CURRENT BALANCE LEVELS IN DEAF AND HEARING-IMPAIRED CHILDREN

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Abstract

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The purpose of this systematic review of literature is to evaluate the current balance levels in deaf and hearing-impaired children. Children with hearing impairments show balance and motor deficits mainly due to damaged or undeveloped areas of the vestibular system. The auditory sense plays a dynamic role in producing functional movements and motor coordination skills. Researchers founded that motor development skills are especially important to Deaf children because better skills lead to participation in Deaf sports as well as increased opportunities for social interaction. For children born or diagnosed as deaf or hearing-impaired, there is still the opportunity to keeping up with their peers through modifying of the learning environment. These capabilities are essential to the attainment of cognition, behavior, social speech, and development. Having the clinics, programs, and teachers understand the capabilities, limitations, and current level of abilities can help educators, paraprofessionals, and other specialist develop appropriate instruction, activities, lessons, and goals for deaf and hearing-impaired children. Recognizing the national need to improve physical activity, accessible assessments, and appropriate techniques can benefit children with hearing impairments in motor development and balance levels.

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Introduction

The Individuals of Disabilities Education Improvement Act (IDEA, 2004) defines an individual who is Deaf as having a hearing-impairment so severe that the individual is unable to process linguistic information through the use of auditory senses, with or without amplification. In infancy and continuing through childhood, there are four identifiable phases of motor development that children progress through (Shumway-Cook & Woollacott, 2007). It is believed that a lack of early auditory input may contribute to one or more motor delays in deaf and hearing-impaired children (Gheysen, 2007). Specifically, researchers have reported that children who are deaf or hearing-impaired are at risk of vestibular dysfunction which may impact their ability to stand upright or remain in a balanced position (Suarez, 2006). The National Institute on Deafness and Other Communication Disorders (2016) reported that approximately three out of every 1,000 children born in the United States will have some type of hearing loss in one or both ears. Hearing loss during childhood has a direct link to delays in motor development in areas, such as balancing, postural control, and coordination between limbs (Mazaheryazdi et al., 2017). For children, with and without disabilities delays in motor development can impact their ability to participate in adequate levels of motor skills which may contribute to an inability to perform physical activities and experience a lifetime of enjoyment through physical activity. For these reasons, researchers working with deaf or hearing-impaired children need to develop instructional strategies that can be implemented by parents and teachers to improve motor development skills (i.e., balance).

Type of Hearing Loss and Impact on Motor Development

Degrees of motor delay are dependent on age of occurrence and severity of hearing loss (Rajendran & Roy, 2011; Rajendra, Roy, & Jeevanantham, 2011; Rine, 2000). Researchers have reported that motor development in children with hearing impairments are occurring at a decelerating rate when compared to their typically developing peers (Rine, 2004). There are three basic types of hearing loss: (a) conductive, (b) sensorineural, (c) mixed (i.e., a combination of the first two; Rajendran & Roy, 2011). Conductive hearing loss occurs through complications inside the ear drum (e.g., infections, swimmers ear, fluid trapped inside) and causes the individual to experience a loss of sound waves which reduces sound level and sound efficiently from the outer ear to the eardrum located in the middle of the ear (The American Speech-Language Hearing Association [AHLA], 2017). Rine (2000), reported that children with sensorineural hearing-impairment, as opposed to conductive loss, have progressive developmental motor deficits.

Sensorineural hearing loss is a severe hearing impairment which can impact communication, speech, and balance skills (Lieberman, 2011). Sensorineural hearing loss has been reported as the most common form of permanent hearing impairment for children who are deaf or hearing-impaired and occurs when the cochlea located inside the inner ear, or neural pathways from the inner ear to the brain have been damaged (e.g., age, noise levels, disease; Liberman, 2011; Rajendran & Roy, 2011). In 2017 the National Center for Hearing Assessment and Management reported that sensorineural hearing loss occurs in three of every 1,000 live births. There are also reports that children with profound sensorineural hearing loss may exhibit deficits in vestibular, balance control, and show a progressive delay in gross motor development (Cushing, Papsin, Rutka, James, & Gordon, 2008). Evidence indicates that undeveloped or vestibular control has been observed in 20% to 70% of children with sensorineural hearing loss (Cushing et al., 2008).

Mixed hearing loss is a combination of conductive and sensorineural hearing loss and includes damage to the outer, middle, and inner ear (AHLA, 2017). The conductive component can be caused by ossicular discontinuity or fixation (Huber, 2006). Causes of mixed hearing loss include illness, genetics, drugs, head trauma, ear infections, or deformity in the development in the ear drums (AHLA, 2017). Therefore, due to the deficits reported for both conductive and sensorineural hearing loss children with mixed hearing loss may demonstrate delays in motor development and balance when compared to their typically developing peers.

Motor Development Levels for Children Deaf or Hard of Hearing

Motor development relates to bodily changes of muscles, bones, and physical abilities that develop over time (Hartman, Houwen, & Visscher, 2011; Shumway-Cook & Woollacott, 2007). Researchers have reported that deaf and hearing-impaired children may have sensory delays caused by damaged or undeveloped auditory systems which contribute to motor delays (Gheysen, Loots, & Waelvelde, 2007; Suarez, 2006; Wolter, 2016). These damaged or undeveloped auditory systems may lead to motor abilities that are described as uncoordinated, clumsy, and have been shown to cause difficulties with balancing (Rajendran & Roy, 2011). Sensory information plays an important role in the control of motor movements and the development of controlled and reflexive movements (Shumway-Cook & Woollacott, 2007). Additionally, a lack of auditory stimulation from birth can bring functional plastic changes in the central nervous system which may lead to changes of the “meaning brain areas” (Suarez et al, 2006).

Balance Levels for Children Deaf or Hard of Hearing

Balance is the ability to maintain position, to move voluntarily and consists of both static and dynamic movements (Patel et al., 2017). Development of balance begins in infancy with the establishment of head and trunk control (Franjoine, Darr, Held, Kott, & Young, 2010). Skills, such as walking, running, and jumping are milestones that are developed during toddler and preschool ages (Shumway-Cook & Woollacott, 2007). Researchers have suggested that deaf or hearing-impaired school aged children have poor balance and significant motor problems when compared to their typically developing peers (Rajendran & Roy, 2011). Therefore, individuals working with children who are deaf and hearing-impaired may want to focus their instruction on static and dynamic balance movements to improve postural and vestibular deficits identified within this population (John, Ozmun, David, Gallahue & 2016).

Static balance is the ability to maintain a steady position in weight bearing, antigravity posture by establishing a base of support for a short period of time (Patel, 2017; Mazaheryazdi, 2017). Vestibular deficits can be detected for children during the

One Leg Stance Test (Patel, 2017). Researchers have reported a difference in static balance in children with a hearing impairment when compared with their children typically developing peers (Patel, 2017). One study of 90 children, 8 to 10 years of age, showed that children with a severe hearing impairment (i.e., conductive, sensorineural, or mixed) of various etiologies, reported that many, but not all, of these children demonstrated impaired static balance (Ebrahimi, Movallali, Jamshidi, Rahgozar, & Haghgoo, 2016).

Dynamic balance is the ability to keep the body balanced while performing a locomotor task, such as skipping, walking, or running (Mazaheryazdi, 2017). To function effectively across environments and tasks, children need the ability to maintain controlled positions (Shumway-Cook & Woollacott, 2007). Most functional motor tasks require the individual to maintain orientation of the body which include several sensory references such as, vestibular system, somatosensory system, and visual system (Mazaheryazdi, 2017). From the sensory system perception young children are reliant on a visual sense to maintain balance; as they grow older somatosensory and vestibular information usually matures by the age of ten (Suarez, 2006).

Postural control involves controlling the body's position relative to the surface on which the individual stands in an upright posture to achieve sufficient stability under diverse conditions (Ebrahimi, 2016). Postural control is essential towards children's motor development throughout the early stages of life (i.e., 0-4 years), and must be established before the individual can participate in skills, such as crawling, walking, running, and hand-eye coordination skills (Shumway-Cook & Woollacott 2007). Some researchers have stated ages 4 to 6 years represent a sensitive time for postural development (Rine, 2004). Therefore, sufficient postural control requires a combination from the visual, vestibular, and auditory sensory systems to create motor responses that maintain the body in balanced position (Kegal, Maes, Baetens, Dhooge, & Waelvelde, 2012).

Deaf children have an increased risk of vestibular dysfunction and delayed postural control (Suarez, 2006). Vestibular dysfunction is found in 20% to 70% of children who are deaf or hearing-impaired (Cushing, 2008).The vestibular system is responsible for stabilizing the eyes, sense of balance, equilibrium, and spatial orientation (Shumway-Cook & Woollacott 2007) and is responsible for three motor reflexes: (a) vestibular-ocular reflex responsible for visual stabilization, (b) vestibular-collic reflex accountable for neck stabilization, and (c) vestibular-spinal reflex, maintains orientation of body and space (Kegal, 2012).

Unlike other senses, such as vision, taste, auditory, and smell that provide noticeable sensory feedback, children who are deaf or hearing-impaired are unaware of vestibular sensations (Shumway-Cook & Woollacott, 2007). Vestibular inputs are significant when it comes to coordination of motor responses and maintaining postural stability during stance and walking (Shumway-Cook & Woollacott, 2007). Children with vestibular loss present delayed gross motor skills, such as standing and walking later than typically developing children (Suarez, 2006). Deviations within the vestibular system can be related to dizziness and unsteadiness which can lead to other problems, such as obtaining balance (Cushing, 2008). Children who are deaf or hearing-impaired have: (a) low physical fitness activity levels, (b) poor balance, and (c) low levels of performance of motor skills when compared to their typically developing peers (Dair, Ellis, & Liberman, 2006; Ellis, 2005; Hopper, 2007; Mazaheryazdi, 2017).

Importance of Physical Education

Hearing loss is the third most common chronic condition that brings serious health implications for children and their families (Rajendran & Roy 2011). Participating in regular physical activity is essential for children’s psychological, emotional, and skill development (Engel-Yeger & Hamed-Dasher, 2013). Joining in activities, games, and other forms of play can help children with and without disabilities learn how to build friendships and develop essential skills to become successful in their homes and communities (Engel-Yeger & Hamed-Dasher, 2013). Physical delays (e.g., balancing, postural control, coordination between limbs) associated with deaf or hearing-impaired children combined with social and emotional delays may reduce the child’s participation in physical activity (Engel-Yeger & Hamed-Dasher, 2013). Therefore, the development of motor skills is an important prerequisite for the physical performance of skilled movements for children who are deaf or hearing-impaired (Rajendran & Roy, 2011). Children with disabilities, including children who are deaf and hearing-impaired tend to be less physically active, substantially fit, and have a higher average of body weight when compared to their typically developing peers (Cervantes & Porretta, 2010). 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 (Cervantes & Porretta, 2010).

Purpose statement. The purpose of this systematic review was to identify pertinent literature focused on the balance levels of children who are deaf and hearing-impaired. This review is designed to describe the characteristics and exercise interventions of the included studies (e.g., participants, quantitative methods, and benefits of exercise interventions). The results of this review are intended to guide and inform practitioners, clinics, programs, and educators towards developing appropriate instruction, activities, lessons, and goals for deaf and hearing-impaired children. Recognizing the national need to improve physical activity, accessible assessments, and appropriate techniques can benefit children with hearing impairments in motor development and balance levels.

Limitations. The limitations within this systematic review were primarily found in the study design and methodology. The inclusion criteria allowed limited impact from factors such as regional focus and population-specific. Statistical limitations may have affected the study design, producing more serious limitations in terms of interpreting the findings. To assess accurate balance and motor developments levels in children with hearing impairments repeated testing is needed.

Delimitations. The systematic review examined literature relating to the current levels of balance levels for children aged 4 to 12 years diagnosed as deaf or hearing-impaired. Moreover, it was also focused on identifying motor development differences between deaf and hearing-impaired children when compared to their typically developing peers. The study reviewed seven articles that included small sample sizes and wide range of etiology. Increasing number of participants and assorting etiologies may limit the number of limitations for future research.

Key Words:

Deaf is defined as having a hearing impairment that is so severe that the individual is unable to process linguistic information through the use of auditory senses, with or without amplification (IDEA, 2004).

Motor development is defined as a continuous adaption to changes in a person's movement capabilities in a never-ending effort to achieve and maintain motor control and movement competence (John, Ozmun, David, & Gallahue, 2016).

Hearing-impaired is defined as having damaged or undeveloped areas of the vestibular system (Rajendran, Roy & Jeevanantham, 2011).

Balance is defined as the ability to maintain position, to move voluntarily and consists of both static and dynamic movements (Patel et al., 2017).

Literature Review

The purpose of this systematic review of literature is to examine the balance levels of children who are deaf and hearing-impaired. This review is designed to guide professionals into developing appropriate instruction, activities, lessons, and goals for deaf and hearing-impaired children. The literature examined in the current review includes: (a) type of hearing loss, (b) motor development levels for children Deaf and hearing-impaired, (c) balance levels for children Deaf and hearing-impaired (d) importance of physical education.

Motor Development Levels for Children Deaf or Hard of Hearing

Motor development involves continuous adaption to changes in a person's movement capabilities in a never-ending effort to achieve and maintain motor control and movement competence (John et al., 2016). Integration of information from the central nervous system can establish motor skills and basic information about the position of the head and motor coordination (Mazaheryazdi, 2017). For example, to walk, run, or play the central nervous system must control, organize, and produce functional movements (Shumway-Cook & Woollacott, 2007). Auditory stimuli associated with visual (i.e., perception) and motor behaviors allow an individual who is deaf or hearing-impaired to localize sound (Wolter, Cushing & Vilchez Madrigal, 2016). Lack of auditory input during early childhood may contribute to motor delays in deaf and hard or hearing children (Gheysen, 2007). For this reason, having children who are deaf and hearing-impaired experience and identify essential environmental situations can benefit them as they grow older and begin to acquire mature patterns of movement (Mazaheryazdi, 2017). Furthermore, learning a new movement skill requires that the individual understands the specific tasks and how his or her individual factors, and environmental factors influence the success of completing the task (John et al., 2016).

Balance Levels for Children Deaf or Hard of Hearing

Static balance is the ability of an individual to establish a base of support for a short period of time while bearing, antigravity posture (Mazaheryazdi, 2017; Patel, 2017). Researchers has concluded that there is a significant difference in static balance in children who are deaf or hearing-impaired when compared with typically children (Patel, 2017). Specifically, Rine (2000) reported that children with a severe hearing impairment (i.e., sensorineural) of various etiologies, demonstrated impaired static balance.

Dynamic balance results from a complex interaction between vestibular, vision, and proprioception sensory systems (Cushing, 2008). Children with hearing impairments demonstrate abnormal dynamic balance (Cushing, 2008). Young children are reliant on their visual capacity to maintain balance and researchers have reported that children improve these skills as they grow older (i.e., 10 years of age; Suarez, 2006). Professionals recommend testing for vestibular hypofunction in children with hearing impairments as early as possible in the preschool year, so treatment can be introduced in a timely fashion (Suarez, 2006).

Importance of Physical Education

Several organizations such as World Health Organization (WHO) and Centers for Disease Control and Prevention (CDC) reported that physical education benefits all individuals (2017). Providing information and instructions to enhance children and their motor abilities may help maintain a long lasting healthy lifestyle, individuals need to be introduced and given opportunities to experience physical education at an early age Liberman, 2004). Participating regularly in physical activity reduces health risks, improves physiological changes and promotes lifelong health benefits (Powell, Paluch, & Blair, 2010). Researchers have reported children with hearing impairments have limitations towards meeting their optimal development (Rajendran & Roy, 2011). Further, researchers have also revealed a variety of factors (e.g., dynamic balance, manual dexterity, ball skills) that limit motor performance in deaf and hearing-impaired children (Gheysen, Loots, & Van Waelvelde, 2008; Hartman, 2011; Horn, Pisni, & Miyamoto, 2006). Based on the reviewed literature, individuals who are deaf or hearing-impaired who experience success in physical activity or sport may be more likely to adopt a physically active lifestyle (Lieberman, 2004). Wall (2004), predicted that it is difficult for children with motor problems to participate in physical activity, especially when their peers begin to perform in more competitive and demanding settings. A barrier that limits participation in deaf and hearing-impaired children comes from not receiving auditory feedback during learning and regulation of motor skills (Hartman, 2011). Researchers have also suggested that environmental factors, such as type of school, curriculum, parenting styles, and opportunities for practice and play can contribute to motor delays (Lieberman, 2004). For these reasons individuals working with children who are deaf or hard of hearing should develop instructional strategies that can be implemented by parents and teachers to improve motor development skills (i.e., balance).

Method

Scope of study

The purpose of this systematic review was to examine literature pertaining to the current levels of balance levels for children aged 4 to 12 years diagnosed as deaf or hearing impaired. Therefore, the following sections within this chapter will focus on: (a) Search Procedures, (b) Inclusion Criteria, (c) Inter-Rater Agreement and (d) Data Extraction.

Search Procedure

The search procedure implemented for this investigation began with the researcher identifying five databases: (a) Sport-discus, (b) PsycInfo, (c) ERIC, (d) PubMed, and (e) BIOSIS to conduct all literature searches. All searches were initiated through the Humboldt State University library using the following key terms to identify possible articles: deaf children, hearing-impaired, balance, motor development, physical education. Key terms were chosen to develop a detailed and inclusive search strategy, with the goal of reducing bias by categorizing all relevant studies towards this topic. Additionally, the researcher only reviewed articles that were published in U.S, peer-reviewed journals from 2000 to 2017, and had at least one participant who had been previously diagnosed with deaf or hearing impaired (see Figure 1).

Inclusion Criteria

The initial search results from each of the data bases revealed a total of 1,692 articles. After removing 1,304 duplicates, a total of 7 articles met the initial criteria. The researcher then reviewed articles that were peer reviewed and matched with key terms and screened for eligibility. These data bases were selected because they provide advance research and ensure access to peer reviewed biomedical literature. Articles selected for inclusion were selected based on the following criteria standards: (a) the study was written in English, (b) the study was published in peer review journal during between 2000 to 2017, (c) the study included at least one participant aged 4 to 12 years (d) that had been previously diagnosed as deaf or hearing impaired, (d) the intended outcome of the study was to improve balance levels, (e) the study must be published in the U.S, see

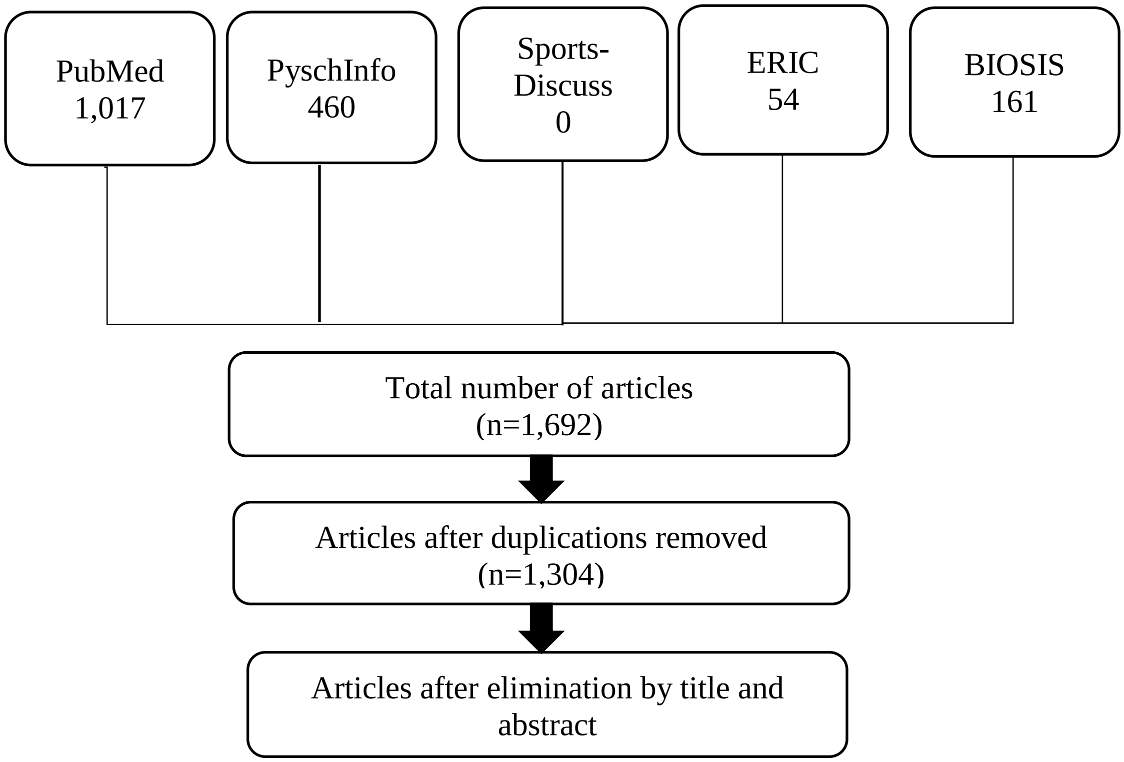

Figure 1 Illustration of Inclusion Criteria

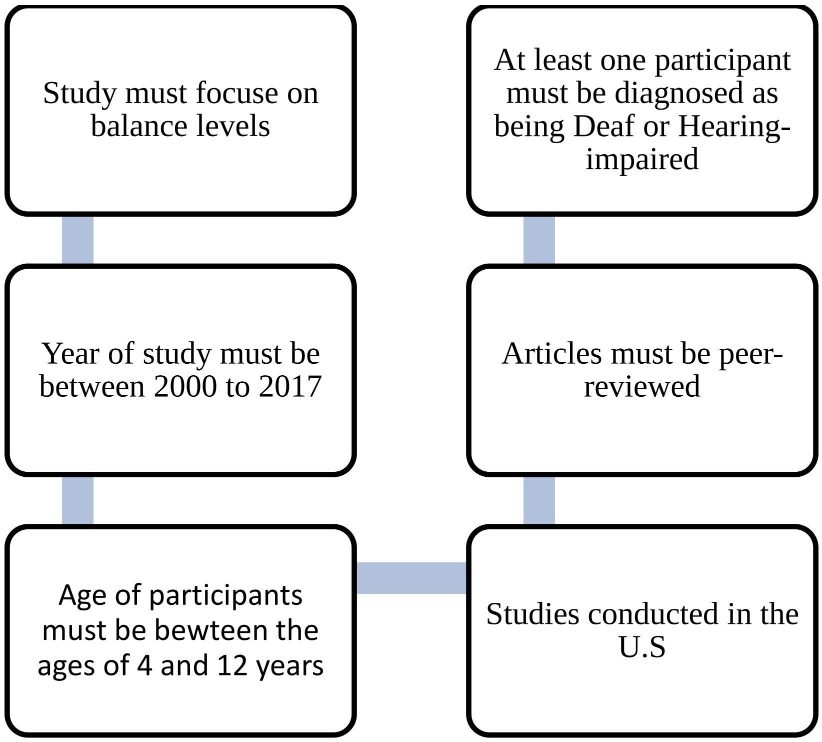

Figure 2 Inclusion Criteria Progression

Inter-Rater Agreement

The primary researcher conducted the key word search in all five databases. All possible articles were then reviewed based on the title and abstract to determine eligibility. Next, we evaluated each study against the predetermined inclusion criteria. To avoid data errors, we independently reviewed and withdrew any articles that did not meet the above inclusion criteria. After completing an independent review of all abstracts, we met to review their final list and make determinations on any articles in question.

Data Extraction

The data collected from all seven articles includes author, year of publication, study design, intervention used, population, location of intervention, and outcomes. The original search methodology was designed to examine current balance levels in deaf and hearing-impaired children. There are large amounts of research relating to other balance domains in children who are deaf and hard of hearing. However, this systematic review specifically focuses on current levels of balance levels for children aged 4 to 12 years diagnosed as deaf or hearing impaired. Therefore, a definitive methodology and synthesis search procedure was initiated.

Results

Participants and Settings

The seven articles provided a total of 206 participants (Boys = 128, Female = 99) with variety of hearing impairments (i.e., Deaf, sensorineural, unilateral, profound sensorineural, severe sensorineural, bilateral hearing impairment) between the ages of 4 to 12. Settings for all studies took place in the U.S (local clinics; Kegal, 2008; Rine, 2000; laboratories; Cushing, 2016; Wolter, 2016; hospitals; Cushing, 2008; Kegal, 2012; Suarz, 2006; Wolter, 2016; public or private schools; Liberman, 2004; Rine, 2000; Rine, 2004). Informed consent was given through written or oral orientation then obtained from each child's primary guardian prior data collection.

Research Methodology

The seven studies demonstrated a wide-range of sample size, measurements, and data collection. Of the seven studies: three studies were classified as observational (i.e., cross-sectional; Cushing, 2008; Kegal, 2012; Liberman, 2004;) and four were classified as experimental design with repeated measures (i.e., Rine, 2000;2004; Suarez, 2006; Wolter, 2016).

Balance Skills Levels

Assessments implemented to measure balance levels of participants included the *Bruininks-Oseretsky Test of Motor Proficiency-2* (Bot-2: Bruininks, Bruininks, 2005). Results indicated that children with sensorineural and unilateral hearing-loss had significantly worse static and dynamic balance when compared to normal hearing children (Cushing, 2008; Wolter, 2016). The balance subset of the *Bot-2* (Bruininks, Bruininks 2005) includes nine tasks for children ages 4 to 21 years old with standing on one leg and walking forward heel to toe on a line with eyes open and eyes closed used to measure balance. Furthermore, Kegal (2012) included the *Clinical Test of Sensory Interaction for Balance* (Shumway-cook & Horak, 1986). The clinical balance subset includes the one-leg stance. Results indicated that children with unilateral and bilateral hearing-impairments performed significantly weaker on static balance when compared to typically developing children (Kegal, 2012).

Motor Development Levels

Rine (2000) reported deficits in motor development for children with sensorineural hearing loss when compared to their typically developing peers using the *Peabody Development Motor Scales-Second Edition* (Folio & Fewell, 2000). These results supported hypothesis that motor delays can be progressive in children with sensorineural hearing loss (Rine, 2000). Further, results from Rine (200) have demonstrated children with bilateral, moderate, and profound sensorineural hearing loss acquire motor skills that develop at a decelerating rate (Rine, 2000). Furthermore, Kegal (2012) reported that hearing-impaired children have clear balance deficits along with weaker performance on manual dexterity and ball skills of children aged 3 to 16 when assessed using the *Movement Assessment Battery for Children-Second Edition* (Henderson, Sugden, Barrett, 2007). Conversely, Rine (2004) also reported that exercise intervention had a significance on the progressive motor development delay in children with sensorineural hearing loss and vestibular impairment (Rine, 2004).

Vestibular Function Levels

To evaluate vestibular function, measurements were conducted through the *Southern California Postrotary Nystagmus Test* (Ayres, 1975*).* Results indicated that children with sensorineural hearing-impairment identified children with a progressive delay in motor or balance development (Rine, 2004). Furthermore, Cushing (2008), Kegal (2012), and Rine (2004) included the *caloric testing and rotatory chair testing (Barany, 1907).* Results from all studies had similar findings that indicated children with bilateral, unilateral, and severe to profound sensorineural hearing loss had vestibular and balance dysfunctions (Cushing, 2008). In addition, Cushing, (2008) and Kegal (2012) included the *vestibular evoked myogenic potentials testing* (Bickford, 1964). Results from Kegal (2012) indicated that children with bilateral, unilateral, and severe to profound sensorineural hearing loss performed significantly weaker on static balance when compared to typically developing children between the ages of 3 and 12 years (Kegal, 2012) in contrast to Cushing (2008) who found no association.

Postural Control Levels

Assessments implemented to measure postural control was the *Postural Control* test. The *Postural Control test* is based on the principles of the *Test of Equilibrium Under Sensory Altered Conditions*. Results indicated that children who are deaf and profound to severe sensorineural hearing loss show difficulty in maintaining balance control when visual information is eliminated (Wolter, 2016; Suarez, 2006). In addition, *Center of Pressure Distribution area* and *Body Sway* was included to assess postural control. Results indicated that children with unilateral and sensorineural hearing impairments postural control was negatively affected by the removal of visual inputs when compared to their normal hearing peers (Wolter, 2016).

Instrumentation

Data collected throughout the seven studies used correlation (i.e., chart reviews; Rine 2000; 2004), experimental (i.e., observations; Cushing, 2008; Rine, 2000; video-taping; Liberman, 2004), and quantitative methods (i.e., interventions; Rine 2004; Suarez, 2006). Throughout the seven studies participants engaged in interventions that primarily focused on improving balance levels along with secondary improvements in motor development, vestibular, and postural control. An extensive description of all instruments, assessments, and measurements is discussed and listed below, see Table 1 for an illustration of the instrumentation.

Table 1 Details of included studies

Author	**Type of study**	**Population**	**Sample size**	**Age (years)**	**Results**
Cushing, 2008	Observational (i.e., Cross-sectional study with repeated measures)	Sensorineural, unilateral, and bilateral hearing loss	40	3-19.3	Children with sensorineural hearing loss show abnormalities in vestibular function and balance abilities.
Kegal, 2012	Observational (i.e., Cross-sectional study with repeated measures)	Unilateral and bilateral hearing loss	48	3-12	Children with unilateral and bilateral hearing impairment have clear motor and balance deficits.
Lieberman, Volding & Winnick, 2004	Observational	Deaf	29	4-9	No significant difference in motor development skills between Deaf children of Deaf parents and Deaf children of hearing parents.
Rine, 2000	Experimental	Sensorineural hearing loss	39	2-7	Children with sensorineural hearing loss showed delay in balance and gross motor development which can be progressive and related to vestibular dysfunction.

Author	Type of study	Population	Sample size	Age (years)	Results
Rine, 2004	Experimental	Sensorineural hearing loss	21	3-8.5	Children with sensorineural hearing loss and concurrent vestibular impairment who participated in exercise intervention improved sensory organization for postural control and motor development skills.
Suarez, 2006	Experimental	Sensorineural hearing loss	36	8-11	Children with sensorineural hearing loss showed difficulty maintaining static balance with and without visual and somatosensory input.
Wolter, 2016	Experimental (i.e., Case control study)	Unilateral sensorineural hearing loss	14	3-8.5	Children with unilateral and sensorineural hearing loss performed significantly worse on balance abilities when compared to children with normal hearing. Significant differences were seen when visual and somatosensory inputs were limited.

Discussion Conclusions, and Recommendations for Future Research

The purpose of this systematic review was to investigate balance levels in deaf and hearing-impaired children. A total of seven articles were reviewed for this purpose. Results from the reviewed studies indicated children between the ages 4 to 12 years demonstrate deficits in balance skills (Cushing, 2008; Kegal, 2012, Liberman, 2004, Suarez, 2006; Rine, 2000;2004, Wolter, 2016). Despite numerous reports on balance levels for deaf and hearing-impaired children there is a limited amount of literature that has reported on the degree of hearing, etiology of hearing loss, and the cofounding factors associated within the disability (Cushing, 2008, Rine 2000;2004, Suarez, 2006).

Discussion

The seven studies reviewed indicates that children who are deaf or have hearing impairments show clear balance and motor deficits primarily due to damaged or undeveloped areas of the vestibular system (Cushing, 2008; Kegal, 2012, Liberman, 2004, Suarez, 2006; Rine, 2000;2004, Wolter, 2016, Rajendran, Roy & Jeevanantham, 2011). Evidence indicates that undeveloped or vestibular control (i.e., balance) has been observed in 20% to 70% of children with sensorineural hearing loss (Cushing, 2008). Consequences from undeveloped or damaged auditory systems may lead to motor abilities that are described as uncoordinated, clumsy, and have been shown to cause difficulties with balancing (Rajendran & Roy, 2011). Within this review there is substantial support indicating a noticeable difference in balance levels for children who are deaf and hearing-impaired when compared with typically children (Kegal, 2012; Cushing, 2008; Suarez, 2006; Liberman, 2004; Wolter, 2016; Rine, 2000;2004).

Six out of the seven studies (Kegal, 2012, Suarez, 2006, Liberman, 2004, Wolter, 2016, Rine, 2000;2004) reported that children with hearing-impairments perform significantly weaker on static balance when compared to typically developing children. These reports vary when compared to Cushing (2008) who found no significance difference in balance levels when comparing the same populations. The reliability of Cushing's (2008) results may have been influenced by cofounding factors such as cochlear implants. The participants in this study were recommended to obtain implantation at an early age and administer device for at least 4 years. Majority of participants did not fulfill expectancy therefore, validity of pre and postoperative assessments may not be used as a reliable measure (Cushing, 2008).

Three of the seven studies (Rine 2000; 2004, Suarez, 2006, & Wolter, 2016) reported that children with hearing impairments and sensory organization deficits displayed difficulties controlling motor abilities (i.e., remaining upright), including balance (Wolter, 2016). These reports are similar to previous researchers who have reported a variety of factors (e.g., dynamic balance, manual dexterity, ball skills) that limit motor performance in deaf and hard of hearing children (Gheysen, Loots, & Van Waelvelde, 2008 Hartman, Houwen, & Visscher, 2011, Horn, Pisni, & Miyamoto, 2006). Children with balance deficits and vestibular loss can display delayed gross motor skills, such as standing and walking later than typically developing children (Suarez, 2006).

Two of the seven studies (Rine, 2004 & Suarez, 2006) reported that exercise intervention can improve multi-modal sensory interdependence. The primary focus of the intervention consisted of emphasizing the enhancement of visual, somatosensory, and balance function. Results indicated significant improvements towards the progressive motor development delay in children with hearing loss and vestibular impairment (Rine, 2004).

One of the seven studies (Rine, 2000) examined the effects of age and gender towards the motor proficiency in children between 2 and 7 years with hearing impairments. Descriptive analysis showed that age but not sex affected scores on the balance and non-locomotor categories on the *Peabody Development Motor Scales-Second Edition* (Folio & Fewell, 2000, Rine, 2000). These results support the hypothesis that motor delays can be progressive in children with sensorineural hearing loss (Rine, 2000). It must be noted, that children with hearing impairments are not losing motor skills, but rather that development is progressing at a decelerating rate (Rine, 2000). Therefore, it is important that measurement tools used to examine motor development and balance levels in children with hearing loss during should take place during preschool and elementary school years to help identify any types of motor delay so appropriate and effective intervention strategies can be implemented (Rine, 2000).

Measures & Settings

A wide range of measures and settings were included across studies to evaluate balance levels in children who are deaf or have hearing impairments. Two of the seven studies used Bruininks-Oseretsky Test of Motor Proficiency-2 (Bot-2: Bruininks, Bruininks, 2005; Cushing, 2008, Wolter, 2016) another study used Movement Assessment Battery for Children-Second Edition (Henderson, Sugden, Barrett, 2007) and one study used the Peabody Development Motor Scales-Second Edition (Folio & Fewell, 2000; Rine, 2000) and one of the seven studies used Southern California Postrotary Nystagmus Test (Ayres, 1975; Rine, 2000). These instruments varied in construction and setting. The settings of the reviewed studies took place in the U.S (local clinics; Kegal, 2008; Rine, 2000; laboratories; Cushing, 2016; Wolter, 2016; hospitals; Cushing, 2008; Kegal, 2012; Suarz, 2006; Wolter, 2016; public or private schools; Liberman, 2004; Rine, 2000; Rine, 2004). Assessing participants in multiple settings may alter interpretation of the experiment's purpose and unconsciously change their behavior to fit that interpretation.

Conclusions, Summary and Recommendations for Future Research

The present systematic review exposes evidence of balance impairments that are associated with deaf and hearing-impaired children. A limitation of this study was a lack of literature focused on deaf and hearing-impaired balance and motor development skills. The main factors investigated were the development levels in balance, motor, vestibular, and postural control, which overall were found to be positively associated with balance levels in deaf and hearing-impaired children. Despite motor delays and balance issues in deaf and hearing-impaired children's motor skills improve with age (Rine, 2000). The findings of this study should help influence future researchers to investigate and emphasize the importance of routine clinical examinations of all categories of gross motor skills as well as educational programs for deaf and hearing-impaired children.

Publishing updated systematic reviews is important for clinical and educational standards. Early identification on motor and balance levels in deaf and hearing-impaired children can impact clinical therapies and help schools develop appropriate physical education programs that are designed to meet the needs and challenges of all children. Overall, these findings highlight the need of testing, monitoring, and documenting motor and vestibular related impairments for this population. Early detection of motor impairments can help facilitate hearing-impaired children to obtain suitable treatment to diminish the damaging impacts of these impairments and ensure a more efficient lifestyle.

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