyes during the eyes-closed test, and moved their weight-bearing foot. The test was terminated after a maximum of 60 seconds had passed [60,61]. Each child was allowed one practice trial before data collection. The test was then performed twice, both with eyes open (EO) and eyes closed (EC), with rest intervals of 3 to 5 minutes between trials [17,44,59]. The best maximum time for each balance test was used for analysis.

### 5.9.4 Dynamic Balance Assessment

Functional reach test: This test is used to assess dynamic balance by measuring the maximum distance a person can reach forward while maintaining a stable base of support [17,55]. Known for its precision and reliability, FRT is easily performed in homes and outpatient settings [55].

The participants performed the FRT using their dominant arm, identified by their preferred hand for tasks such as writing, eating, or throwing a ball [17]. A meter was fixed to the wall parallel to the floor, with the zero mark aligned with the participant's acromion. The participants stood with their feet parallel, raised their dominant arm to 90°, and made a fist. The initial reach was measured from the acromion process to the third metacarpal in centimeters. They then reached forward as far as possible, without touching the wall or taking a step, and held the position for 3 seconds [55,62]. The end reach was recorded, and the process was repeated three times. The average of these trials was calculated, and the difference between the initial reach and final reach was used for analysis [17,55,62].

### 5.9.5 Pediatric Balance Scale for Functional Balance

The Pediatric Balance Scale (PBS): Adapted from the Berg Balance Scale (BBS) is a reliable tool for assessing functional balance in school-aged children. Its quick administration (less than 15 minutes), easy scoring, and lack of need for specialized equipment make it a preferred choice in routine physical therapy evaluations [56,57]. The PBS assesses a range of activities essential for safe, independent functioning at home, at school, and in the community. It includes 14 tasks (6 static and 8 dynamic) [28,63]. To conduct the assessment, the following materials were used: a bench, a chair with back support and armrests, a stopwatch, a meter, a step stool, a chalkboard eraser, a ruler, and chalk [46,56,57].

The Pediatric Balance Scale (PBS) consists of 14 tasks that require the child to perform static and dynamic balance. It includes sitting to standing, standing to sitting, transfers, standing unsupported, sitting unsupported, standing with the eyes closed, standing with the feet together, standing with one foot in front, standing on one foot, turning 360 degrees, turning to look behind the shoulders, retrieving objects on the floor, placing alternate foot on stool, and reaching forward with an outstretched arm [32,46]. Each task was scored from 0 to 4, with 4 indicating better performance. The scores for all tasks were summed, with a maximum possible score of 56 points.

Higher scores were associated with better balance. Typically, healthy children aged seven years and older achieve the maximum score of 56, and there is no mention in the literature regarding the classification of lower scores [46,56,57]. However, scores of 45 or below are associated with a high risk of recurrent or multiple falls with a significant increase below a score of 40 [28].

### 5.10 Data Quality Control

Standardized tools were utilized to collect the data. To minimize information bias, the questionnaires were translated from English to the local language, Amharic, and then back to English to ensure consistency. Data collectors underwent a one-day training to equip them with the skills needed to collect appropriate data from study participants.

A pretest was conducted on 10% of the study participants a week before the data collection period. During this pretest, the internal consistency of the Kobo Toolbox was assessed. Based on the pretest results, several modifications were made, including correcting typing errors, reorienting data collectors, and rearranging the questionnaires. At the end of each data collection day, the principal investigator reviewed the data on the Kobo Toolbox server, discussed any issues with the data collectors, and provided daily feedback until data collection was completed. To address any errors or ambiguities the principal investigator took corrective measures. However, the restrictions of Kobo Toolbox application made data incompleteness impossible.

### 5.11 Data Processing and Analysis

Data were collected using Kobo Toolbox and exported directly into SPSS (version 27) software for cleaning, coding, editing, and analysis. The normality of the data was assessed using the Kolmogorov-Smirnov/Shapiro-Wilk tests. Independent-samples t-tests were used to compare results between normal-hearing and hearing-impaired children. Descriptive statistics were presented with means and standard deviations, and a p-value of less than 0.05 was considered statistically significant. Correlation and linear regression models were employed to explore relationships among continuous variables. The study's findings were interpreted based on these comprehensive statistical analyses.

### 5.12 Ethical Considerations

This study received approval from the Departmental Research and Ethics Committee (DREC) of the Medical Physiology Department, School of Medicine, Health Science College, from Addis Ababa University. Approval was granted under reference number Phys/18/2024. Following ethical clearance, the investigators subsequently proceeded to the Addis Ababa Education Bureau and selected public schools to obtain authorization for data collection. Approval was obtained from the Director of the Special Needs Inclusive Education and Adults Basic Education Directorate, City Government of Addis Ababa Education Bureau, under reference number □9.1/11,008/□28-40/35.

Prior to data collection, the children were informed about the objectives, and purpose of the study, and had the right to withdraw at any time. They were also instructed to share this information with their families and return it with a signed informed consent form. This ensured that written informed consent was obtained from the participant's families via a signed questionnaire, guaranteeing voluntary participation. The confidentiality and privacy of the participants were strictly maintained by omitting any personal identifiers, and the data were collected anonymously. Thus, this study was conducted in accordance with the Declaration of Helsinki (1964), upholding the highest ethical standards for human studies.

### 5.13 Dissemination of the Results

The results will be shared with stakeholders to raise awareness and establish baseline data, supporting future interventions and research. This information will aid informed decision-making and policy development in relevant sectors. The findings will be submitted to the Department of Physiology at Addis Ababa University's College of Health Sciences, and key institutions such as the Ministry of Health, Ethiopian Public Health Institute, Education Bureau, and the selected schools. Furthermore, the study's findings will be presented in scientific workshops and conferences. Finally, the results will be submitted to reputable scientific journals for publication.

## 6. Results

### 6.1 Sociodemographic Characteristics of the Study Participants

One hundred forty-eight sex-matched normal and hearing-impaired schoolchildren (74 from each group) participated in this study, with a response rate of 97.37%. The age range of the participants was 7 to 18 years. The majority of the participants were between 15 and 18 years old 67 (45.3%), while the smallest proportion were between 7 to 10 years 32 (21.6%). One hundred participants were from grades 1-8, and forty-eight were from grades 9-12. The largest proportion in both groups were Orthodox Christians 107 (72.3%) (**Table 1**).

**Table 1: Sociodemographic Characteristics of Study Participants**

| Characteristics | Categories | Normal-hearing n=74(50%) | Hearing-impaired n=74(50%) | Total n=148(100%) |
|---|---|---|---|---|
| Sex | Male | 37(25) | 37(25) | 74(50) |
| | Female | 37(25) | 37(25) | 74(50) |
| Age(years) | 7-10 | 19(12.8) | 13(8.8) | 32(21.6) |
| | 11-14 | 24(16.2) | 25(16.9) | 49(33.1) |
| | 15-18 | 31(20.96) | 36(24.34) | 67(45.3) |
| Education | 1-4 | 25(16.9) | 25(16.9) | 50(33.8) |
| (Grade/Class) | 5-8 | 25(16.9) | 25(16.9) | 50(33.8) |
| | 9-10 | 12(8.1) | 12(8.1) | 24(16.2) |
| | 11-12 | 12(8.1) | 12(8.1) | 24(16.2) |
| Religion | Orthodox | 50(33.8) | 57(38.5) | 107(72.3) |
| | Muslim | 15(10.1%) | 12(8.1) | 27(18.2) |
| | Protestant | 9(6.2) | 5(3.4) | 14(9.5) |

### 6.2 Anthropometric and Clinical Characteristics

Children with normal hearing had significantly lower body weight than hearing-impaired schoolchildren (40.65±11.5 vs. 45.5±11.3 Kg, $p<0.01$). However, there were no significant differences in height and age between the normal-hearing and hearing-impaired schoolchildren (**Table 2**).

**Table 2: Anthropometry and Age of Normal and Hearing-Impaired Schoolchildren**

| Characteristics | Categories | Normal Hearing (mean ±SD) | Hearing-Impaired (mean ±SD) | p value[+] |
|---|---|---|---|---|
| Anthropometry | Height (cm) | 149.8±15.4 | 153.9±14.7 | 0.097 |
| | Weight (kg) | 40.65±11.5 | 45.5±11.3 | 0.010 |
| Age (years) | | 13.19±3.53 | 13.95±3.4 | 0.188 |

+: Independent t-test

The majority 45 (60.8%) of hearing-impaired schoolchildren had profound hearing loss, whereas 18 (24.3%), 7 (9.4%), and 4 (5.4%) had severe, moderately severe, and moderate hearing loss, respectively (**Figure 3**).

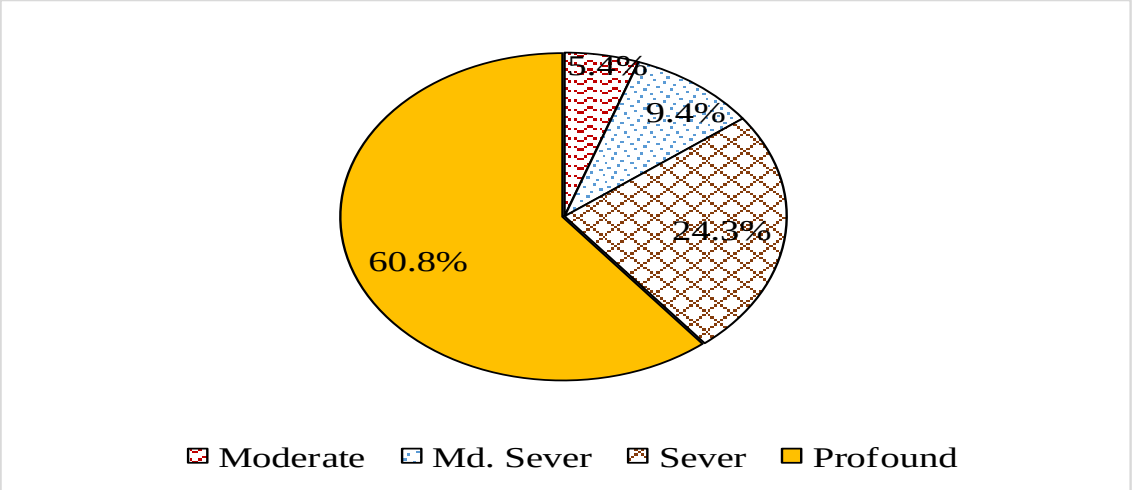



**Figure 3: Hearing Status of Hearing-impaired Schoolchildren**: Md: Moderately

Concerning the etiology of hearing loss, 51 (68.9%) of cases were congenital, with 18 (24.3%), 4 (5.4%), and 1 (1.4%) attributed to idiopathic-causes, chronic ear infections, and falls, respectively. The majority 68 (91.8%) of hearing impairments occurred at birth, 3 (4.1%) before age 5, and 3 (4.1%) between ages 5 and 10. However, 72 (97.3%) of the children with hearing impairments did not use hearing aids. Only three (2%) of the entire group being involved in physical activities outside of the school, all of whom were normal-hearing children. None of the hearing-impaired students participated in physical activities outside of school (**Table 3**).

**Table 3: Clinical Characteristics of Schoolchildren Based on Parents Report**

| Parameters | Categories | Hearing-impaired n=74(100%) |
|---|---|---|
| Etiology of Hearing Loss | Congenital | 51(68.9) |
| | Idiopathic | 18(24.3) |
| | Chronic-Ear Infection | 4(5.4) |
| | Falling | 1(1.4) |
| Onset of HI | At Birth | 68(91.8) |
| | <5 | 3(4.1) |
| | 5-10 | 3(4.1) |
| Non-Hearing-aids User | | 72(97.3) |

HI: Hearing Impairment

### 6.3 Static and Dynamic Balance Performance Comparison

The static balance scores in the single leg stance eyes open test (47.6±12.2 vs. 30.6±15.8 sec, p<0.001) and eyes closed test (15.4±7.9 vs. 4.2±4.2 sec, p<0.001) were significantly greater in the normal hearing group than in the hearing-impaired group. The dynamic balance scores in the functional reach test (26.3±6.6 vs. 22.2±4.3 cm, p<0.001), and the pediatric balance scale (55.8±0.5 vs. 54.4±1.2, p<0.001) scores of the children with normal hearing were significantly greater than the hearing-impaired group (**Figure 4**).

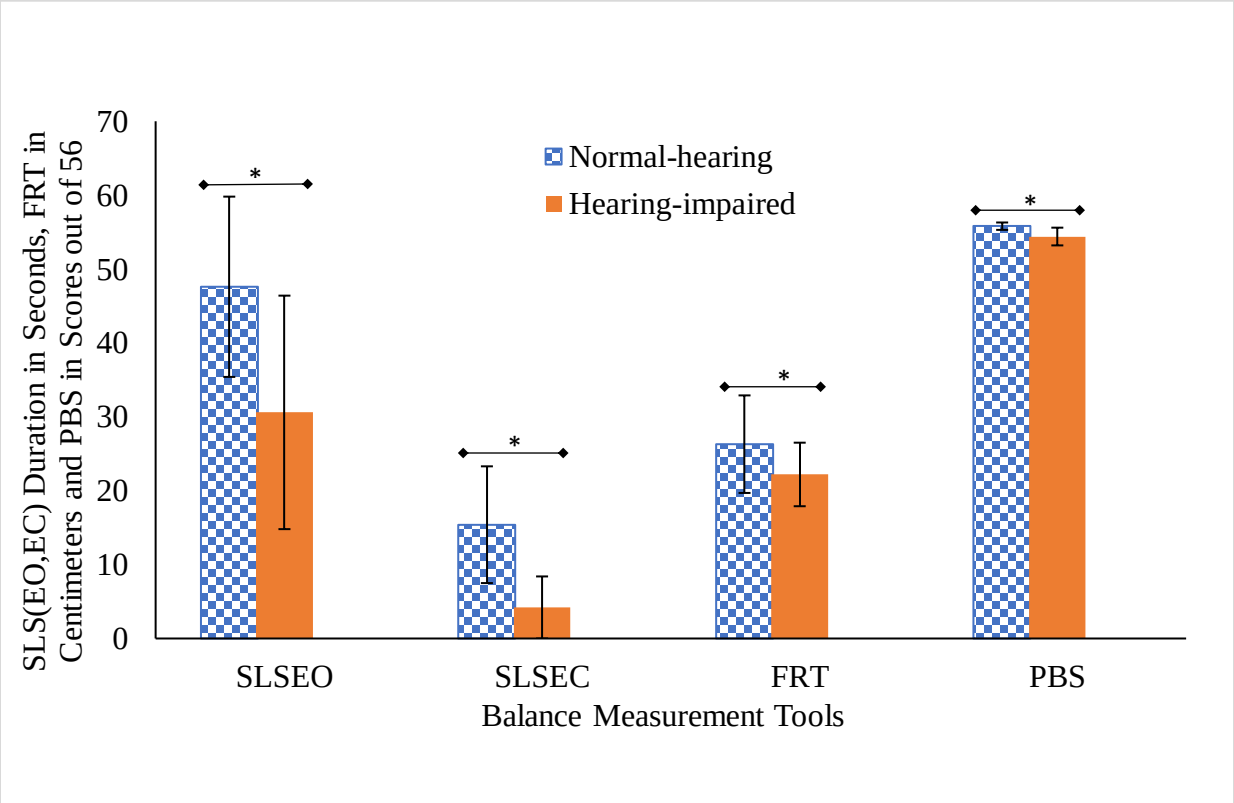



**Figure 4: Static and Dynamic Balance Performance Comparison**. Each bar represents mean ± SD of SLSEO, SLSEC, FRT and PBS. * p<0.001 when hearing-impaired group compared with normal hearing group with Independent t-test. PBS: Pediatric Balance Scale, FRT: Functional Reach Test, SLSEC: Single leg instance eyes close, SLSEO: Single leg instance eyes open.

### 6.3.1 Effect of Sex on Balance Performance

The SLSEO (45.5±12.6 vs. 29.2±15.8 sec, P<0.001), SLSEC (14.2±7.5 vs. 5.4±5.24 sec, P<0.001), FRT (25.7±6.3 vs. 21.8±4.1 cm, P<0.002), and PBS (55.8±0.5 vs. 54.5±1.2 score, P<0.001), scores were significantly greater in males with normal hearing than the same sex with hearing impairments. The SLSEO (49.7±11.5 vs. 32.0±15.9 sec, P<0.001), SLSEC (16.6±8.4 vs. 3.2±2.0 sec, P<0.001), FRT (26.9±6.9 vs. 22.6±4.5 cm, P<0.003), and PBS (55.9±0.5 vs. 54.3±1.1 score, P<0.001), scores of females with normal hearing were significantly greater than those of the same sex of hearing-impaired children (**Figure 5**).

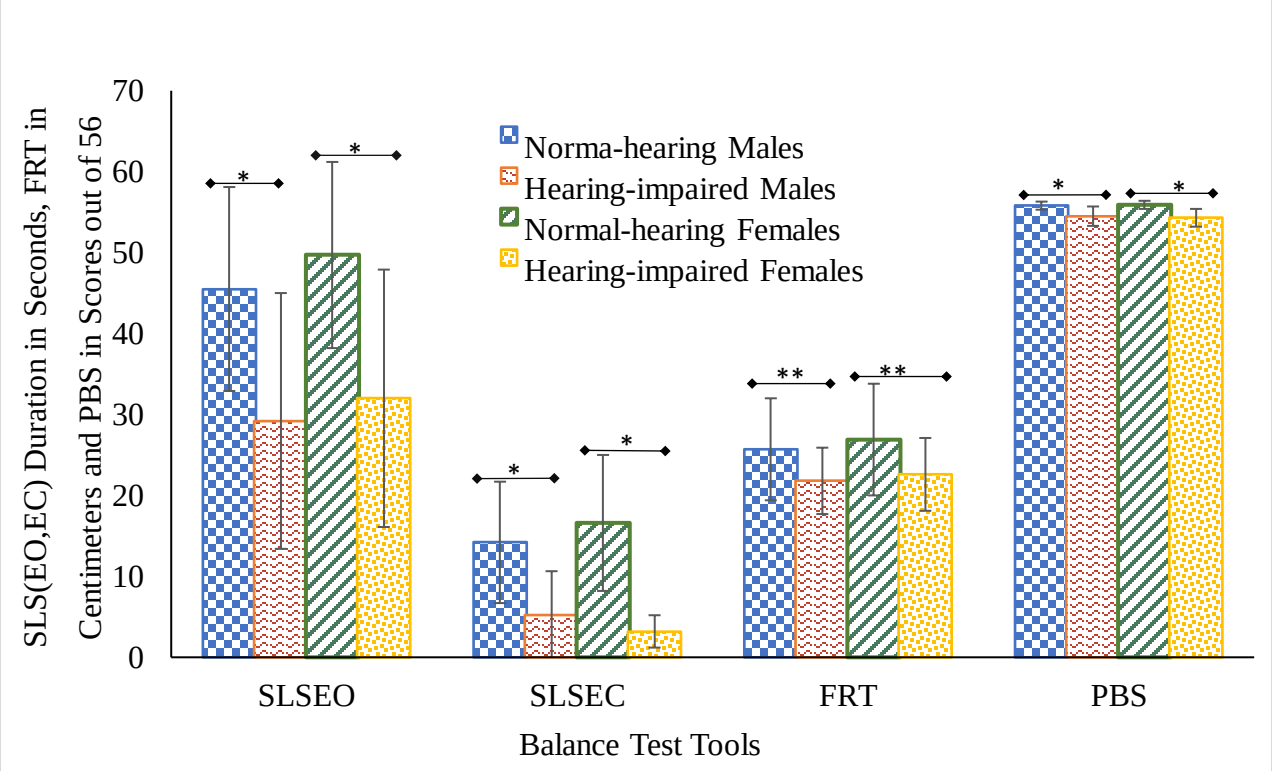



**Figure 5: Static and Dynamic Balance Performance Comparison of Children Categorized by Sex**. Each bar represents mean ± SD of SLSEO, SLSEC, FRT and PBS. * P<0.001, ** P<0.01, when hearing-impaired group compared with normal hearing group categorized by sex using Independent t-test. SLSEC: Single leg instance eyes close, SLSEO: Single leg instance eyes open, PBS: Pediatric Balance Scale, FRT: Functional Reach Test.

### 6.3.2 Effect of Age on Balance Performance

The SLSEO (40.7 ± 13.1 vs. 28.2 ± 14.6 sec, P<0.017), SLSEC (12.2 ± 7.1 vs. 4.9 ± 4.9 sec, p<0.001), FRT (18.9±2.8 vs. 16.8±2.5 cm, P<0.039), and PBS (55.4±0.77 vs. 54.0±1.6, P<0.01) scores of children in age 7-10 years were significantly greater in normal hearing than the hearing-impaired of the same age group.

The SLSEO (47.8±12.9 vs. 31.7±14.0 sec, P<0.001), SLSEC (14.6±7.4 vs. 5.8±5.2 sec, P<0.001), FRT (25.6±5.7 vs. 22.7±4.3 cm, P<0.05), and PBS (55.8±0.4 vs. 54.4±1.3 scores, P<0.001) scores of children in age 11-14 years were significantly greater in normal hearing than the hearing - impaired of the same age group.

The SLSEO (51.7±9.2 vs. 30.7±17.7 sec, P<0.001), SLSEC (19.3±7.2 vs. 3.2±2.9 sec, P<0.001), FRT (31.3±3.9 vs. 23.7±3.3 cm, P<0.001), and PBS (55.9±0.2 vs. 54.5±0.8, P<0.001) scores of children in age 15-18 year were significantly greater in normal hearing than the hearing-impaired of the same age group (**Table 4**).

**Table 4: Balance Performance of Normal and Hearing-Impaired Children, Categorized by Age**

| | Age groups | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 7-10 years (n=32) | | | 11-14 years (n= 49) | | | 15-18 years (n= 67) | | |
| Balance Tests | Normal hearing | Hearing-impaired | P value$^{+}$ | Normal hearing | Hearing-impaired | P value$^{+}$ | Normal hearing | Hearing-impaired | P value$^{+}$ |
| SLSEO | 40.7±13.1 | 28.2±14.6 | 0.017 | 47.8±12.9 | 31.7±14 | 0.001 | 51.7±9.2 | 30.7±17.7 | 0.001 |
| SLSEC | 12.2±7.1 | 4.9±4.9 | 0.001 | 14.6±7.4 | 5.8±5.2 | 0.001 | 19.3±7.2 | 3.2±2.9 | 0.001 |
| FRT | 18.9±2.8 | 16.8±2.5 | 0.039 | 25.6±5.7 | 22.7±4.3 | 0.05 | 31.3±3.9 | 23.7±3.3 | 0.001 |
| PBS | 55.4±0.77 | 54.0±1.6 | 0.01 | 55.8±0.4 | 54.4±1.3 | 0.001 | 55.9±0.2 | 54.5±0.8 | 0.001 |

Each value represents the mean ± SD of balance tests performed by children with normal and hearing-impaired groups categorized by age. SLSEO; Single Leg Stance Eyes Opened, EC: Eyes Closed, FRT: Functional Reach Test, PBS; Pediatric Balance Scale, +; Independent t-test

In the normal hearing group, children aged 7 to 10 years old had significantly lower balance score in the SLSEO test compared to those aged 15 to 18 years (-11.1 ± 3.3, $p < 0.004$). Similarly, children aged 11 to 14 years scored lower than the 15 to 18-years old in the SLSEC test (-8.1 ± 1.9, $p < 0.001$). Furthermore, children aged 7 to 10 scored lower in the FRT compared to both the 11 to 14-years (-6.6 ± 1.3, $p < 0.001$) and the 15 to 18-years (-12.3 ± 1.27, $p < 0.001$). Additionally, children aged 11 to 14 scored lower in the FRT compared to the 15 to 18-years (-5.7 ± 1.2, $p < 0.001$). In the PBS test, children aged 7 to 10 also demonstrated poorer balance performance compared to both the 11 to 14-years (-0.41 ± 0.14, $p < 0.013$) and the 15 to 18-years (-0.55 ± 0.13, $p < 0.001$). Among hearing-impaired children, the 7-10 years group performed poorer than both the 11-14 (-5.8 ± 1.2, $p<0.001$) and 15-18 year groups (-6.9 ± 1.2, $p<0.001$) in the FRT (**Table 5**).

**Table 5: Comparison of Balance among Age Groups in Normal and Hearing-impaired Children**

| Balance Tests | Hearing Status | Age Group | Mean difference[+] | Std. Error | P-value |
|---|---|---|---|---|---|
| SLSEO | Normal Hearing | 7-10 vs. 11-14 years | -7.1 | 3.5 | 0.1 |
| | | 7-10 vs. 15-18 years | -11.1 | 3.3 | 0.004 |
| | | 11-14 vs.15-18 years | -3.9 | 3.1 | 0.42 |
| SLSEC | Normal Hearing | 7-10 vs. 11-14 years | -3.5 | 2.2 | 0.270 |
| | | 7-10 vs. 15-18 years | -4.6 | 2.1 | 0.079 |
| | | 11-14 vs. 15-18 years | -8.1 | 1.9 | 0.001 |
| FRT | Normal Hearing | 7-10 vs. 11-14 years | -6.6 | 1.3 | 0.001 |
| | | 7-10 vs. 15-18 years | -12.3 | 1.27 | 0.001 |
| | | 11-14 vs. 15-18 years | -5.7 | 1.2 | 0.001 |
| PBS | Normal Hearing | 7-10 vs. 11-14 years | -0.4 | 0.14 | 0.013 |
| | | 7-10 vs. 15-18 years | -0.55 | 0.13 | 0.001 |
| | | 11-14 vs. 15-18 years | -0.13 | 0.12 | 0.531 |
| SLSEO | Hearing-impaired | 7-10 vs. 11-14 years | -3.6 | 5.5 | 0.793 |
| | | 7-10 vs. 15-18 years | -2.6 | 5.2 | 0.874 |
| | | 11-14 vs. 15-18 years | 0.9 | 4.2 | 0.969 |
| SLSEC | Hearing-impaired | 7-10 vs. 11-14 years | -1.7 | 1.1 | 0.254 |
| | | 7-10 vs. 15-18 years | -2.6 | 1.32 | 0.139 |
| | | 11-14 vs. 15-18 years | -0.88 | 1.398 | 0.816 |
| FRT | Hearing-impaired | 7-10 vs. 11-14 years | -5.8 | 1.2 | 0.001 |
| | | 7-10 vs. 15-18 years | -6.9 | 1.2 | 0.001 |
| | | 11-14 vs. 15-18 years | -1.070 | 0.923 | 0.481 |
| PBS | Hearing-impaired | 7-10 vs. 11-14 years | -0.360 | 0.403 | 0.647 |
| | | 7-10 vs. 15-18 years | -0.528 | 0.382 | 0.355 |
| | | 11-14 vs. 15-18 years | -0.168 | 0.307 | 0.849 |

[+]The ANOVA Post-Hoc Tukey Test: Mean Differences in Balance Performance between Age Groups. SLSEO/EC: Single Leg Stance Eyes Opened/Eyes Closed, FRT: Functional Reach Test, PBS: Pediatric Balance Scale.

### 6.3.3 Effect of Hearing Status on Balance Performance

Children with moderate to moderately severe hearing impairments had significantly higher SLSEC scores than those with severe to profound impairments (9.9 ± 6.3 vs. 3.3 ± 2.7 sec, p<0.006). However, their balance performance on SLSEO, FRT, and PBS tests was comparable (**Table 6**).

**Table 6: Balance Assessment According to Hearing Status in Hearing-impaired Groups**

| | Hearing status | | |
|---|---|---|---|
| Balance Tests | Moderate and Md. sever (n=11) Mean ±SD | Sever and profound (n=63) Mean ±SD | P-value[+] |
| SLSEO | 33.0 ±8.1 | 30.2 ±16.9 | 0.39 |
| SLSEC | 9.9 ±6.3 | 3.3 ±2.7 | 0.006 |
| FRT | 22.2 ±6.5 | 22.2 ±3.9 | 0.99 |
| PBS | 54.6 ±1.3 | 54.3 ±1.2 | 0.43 |

SLSEO/EC; Single Leg Stance Eyes Opened/Eyes Closed, FRT; Functional Reach Test, PBS; Pediatric Balance Scale, +; Independent t-test.

### 6.4. Correlation between Static and Dynamic Balance

The SLSEO test results were moderately correlated with the SLSEC (0.56), FRT (0.34), and PBS (0.58). The SLSEC test showed a weak correlation with the FRT (0.29) and a moderate correlation with the PBS (0.53). Additionally, the FRT and PBS were moderately correlated (0.47) (**Table 7**).

**Table 7: Correlation between Static and Dynamic Balance**

| Correlations Among Balance Tests | SLSEO(r) | SLSEC(r) | FRT(r) | PBS(r) |
|---|---|---|---|---|
| Single Leg Stance Eyes Open test | 1 | 0.56* | 0.34* | 0.58* |
| Single Leg Stance Eyes Closed test | 0.56* | 1 | 0.29* | 0.53* |
| Functional Reach test | 0.34* | 0.29* | 1 | 0.47* |
| Pediatric Balance Scale | 0.58* | 0.53* | 0.47* | 1 |

SLSEO/EC: Single Leg Stance Eyes Opened/Eyes Closed, FRT: Functional Reach Test, PBS: Pediatric Balance Scale, (r): Pearson correlation coefficient, *: correlation is significant at p<0.01.

### 6.5 Predictors of Balance Performance

There were statistically significant positive relationships between height and FRT ($\beta = 0.1$, $p<0.02$) and age with FRT ($\beta = 0.8$, $p<0.001$). Conversely, hearing impairment was a significant negative predictor across all balance tests, with FRT ($\beta = -1.5$, $p<0.001$), PBS ($\beta = -0.4$, $p<0.001$), SLSEO ($\beta = -4.98$, $p<0.001$), and SLSEC ($\beta = -3.2$, $p<0.001$) (**Table 8**).

**Table 8: Predictors of Balance Performance in Normal and Hearing-impaired Schoolchildren** (Multilinear Analysis)

| | FRT | | PBS | | SLSEO | | SLSEC | |
|---|---|---|---|---|---|---|---|---|
| Variables | (β) ± SE | P-value | (β) ± SE | P-value | (β) ± SE | P-value | (β) ± SE | P-value |
| Height | 0.1 ±.04 | 0.02 | 0.7± 0.9 | 0.46 | 0.3±0.14 | 0.76 | 0.07±0.06 | 0.23 |
| Age | 0.8 ±0.2 | 0.001 | 0.05 ±0.04 | 0.24 | 0.14 ±0.6 | 0.8 | 0.5±0.3 | 0.51 |
| HI | -1.5 ±0.2 | 0.001 | -0.4 ± 0.04 | 0 .001 | -4.98 ±0.64 | 0.001 | -3.2 ± 0.28 | 0.001 |

SLSEO/EC: Single Leg Stance Eyes Opened/Eyes Closed, FRT: Functional Reach Test, PBS: Pediatric Balance Scale, (β): Regression coefficient, SE: Standard Error, HI: Hearing-impairment.

# 7. Discussion

## 7.1 Static and Dynamic Balance

The results of this study indicate that the static balance performance of hearing-impaired schoolchildren, as determined by single leg stance test (both eyes open and eyes closed), was significantly lower than that of their normal hearing peers. This result is consistent with previous findings indicating that children with hearing impairments performs poorly on the static balance than normal hearing children did [12,17,32,49]. Similar with the current finding, a study conducted before also revealed that children with severe and profound sensory neural hearing loss demonstrate static balance instabilities compared to children with normal hearing [30]. Another study in Egypt demonstrated that static balance abilities were significantly poorer in children with hearing impairments than in their normal hearing peers [44]. In contrast, a study conducted in Poland [15] reported that hearing-impaired children demonstrated superior static balance parameter values compared with their peers with normal hearing. This discrepancy may be attributed to several differences between the two studies. While they studied children aged 8-17 years, our sample included participants aged 7-18. Additionally, their study did not match participants by sex, whereas ours ensured sex-matched groups. They also had a larger sample size, with 228 participants (65 hearing-impaired and 163 normal hearing), compared to our 148 participants, and equally divided between 74 normal-hearing and 74 hearing-impaired. Lastly, their study employed a case-control design, while we used a comparative cross-sectional approach, which could further account for the variation in findings.

Using functional reach test and compared with their normal-hearing peers, hearing-impaired schoolchildren also had lower dynamic balance performance. This result is consistent with a study conducted in India, which revealed that normal hearing children demonstrated superior balance according to the FRT than did children with hearing impairments [27]. Similarly, in a previous study [12], students with hearing loss exhibited lower dynamic balance performance than those with normal hearing. Another study in Egypt revealed that dynamic balance ability was significantly poorer in children with hearing impairments than in their normal hearing peers [44]. Schwab [38] also demonstrated that deaf children achieved significantly lower equilibrium scores than did the control group. However, a study conducted in Nigeria did not find significant differences in dynamic balance between hearing impaired and normal hearing children [17] while

in our study there was a significant dynamic balance difference between normal and hearing impaired children. This discrepancy may be due to differences in sociodemographic factors. They studied participants aged 8-17 years, while our study included a slightly broader age range of 7-18 years. Additionally, their sample size consisted of 160 participants, compared to our 148 participants. These variations could help explain the differing outcomes between the two studies. Another study in India also revealed that dynamic balance was comparable between children with and without hearing impairments [49]. This discrepancy between the current and studies conducted before might attributed to variations in sociodemographic factors (they assessed age range of 7 to 15), sample sizes they studied (30 normal hearing and 30 hearing impaired children) while in our study we included 74 normal and 74 hearing impaired with aged between 7-18 years.

In this study, the pediatric balance scale (PBS) scores of hearing-impaired schoolchildren were significantly lower than those of normal hearing children. This finding is supported by other previously conducted studies. A study conducted by Metgud and Topkar [55] showed that PBS scores were significantly lower in hearing-impaired children than in normal hearing children. Similarly, [53] and [32] demonstrated that children with hearing impairments exhibited poorer balance performance.

The observed balance deficits in schoolchildren with hearing-impairments could be attributed to the close anatomical relationship between the auditory and vestibular systems. Inadequate sensory organization in hearing-impaired schoolchildren might occur due to damage to the vestibular system and nerves. Since the sensory system for balance also includes the visual and somatosensory systems [20], these children might experience broader issues with balance and coordination problem. If information from the auditory system received by the brain is limited, the perception of body position can be impaired, resulting in posture instability [15]. Hearing provides spatial acoustic information essential for maintaining postural balance [35]. Children with normal hearing use auditory cues to improve postural sway. However, this ability diminishes with hearing loss but can be restored with hearing aids [36]. Consequently, individuals with conductive hearing loss experience balance disturbances [35]. This aligns with our study, which included children with both conductive and sensorineural hearing loss, most of whom did not use hearing aids.

At the same time, cochlear and vestibular receptors share the continuous membranous labyrinth of the inner ear [28]. Thus, abnormalities affecting the inner ear affects both hearing and balance [33]. Damage to the cochlea, regardless of its cause, negatively affect vestibular organs [38]. This strong relationship is evident in the high prevalence of vestibular disorders among children with sensorineural hearing loss [39]. Vestibular organ injury leads to balance and motor development disorders [40]. The higher balance instability is directly correlated with the severity of sensory neural hearing loss [30]. This is consistent with our study, where the majority of the hearing-impaired children exhibited severe to profound hearing loss.

Although the vestibular nerve enters the vestibular nucleus in the brainstem and then to the cerebellum, the nerve after leaving the labyrinth alone, connects with the auditory nerve and moves together. The nerves then are separated after two-thirds of the common path [20], indicating that there may be cross-talk between them. People with hearing impairments lack adequate sound stimuli and vestibular stimulation, which leads to problems in motor development and awkwardness in coordination and balance disorders [15,20,35]. A previous study revealed that certain congenital or acquired hearing deficits affect the vestibular branch of cranial nerve VIII, resulting in vestibular problems and poor balance performance [15].

On the other hand, balance disorders are determined by the severity of hearing impairments. A previous study showed that children with profound hearing loss faced greater balance disorders than those with mild hearing loss [38]. Otherwise, children with moderate or unilateral hearing impairments with lower risks for communication and language deficits still face similar risks for motor and balance deficits as profoundly hearing-impaired children [64]. This indicates that moderate or unilateral hearing impairments should not be neglected.

Moreover, social isolation and frustration in children with hearing impairments can also cause physical delays that can affect balance performance. The physical delay and emotional challenges in children with hearing impairments reduce physical activity [16], which may affect balance. Children with hearing impairments are physically inactive and increase their body weight [16] as shown in this study. In this case, previous studies showed the relationship between higher body weights had low balance performance [41,48]. Thus, the higher body weight in children with hearing impairments that have been shown in this study could contribute to poor balance performance. Similarly, children with hearing impairment have weak muscle strength, self-

confidence, and adaptive sensory interactions [20], which can also affect balance performance. However, children who participated in sports classes demonstrated improved body balance [21].

Alternately, inadequate motor development in hearing-impaired children is closely linked to their balance and basic motor skills. Motor development and learning depend on environmental stimuli, and deficits in perceiving these stimuli lead to motor developmental issues affecting balance [55]. These children typically develop essential motor skills, such as maintaining head control, sitting, standing and walking more slowly than their peers with normal hearing [15,39]. Hearing deficits prolong motor development timelines [19], which could also affect balance performance. Studies have shown that children with poor motor development had weaker static and dynamic balance performance [12,17,27,44,55].

### 7.2 Effects of Sex, Age and Hearing-status on Balance Performance

In this study, both girls and boys with hearing-impairments demonstrated lower scores on various balance performance tests than did those of the same sex with normal hearing. This aligns with the findings of Said (2013), who reported that children with hearing impairments in Egypt had lower success rates on different balance skill tests than did children with normal hearing of the same sex. Another study conducted by Mehrem et al. [42] also reported that children with sensorineural hearing loss have poorer postural control skills than their normal-hearing counterparts of the same sex. Melo et al. [30] also reported that children with SNHL exhibited greater balance instability than their normal hearing peers of similar sex did, which further support our findings. In this case, it was the hearing impairment contributed to the poor balance performance rather than sex.

In this study, balance performance improved with age in normal hearing schoolchildren, but not in hearing impaired peers. This finding aligns with previous research indicating that children's postural stability improved with age [21]. This could be attributed to the influence of hearing status in our study. Unlike our study, which included both hearing-impaired and normal children, the previous study [65] included only normal hearing children.

On the other hand, statistically significant differences in balance performance were evident across all age groups. The hearing-impaired group performed lower than the normal-hearing group in all balance performance tests. This finding aligns with those of previous studies showing that children

with SNHL exhibit lower balance performance than their normal-hearing counterparts did in all age groups [12,17,30,46]. Another study indicated that children with hearing-impairments scored lower on various clinical balance tests across at all age groups than did those with normal hearing [44]. In support this finding, a study in which the PBS was used also revealed significant intergroup differences when the children were stratified by age range in that children with hearing loss exhibited lower balance performance across all age groups than the normal hearing group did [32]. Another study further confirmed that students with hearing loss displayed poor static and dynamic balance compared with normal-hearing peers of the same sex and age groups [12]. This finding indicates that the balance problems were due to hearing-impairments rather than to age.

Our study revealed no significant difference in balance performance between children with moderate to moderately severe hearing impairments compared to those with severe to profound hearing impairments in pediatric balance scale. This finding aligns with those of a previous study in which children with sensory neural hearing loss who underwent pediatric balance scale assessment showed no significant difference between moderate to moderately severe hearing loss compared to severe to profound hearing loss [32]. The single-leg stance eyes open test and the functional reach test also did not show statistically significant differences between children with moderate to moderately severe hearing loss and those with severe to profound hearing loss. This finding contrasts with that of Melo et al [30], who reported that greater degrees of SNHL lead to increased balance instability in children. Other studies also indicated that children with moderate hearing impairments exhibited significantly better balance than children in the profound, severe, and moderately-severe groups [30,43]. The contrasting findings may be due to variations in the sample size, severity and type of hearing impairments. In this study, 85.7% of the children with hearing impairments had severe and profound hearing loss, whereas 14.9% had moderate and moderately severe hearing loss.

Conversely, a significant difference in balance performance was found in the SLSEC test. Children with severe and profound hearing loss exhibited poorer balance performance than did their peers with moderate to moderately sever hearing-impairments. This result aligns with research conducted in India [11]. Another study is also revealed that children with severe and profound SNHL exhibited significantly greater balance instability than did their peers with mild and moderate hearing loss in eye-closed tests [30].

### 7.3. Correlation between Static and Dynamic Balance

In our study, correlations between static and dynamic balance were observed. This finding aligns with previous studies [59,64]. However, unlike our study, a study conducted before did not show a significant correlation between static and dynamic balance [17]. The discrepancy may be attributed to differences in study results. While our research identified a significant difference in dynamic balance between hearing-impaired and normal-hearing children, Ayanniyi et al. found no such difference. Additionally, the difference in sample size may play a role: their study included 49 boys and 31 girls with hearing impairments, along with 80 age- and sex-matched controls. In contrast, our study featured an equal distribution of 74 boys and 74 girls, comprising both normal-hearing and hearing-impaired participants. The absence of a perfectly matched sample in their study could help explain the contrasting findings between the two studies.

Both the cochlea and the vestibular receptors, including the semicircular canals and otolith organs, are anatomically and phylogenetically related, sharing the continuous membranous labyrinth of the inner ear and operating through similar receptor cells. Consequently, abnormalities or diseases affecting the inner ear are likely to impact both hearing and balance [28,33].

### 7.4. Predictors of Static and Dynamic Balance Performance

In this study, age and height positively predicted balance performance as measured by functional reach test, and between age and the single leg stance eyes open test. Our findings are consistent with previous research showing that functional reach test scores increase with age and is positively correlated with height [62]. Another study also reported that greater body height had a positive impact on postural stability and improved with age [21]. This finding indicates that as age and height increase, the functional reach test performance is get improved [28]. Age was associated with better single leg stance eyes open performance, which aligns with previous research [61] that identified age as a significant predictor of single leg stance eyes open test performance. As age increases, children's involvement in different activities is also increased which contributes to better balance performance [66]. Additionally, muscle strength increases with age and is facilitated by the development of simple motor skills [67], which enhances their ability to perform reaching movements and maintain balance.

Hearing loss was identified as a significant predictor negatively affecting balance performance, with statistically significant negative correlations observed in functional reach test, pediatric balance scale, single leg stance eyes open and eyes closed tests. This finding aligns with previous research by Melo et al. [30] reported that as hearing loss worsens, balance is negatively affected. Additionally, studies have shown that the balance performance of hearing-impaired children is lower than that of children with normal hearing [12,15,32,42,44].

### 7.5 Strength of the Study

This study's comparative design provides valuable insights into the effects of hearing impairments on balance issues. Furthermore, the use of a sex-matched sample provides the representativeness and credibility of the findings regarding balance performance in schoolchildren.

### 7.6 Limitations of the study

One limitation of this study is the inability to differentiate types of hearing loss. Additionally, vestibular function was not evaluated using objective test methods, such as caloric testing, vestibular evoked myogenic potentials (VEMP), or rotational chair testing.

# 8. Conclusion & Recommendations

## 8.1 Conclusion

From the data obtained in this study, it is concluded that children with hearing impairments have significantly lower static and dynamic balance performance compared to their normal-hearing peers of the same age and sex. A positive correlation was observed between the static and dynamic balance performance of normal hearing and hearing-impaired schoolchildren.

## 8.2 Recommendations

Routine balance assessment is crucial for every child diagnosed with hearing loss, regardless of age or sex. It is essential to raise awareness among health professionals, especially those specializing in hearing health and neuromotor development. These professionals should adopt a holistic approach that considers both hearing and neuromotor development, and regular health screenings are necessary to monitor physical development and detect balance issues early.

Schools should implement specialized programs to enhance balance and coordination in children with hearing impairments. These programs should include balance screenings, physical therapy, and adaptive physical education, with physiotherapists and sport teachers playing a key role in delivering these interventions within educational settings.

Further research should investigate the relationship between static and dynamic balance in children with hearing impairments using objective balance tests.

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## 10. Annexes

### 10.1 English version participant Information sheet

Good morning or Afternoon? How are you? My name is ----------. I am a data collector for the study, which will be conducted in public schools located in Addis Ababa. This school, is one of the study areas in which data will be collected for the study "static and dynamic balance performance of normal and hearing-impaired school children in public schools in Addis Ababa" by Haimanot Andualem. Who is studying his master's degree in Medical Physiology at Addis Ababa University College of Health science, School of Medicine, Physiology Department.

You are kindly, asked your child will be participant of this study. Before you decide, it is important for you to read (listen) the following information carefully and ask, if there is anything that is not clear to take part in the study. The purpose of this study is to assess the effect of hearing impairment on static and dynamic balance. As I have mentioned above, this study is just for research purpose but we hope that the information obtained will be used to inform schools, hospitals, physiotherapy centers and other policy formulators the potential result of which could be improve to attention on special need service provider delivery in the country.

**Title**: Assessment of static and dynamic balance performance and its associated factors of normal and hearing-impaired schoolchildren in public schools in Addis Ababa, Ethiopia, 2023.

**Procedure and duration**: The study involves audiometric hearing assessment and some balance testing procedures with bare foot and eye closed tests. Every data collected kept confidentially with a short period.

**Risk and benefits**: There are no risk involved in this study. You may feel some balance loss while testing but this will not have bad consequence someone from data collector will support. There are direct medical benefits to you for participating in this study tell you that your balance performance. A potential benefit of the study will be improvement of the attention of special need service providers, and health service delivery based on the recommendation of these study findings.

**Confidentiality**: This research will be conducted in accordance with all the Ethiopian laws and regulations that protect rights of human research subjects. All records and other information obtained kept strictly confidential and your protected health information will not be used without

permission. All data collection tools will be assigned codes or numbers to safeguard any information that could potentially identify participants. The results of this study may be published; however, no names or other identifying information will be disclosed.

**Volunteer participation**: it is up to you to decide whether to take part in this study. Refusal to participate or the decision to withdraw from this research will involve no penalty or loss of benefits and this will not affect your relationship with the investigator and the data collector team.

**Cost and compensation to participant**: There will not be compensation to the subjects for participation in this study.

**Institution review Board:** This study has obtained approval from the Institutional Research and Ethics Committee of Addis Ababa University, College of Health Sciences, School of Medicine, Physiology Department. It has permission from Addis Ababa Education bureau and this school too.

**Contact address**: If, there are any questions or enquires at any time about the study or procedures, please contact the PI using the following address:

Principal investigator: Haimanot Andualem

E-mail: fisihatsiyon@gmail.com: Mobile phone: +251924536903

Are you willing to your child to participate in this study? If the answer is yes, please continuing.

**10.2 Informed Consent Agreement Form**

By signing this consent form, I confirm I have read/heard and have had the opportunity to ask questions. I voluntarily agree my child to take part in this study.

Name of the participant (parents)……signature……. date…….

**Assent form for children between 8-17 years**

I understand the study after I have heard the information sheet or read and explained to me. I have had my questions answered. I know that I can ask questions later if I have them. I agree I want to be in the study.

**Signatures**

Assent Print Name: _____ Signature: _____Date: _____

**10.3 English Version Data collection Checklist form**

School Name ---------- Date……Time …...

Student Code----------

Table 3. English version data collection checklist form to assess static and dynamic balance performance and its associated factors of normal and hearing-impaired schoolchildren in Addis Ababa.

Part 1: Evaluation of Student Socio-Demographic Characteristics for Assessing Static and Dynamic Balance Performance and Its Associated Factors in Normal and Hearing-Impaired Schoolchildren in Public Schools in Addis Ababa.

**100. Socio-Demographic factors**

101. Age of the student … (In years)

102. Sex 1. Male 2. Female

103. Grade (class level) of student… St/nd/rd/th

104. Religion

1. Orthodox 2. Muslim 3. Protestant 4. Catholic 5. Others

105. Do you have known Hearing Impairments?

1. Yes 2. No … If the answer is No, skip question 106&107

106. From the following, after which exposure do you expect the occurrence of hearing impairments? You can choose more than one.

1. Meningitis 2. Mumps 3. Measles 4. Exposure to loud noise 5. Ear infection

6. Congenital 7. Idiopathic 8. Others

107. How many years the duration of hearing impairment?

1. 1-5 years 2. 5-10 years 3. > 10 years 4. At birth

108. Are you regularly participating in sport activities other than school sport program starting from last month?

1. Yes 2. No … If the answer is no, skip Question 110&111

109. How many days per week do you have participating?

1. 1 day/week 2. 2 days/week 3. 3 days/week 4. 4 day/week

110. At what type of sport activity are you participating? Please specify…....

**Part 2: Assessments of Hearing status and Balance performance**

**200. Weight, Height and Hearing status assessments**

201. Weight and height 1. Weight in gram 2. Height in cm …….

202. Grade of hearing

1. Normal 20 dB 2. Slightly 20-34 dB 3. Moderately 35-49 dB

4. Moderately Sever 50-64 dB 5. Sever 65-79 dB 6. Profound 80-95 dB 7. >95 dB

203. Type of Hearing Impairment

1. Sensory Neural Hearing Loss 2. Conductive HL 3. Mixed

**300. Static Balance assessments**

301. Single Leg stance with (Eyes open) test

Duration of time without loss of balance in seconds…

302. Single leg stance with (Eyes closed) test

Duration of time without loss of balance in seconds…

**400. Assessments of Dynamic Balance**

401. Initial position of **Functional Reach Test in** centimeters…

402. Final-result of Functional reach test without loss of balance in centimeters …

403. Final FRT minus Initial FRT in centimeters…...

| | | |
|---|---|---|
| 500 | Assessment of static and dynamic balance by using Pediatrics Balance Scale | |
| Task 1 | Sitting to Standing (best of three trials) | Able to stand without using hands and stabilize independently (+4)<br>○ Able to stand independently using hands (+3)<br>○ Able to stand using hands after several tries (+2)<br>○ Needs minimal assist to stand or to stabilize (+1)<br>○ Needs moderate or maximal assist to stand (0) |
| Task 2 | Standing to sitting (best of three trials) | Sits safely with minimal use of hands (+4)<br>○ Controls descent by using hands (+3)<br>○ Uses back of legs against chair to control decent (+2)<br>○ Sits independently, but has uncontrolled descent (+1)<br>○ Needs assistance to sit (0) |
| Task 3 | Transfers (best of three trials) | ○ Able to transfer safely, with minor use of hands (+4)<br>◉ Able to transfer safely; definite need of hands (+3)<br>○ Able to transfer with verbal cueing and/or supervision (spotting) (+2)<br>○ Needs one person to assist (+1)<br>○ Needs two people to assist or supervise (close guard) to be safe (0) |
| Task 4 | Standing Unsupported | ○ Able to stand safely 30 seconds (+4)<br>○ Able to stand 30 seconds with supervision (spotting) (+3)<br>○ Able to stand 15 seconds unsupported (+2)<br>○ Needs several tries to stand 10 seconds unsupported (+1)<br>○ Unable to stand 10 seconds unassisted (0) |
| Task 5 | Sitting with Back Unsupported and Feet Supported on the Floor | ○ Able to sit safely and securely 30 seconds (+4)<br>○ Able to sit 30 sec under supervision/require use of upper extremities for sitting (+3)<br>○ Able to sit 15 seconds (+2) |

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| | | ○ Able to sit 10 seconds (+1)<br>○ Unable to sit 10 seconds without support (0) |
| Task 6 | Standing Unsupported with Eyes Closed (best of three trials) | ○ Able to stand 10 seconds safely (+4)<br>○ Able to stand 10 seconds with supervision (spotting) (+3)<br>○ Able to stand 3 seconds (+2)<br>○ Unable to keep eyes closed 3 seconds but stays steady (+1)<br>○ Need help to keep from falling (0) |
| Task 7 | Standing Unsupported with Feet Together (best of three trials) | ○ Able to place feet together independently and stand 30 seconds safely (+4)<br>○ Able to place feet together independently and stand for 30 sec with supervision (+3)<br>○ Able to place feet together independently but unable to hold for 30 sec (+2)<br>○ Needs help to attain position but stand 30 sec with feet together (+1)<br>○ Needs help to attain position and/or unable to hold for 30 seconds (0) |
| Task 8 | Standing Unsupported One Foot in Front (best of three trials) | ○ Able to place feet tandem independently and hold 30 seconds (+4)<br>○ Able to place foot ahead of other independently and hold 30 sec (+3)<br>○ Able to take small step independently and hold 30 sec, or requires assistance to place foot in front, but can stand for 30 sec (+2)<br>○ Needs help to step, but can hold 15 seconds (+1)<br>○ Loses balance while stepping or standing (0) |
| Task 9 | Standing on One Leg (3 trials average score) | ○ Able to lift leg independently and hold 10 seconds (+4)<br>○ Able to lift leg independently and hold 5 to 9 seconds (+3)<br>○ Able to lift leg independently and hold 3 to 4 seconds (+2)<br>○ Tries to lift leg; unable to hold 3 seconds but remains standing (+1)<br>○ Unable to try or needs assist to prevent fall (0) |

| | | |
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| Task 10 | Turn 360 Degrees | ○ Able to turn 360 degrees safely in 4 seconds or less each way (total < 8 sec) (+4)<br>○ Able to turn 360 degrees safely in one direction only in 4 seconds or less, complete turn in other direction requires more than four seconds (+3)<br>○ Able to turn 360 degrees safely but slowly (+2)<br>○ Needs close supervision (spotting) or constant verbal cueing (+1)<br>○ Needs assistance while turning (0) |
| Task 11 | Turning to Look Behind Left & Right Shoulders While Standing Still | ○ Looks behind/over each shoulder; weight shifts while trunk rotation (+4)<br>○ Looks behind/over one shoulder with trunk rotations; weight shift in the opposite direction is to the level of the shoulder; no trunk rotation (+3)<br>○ Turns head to look to level of shoulder; no trunk rotation (+2)<br>○ Needs supervision when turning; the chin moves > half the distance to the shoulder (+1)<br>○ Needs assistance to keep losing balance; movement of chin is < half distance to shoulder (0) |
| Task 12 | Pick up Object from the Floor from a Standing Position | ○ Able to pick up an eraser safely and easily (+4)<br>○ Able to pick up eraser but needs supervision (spotting) (+3)<br>○ Unable to pick up eraser but reaches 1 to 2 inches from eraser and balance independently (+2)<br>○ Unable to pick up eraser; needs supervision while attempting (+1)<br>○ Unable to try, needs assistance to keep from losing balance/falling (0) |
| Task 13 | Placing Alternate Foot on Step Stool while Standing Unsupported | ○ Stands independently and safely and completes 8 steps in 20 sec (+4)<br>○ Able to stand independently and complete 8 steps >20 seconds (+3)<br>○ Able to complete 4 steps without assistance, requires close supervision (+2)<br>○ Able to complete 2 steps; needs minimal assistance (+1)<br>○ Needs assistance to maintain balance or keep from falling (0) |

| | | |
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| Task 14 | Reaching Forward with Outstretched Arm while standing (3 trials average results) | ○ Can reach forward confidently >10 inches (+4)<br>○ Can reach forward >5 inches, safely (+3)<br>○ Can reach forward >2 inches, safely (+2)<br>○ Reaches forward but needs supervision (spotting) (+1)<br>○ Loses balance while trying, requires external support (0) |
| | Total | …….. out of 56 |

**10.4 Amharic version consent and data collection form**

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Table-4; Amharic version data collection checklist form to assess static and dynamic balance of hearing-impaired schoolchildren in Addis Ababa**.**

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