PHYSICAL ACTIVTY AND YOUTH WITH HEARING IMPARIMENTS: A REVIEW

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ABSTRACT

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Objectives: The purpose of this review was to analyze the literature regarding physical activity and children with hearing impairments.

Methods/Inclusion Criteria: The inclusion criteria of this review were articles from 2006-2018, with the population of children 4-18 years old with hearing impairments, and with the study involving components related to physical activity.

Summary: Children with hearing impairments tended to have lower physical activity levels and spent more time sedentary than typically developing peers. Compared to children with other disabilities, children with hearing impairments were more participated more, but still didn't meet physical activity recommendations. Children with hearing impairments have demonstrated poorer balance abilities and lower fitness levels than hearing peers. Aside from deficits in coordination, several studies found non-significant to no differences in other components of motor development. Sports participation for children with hearing impairments allows socialization, development of communication and physical skills. Participation in sports was positively correlated to parental attitudes and involvement in sport and physical activity.

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INTRODUCTION

Regular physical activity is key to improving health; with consistent participation resulting in many health-related benefits for adults and children, such as promoting development and reducing the risk of chronic diseases (U.S. Department of Health and Human Services [USDHHS], 2018). The 2018 Physical Activity Guidelines for Americans recommends that children participate in 60 minutes of moderate-to-vigorous physical activity daily; incorporating aerobic, muscle- and bone-strengthening activities (USDHHS, 2018). According to Healthy People 2020, only 28.7% of children achieve the current recommendations for aerobic exercise and 55.6% of high school students met the muscle-strengthening participation guidelines in 2011 (Office of Disease Prevention and Health Promotion [ODPHP], 2019). This data further drives their current objectives of increasing the number of adolescents who meet the physical activity guidelines, as well as additional goals to increase the percentage of schools that provide daily physical education and scheduled recess time (ODPHP, 2019). Children with disabilities, including those with hearing impairments, have been found to have significantly lower physical activity levels and spend an increased amount of time sedentary than typically developing peers (Lobenius-Palmér, Sjöqvist, Hurtig-Wennlöf, & Lundqvist, 2018). Similarly, children who are deaf have a higher prevalence of being overweight compared to national percentages as calculated with body mass index (Dair, Ellis, & Lieberman, 2006).

Approximately 466 million individuals in the world have disabling hearing loss, with 34 million of these being children (World Health Organization [WHO], 2019). Hearing loss has impacts communication and may affect language development of children if unaddressed and may potentially lead to social exclusion (WHO, 2019). Having a hearing impairment at a young age may affect development of speech and language, including expressive and receptive communication skills (American Speech-Language-Hearing-Association [ASHA], 2015). Language deficits may lead to learning problems, lowered academic achievement, and social isolation from peers (ASHA, 2015). In addition to academic and social development, communication issues may further impact behavioral, affective and cognitive development (ASHA, 2015; Winnick, 2011). Physical activity patterns and fitness levels of these individuals may be affected due to connections to these developmental domains (Hopper, 2006). However, given appropriate instruction and practice time, children with hearing impairments should be able to develop fundamental motor skills and participate effectively in physical activity (Dummer, Haubenstricker, & Stewart, 1996).

Historical Impact of Physical Activity for Children with Hearing Impairments

Early studies on children and youth with hearing impairments have focused on differences in balance, psychomotor capabilities and physical fitness. Lindsey and O'Neal (1976) found significant changes in the balance abilities of Deaf children when visual input was taken away. Butterfield (1983) assessed the balance skills of children who were deaf and looked for differences between genetic and idiopathic etiology groups, finding that the genetic group performed better on static balance tests but that overall gross motor performance wasn't significantly related to etiology. When testing for balance, Potter and Silverman (1984) found that 44% of children who are deaf demonstrated abnormal standing balance during experimental trails with their eyes open, and 35% when their eyes were closed. Potter and Silverman (1984) also concluded that while children who are deaf may have poor static balance, there was no significant correlation to vestibular function to overall balance abilities.

In historical research, balance has been the most frequent focus of research regarding children with hearing impairments. A comprehensive review by Hopper (2006) complied 19 articles regarding Deaf community and physical activity, with twelve of the articles including static or dynamic balance components. In addition, this review noted various methodological problems within these historical studies, including the assessment methods and tools, comparisons between differing groups, and participant selection methods. While balance was a common area of consideration, whether alone or in combination with other components of physical activity, the fitness and gross motor skills of children with hearing impairments have also been included in historical studies.

Physical fitness components that have been measured include maximal oxygen intake, agility, power, and speed (Pender & Patterson, 1982; Shepard, Ward & Lee, 1987). In terms of psychomotor skills, research has assessed fundamental motor skills, research has assessed manual dexterity, accuracy, climbing, throwing, kicking, catching, motor control and coordination (Myklebust, 1964; Geddes, 1978; Brunt & Broadhead, 1982). Research by Myklebust (1964) found that Deaf boys fell within the 50% for dexterity. The Test of Gross Motor Development (TGMD) has been utilized to assess motor skills of same-age children with and with-out hearing impairments, to find that subtest scores were lower for children who were deaf but overall there were only small differences in average scores (Dummer, Haubenstricker, & Stewart, 1996). Winnick and Short (1986) found no significant differences in physical fitness between Deaf children and those without hearing impairments. When comparing between children who are deaf who have parent who are also deaf to those without hearing impairments, no significant differences were present in locomotor or object control tests of motor development (Lieberman, Volding, & Winnick, 2004).

Barriers to Physical Activities

For students with hearing impairments, perceived barriers to participation in physical activities include the attitudes of the general public towards individuals with disabilities and lack of accessible information (Tsai & Fung, 2005). For children with cochlear implants, fear of blows to the head and the challenges of hearing during a group activity or in situations with lots of movement and background noise limited participation in athletics as reported by their parents (Bat-Chava, Deignan, 2001). Constraints such as physical ability and coordination, motivation, and facility accessibility were present but perceived to be less significant (Tsai & Fung, 2005). Peer relationships of students with cochlear implants has also been considered, as Bat-Chava and Deignan (2001) completed a qualitative analysis on the communication and relationships of these children. After receiving a cochlear implant, parents reported improvements in oral communication, positive change in personality and confidence levels, and opportunities to form relationships with peers. Interacting and socializing with peers who are also deaf or hard-of-hearing may give these children opportunities build relationships and develop communication skills which can then be utilized when socializing with peers without hearing impairments (Bat-Chava & Deignan, 2001).

Purpose of Review

The purpose of this review is to update the previous review by Hopper (2006) with current literature regarding the physical activity levels, physical fitness levels, gross motor skills and development, physical education, physical activity and sport programs and organizations involved with children who are deaf or hard-of-hearing.

HEARING LOSS OVERVIEW

Hearing loss is the third most prevalent physical condition within the United States (Blackwell, Lucas, & Clarke, 2012). From 2001-2008, 12.7% of individuals aged 12 or older were shown to have bilateral hearing loss and 20.3% had loss of hearing in one ear (Lin, Niparko, & Ferrucci, 2011). In addition, the prevalence of hearing loss for adolescents (including unilateral, bilateral, low frequency, high frequency, slight loss and mild or great hearing loss) increased 4.6% (from 14.9% to 19.5%) in 2005-2006 as compared to data from 1988-1994 (Shargorodsky, Curhan, Curhan, & Eavey, 2010). Over one billion youth are at risk of developing hearing loss due to exposure to noise, and it is estimated that one in ten people (over 900 million) will have hearing loss by 2050 (WHO, 2019). Hearing loss is classified as deaf or hard-of-hearing depending on the significance of the hearing loss and its effect on hearing communication (Winnick, 2011; WHO, 2019).

In the Individuals with Disabilities Education Act (IDEA, 2004), deafness is defined as “a hearing impairment that is so severe that the child is impaired in processing linguistic information through hearing, with or without amplification.” Hard-of-hearing is a hearing loss that results in difficulty understanding speech, either with or without hearing aids (Winnick, 2011). The IDEA (2004) states that hard-of-hearing as a fluctuating or permanent form of hearing loss which may affect the student’s ability within the educational system.

Hearing loss is classified into various grades of severity, using the decibel (dB) to measure sound intensity (WHO, 2019). The World Health Organization (n.d.) classifies a slight or mild hearing loss ranges between 26-40 dB, a moderate hearing loss (41-60 dB) leads to difficulties hearing regular speech, and a severe hearing loss is between 61-80 dB and a profound hearing loss is over 81 dB. Descriptive labels for hearing loss severity aren't standardized and their use varies throughout historical studies and reports (Clark, 1981). Hearing loss is considered disabling when it is over 40 dB in the better ear for adults and over 30 dB for children (WHO, 2019). With little or no hearing, Deaf individuals primarily classify under profound hearing loss (over 81 dB) where as hard-of-hearing ranges from mild to severe (WHO, 2019). Audiograms use the detection of tones to measure the level of hearing impairment, with various frequency and intensity thresholds utilized to provide an estimate of hearing loss or auditory sensitivity (National Research Council (NRC), 2004). Hearing loss can affect both ears (bilateral) or one ear (unilateral), and be asymmetrical, resulting in different degrees of loss in each ear, or symmetrical (Centers for Disease Control and Prevention (CDC), 2018).

Hearing loss occurs when any part of the auditory pathway is damaged (NRC, 2004). The three main types of hearing loss are conductive, sensorineural, and mixed (Winnick, 2011). Conductive hearing loss occurs when sound is unable to be transmitted well to the inner ear, resulting in sounds being muffled or hard to hear (Winnick, 2011). This often occurs with damage to the conductive system of the ear, including the ear canal, ossicles, and tympanic membrane (NRC, 2004). Conductive hearing loss is a mechanical form of hearing loss that isn't associated with auditory nerve damage, whereas sensorineural hearing loss is a form of hearing loss involving damage to the inner ear, nerve connecting the inner ear to the brain or higher auditory centers within the brain which results in decreased sound levels, and an altered ability to understand speech or hear clearly (NRC, 2004; Winnick, 2011). Mixed hearing loss is a combination of conductive and sensorineural hearing loss components (Winnick, 2011). Auditory Neuropathy Spectrum Disorder results in a type of hearing loss where damage to the inner ear or nerve prevents the sound that enters the ear from being processed by the brain (CDC, 2018).

Etiology

Hearing loss can be present at birth (congenital) or attained later in life (delayed-onset or acquired) (CDC, 2018). Congenital hearing loss can be hereditary, due to a genetic syndrome or various other factors such as infections, autoimmune conditions, premature birth, birth injuries, maternal drug and alcohol use while pregnant, high blood pressure while pregnant, or anoxia- where the baby has reduced oxygen levels (Winnick, 2011; ASHA, n.d.). Acquired hearing loss can be caused by injury, illness, or certain medical conditions such as ear infections, meningitis, encephalitis, measles, chicken pox, loud noise damage, or head injuries (Winnick, 2011; ASHA, n.d.). When the hearing loss happens before speech is developed, it is referred to as pre-lingual hearing loss (CDC, 2018). Post-lingual hearing loss occurs after one learns to talk (CDC, 2018). Hearing loss can also have a sudden onset or be progressive, with the level of hearing loss being stable or fluctuating (CDC, 2018). Approximately 60% of hearing loss in children under 15 years old can be attributed to preventable causes (WHO, 2019). Strategies for prevention include immunizing against childhood diseases, following hygienic and healthy ear care practices, reducing exposure to loud sounds and educational programs for youths and their families (WHO, 2019).

Hearing Aids

Hearing aids and assistive devices may be utilized by individual with hearing impairments. Hearing aids amplify sound to improve the hearing and speech comprehension (National Institute on Deafness and Other Communication Disorders [NIDCD], 2013). Small electronic devices magnify the sound, allowing hair cells within the ear to perceive the vibrations and convey them to the brain in the form of neural signals (NIDCD), 2013). Hearing aids can be behind-the-ear (BTE), on-the-ear or mini BTE, in-the-ear (ITE), in-the-canal (ITC) and completely-in-canal (CIC) based on the type and severity of hearing loss as well as the user's listening needs (U.S. Food and Drug Administration [FDA], 2018). BTE aids are utilized for individuals of all ages with hearing loss ranging from mild to profound (NIDCD, 2013). BTE aids are often used with children, as it accommodates the various ear molds needed as the child grows (FDA, 2018). ITE and canal aids aren't typically used with children, as they would need to be replaced periodically as the child outgrows them (NIDCD, 2013). In addition, both ITC and CIC aids aren't recommended for individuals with severe or greater hearing loss due to power and volume constraints from their size (NIDCD, 2013).

Cochlear Implants

Cochlear implants are electronic devices that are implanted to get past damaged areas of the ear and directly stimulate auditory nerves, giving the individual representation of sound signals in the brain (NIDCD, 2016; Winnick, 2011). They are comprised of an internal component that is surgically placed under the skin and an external component that is behind the ear (NIDCD, 2016). Cochlear implants are used for individuals who are Deaf or have a severe level of hearing impairment (NIDCD, 2016). Children under 18 months who receive an implant have similar rates of language development as children with typical hearing (NIDCD, 2016). Several studies have looked into the potential impact of cochlear implants on children's balance and motor skills, finding that children performed better on balance tests when wearing their implant compared to when they weren't utilizing it (Cushings, Chia, & James, 2008) and no significant differences in motor skills between Deaf children with and without implants (Gheysen, Loots, &Van Waelvelde, 2008).

Communication

A wide range of communication modalities and approaches are available for individuals with hearing impairments to communicate and develop language (Winnick, 2011). For children, early detection of hearing loss is necessary to minimize the impact on social and language development (WHO, 2019). Auditory-verbal and auditory only means of communication focus on developing spoken language through use of residual hearing, aids, and integration into communities utilizing spoken language (Gravel & O'Gara, 2003). Auditory-oral approaches to developing communication is similar to the auditory-verbal, but incorporates reading gestures, speech and facial expressions (Gravel & O'Gara, 2003). Cued speech combines spoken language with visual hand shapes and positions (Gravel & O'Gara, 2003). Whereas Manually Coded English (MCE) has various forms (including Signed Exact English) that utilize visual representations such as signs and finger spelling to signify English (Gravel & O'Gara, 2003). Total communication is a multimodal form of communication, involving manual, auditory and oral methods (Gravel & O'Gara, 2003). The manual mode of communication is sign language, which is a natural, visual language with styles varying by county or region that is utilized by the Deaf community as well as individuals who are hard-of-hearing (Winnick, 2011; Gravel & O'Gara, 2003). American Sign Language (ASL) is the primary language used in North America (NIDCD, 2019).

The lowercase “deaf” is utilized when referring to the audiological condition and the uppercase “Deaf” when discussing the community of Deaf individuals who share a culture and a language: ASL (Padden & Humphries, 1988). Often not considering deafness a disability, Deaf individuals use terminology such as Deaf person and Deaf community as opposed to person-first terms (Hopper, 2006). Members of the Deaf community share history, morals, experiences and beliefs related to themselves and their connections to the larger society (Padden & Humphries, 1988; Benedict & Legg, 2014). The diverse backgrounds of Deaf individuals are reflected within the community and children born to hearing parents can be included into the Deaf community via social interaction and language immersion in Deaf programs or with other Deaf individuals (Benedict & Legg, 2014).

Educational Trends

Under IDEA, students with deafness, hearing impairments and deaf-blindness are included within the 13 disability categories which makes them eligible to potentially receive special education services, including adapted physical education, as part of their free and appropriate public education (IDEA, 2004). As required in IDEA, students with disabilities must be educated in the least restrictive environment and included within the general education setting as much as possible based on their unique needs (IDEA, 2004). In the United States, 85% of students who are deaf or have hearing impairments are educated within public school programs (Schultz, Lieberman, Ellis, & Hilgenbrinck, 2013). In addition, approximately 87% of students with hearing impairments participate in a general education classroom setting during their school day (U.S. Department of Education, 2009). The percentage of students who are deaf of hard-of-hearing who attend a special school has decreased over the past 25 years by half, with each year having a smaller number of students attending these schools, which may affect the barriers that these students face and the need for appropriately trained teachers in general education schools (Mithcell & Karchmer, 2006).

Common barriers to the education of students who are deaf or hard-of-hearing in general settings include classroom instructional patterns, accompanying delays to academics or communication and both the perceptions and preparedness of the teachers (Berndsen & Luckner, 2010). Challenges facing teacher preparation programs include recent developments in Deaf education, curriculum development and university support (Lenihan, 2010). Data collection by Lenihan (2010) found that 54 out of 65 teacher preparation programs in the U.S. primarily focused on visual communication strategies for education children with hearing impairments and 11 programs prepared teachers work with students who utilize spoken language.

Communication and language supports and accommodations for students with hearing impairments include environmental modifications, such as noise reduction and seating, use of technology, visuals, pre- and post-teaching, and scaffolding (Berndsen & Luckner, 2010). Acoustic highlighting, involving techniques such as purposeful emphasizes, pauses and rephrasing, as well as repair strategies including repeating and providing key words can also support the learning of students with hearing impairments within the classroom Berndsen & Luckner, 2010). Educational audiologists and interpreters can help work with the teacher and student to recognize appropriate tools and facilitate effective communication within the classroom (Winnick, 2011). Communication with the student, family, and other teachers can help identify areas of need and provide ongoing support for the student (Berndsen & Luckner, 2010).

For physical education, this can involve incorporating demonstrations, modeling, visual instruction, clear and specific signs, minimized background noise, socialization techniques and the use of a peer tutoring program (Schultz, Lieberman, Ellis & Hilgenbrinck, 2013; Winnick, 2011). In an inclusive physical education setting, incorporating trained peer tutors has been shown to increase the amount of time that deaf children spend participating in moderate to vigorous physical activity (from 22% to 41.5%), as well as the time for the tutor themselves (19% to 37.9%) (Lieberman, Dunn, van der Mars, & McCubbin, 2000).

Safety Considerations in Physical Education

Students with cochlear implants should be cautious with activities that pose an increased potential for head injury, damage to the device, or risk of electrical discharges that may cause software errors (Vidranksi & Brozović, 2015). Non-recommended activities include contact sports, successive jumps, tasks with a risk of falling as well as activities that may get the implant wet (i.e., swimming and high intensity activities that result in sweating) in which the individuals should use appropriate covers for the external portion of the implant (Vidranksi & Brozović, 2015; Winnick, 2011).

Organized Sports Programs

Public Law 101-336, the Americans with Disabilities Act (1990) supports the civil rights of individuals with disabilities, and has supported their participation in sport and physical activity. The first games for any group of individuals with disabilities, the International Silent Games held in 1924, included athletes who were deaf from nine different countries (Deaflympics, 2019). Following this event, Le Comité International des Sports Silencieux (the International Committee of Silent Sports) was formed and later renamed to the Le Comité International des Sports des Sourds (The International Committee of Sports for the Deaf) or the ICSD (Deaflympics, 2019). To this day, only individuals who are deaf are allowed to be members of the board of the ICSD (Deaflympics, 2019).

In the United States, the USA Deaf Sports Federation (USADSF) was the first established disability sports organization, formerly known as the American Athletic Union of the Deaf when is began in 1945 (USADSF, 2019). Deaf sport organizations give hard-of-hearing and deaf athletes changes to compete at various levels and aim to facilitate sports participation while accommodating to the specific disadvantages that may be caused by hearing loss- including adaptations such as hand signals, lights, flags and communication supports (USADSF, 2019). The Deaflympics works to meet similar needs of Deaf and hard-of-hearing athletes (USADSF, 2019). In addition to providing opportunities for physical activity and competition, deaf sports organizations also serve as social outlets for individuals with hearing loss and those within the Deaf community (USADSF, 2019). One barrier to participation in Deaf sport is lack of awareness, which can be minimized by schools providing information and exposure about Deaf sport activities and their role in the Deaf community as well as implementing physical education programs that would enable successful participation in the various sports (Stewart & Ellis, 2005).

METHODS

The literature selected for this review was searched utilizing Humboldt State University's library search engine, One Search, as well as Academic Search Premier, Research Gate and Google Scholar. The keywords included: *children, hearing impairment, hard-of-hearing, deaf, physical activity, physical fitness, physical education, motor development, movement, sports,* and *participation*. The articles selected were published between 2006 and 2018. Studies included focused on children between the ages of 4 and 18 years old who were either deaf, hard-of-hearing or had a hearing impairment. Students who were diagnosed with deaf-blindness were excluded from the study. Systematic and comprehensive reviews as well as papers providing recommendations about relevant topics (i.e., strategies to include students with hearing impairments in physical education) were not included in the final article selection, but were commented on in the synthesis. Articles dating before 2006 were also used to draw comparisons in the synthesis and results. The results of this search led to the inclusion of 20 articles meeting the criteria from a total of 16 journals. The Journal of Deaf Studies and Deaf Education, Adapted Physical Activity Quarterly, American Annals of the Deaf, and the International Journal of Special Education were all journals that provided more than one article meeting the inclusion criteria.

RESULTS

The following literature compilation includes major research studies completed between 2006 and 2018 regarding children with hearing impairments (HI) and components related to physical activity (PA). Table 1 provides a brief summary for each study.

Table 1

Articles from 2006-2018 for Children with HI and PA Components

Authors / Year / Location	Population	Variables	Assessments	Results
Dair, Ellis and Lieberman (2006), U.S.	151 children who are deaf, aged 6-11	Body Mass Index	BMI	When compared to national averages, deaf children have a higher prevalence of overweight BMIs.
Hartman, Visscher, and Houwen (2007), Netherlands	Children who are deaf, aged 9-12	Physical fitness	Eurofit	Children who were deaf performed worse than hearing peers. The overall fitness of deaf children improved non-significantly with age.

Authors / Year / Location	Population	Variables	Assessments	Results
Keilmann, Limberger, and Mann (2007), Germany	131 children with HI, aged 6-11, at both special schools and public schools	Psychological and physical wellbeing	Frankfurt Self-Concept Scales for Children	While self-perception and psychological well-being vary based on both HI and school placement, the physical health of these children was not affected.
Sit, McManus, McKenzie and Lian (2007), Hong Kong	Children with disabilities (including HI) in grades 4-6 at 5 special education schools	Physical activity levels during PE and recess	System for Observing Fitness Instruction Time (SOFIT)- observed during 2 days over a 2-week period	Students spent approximately 50% of their time demonstrating sedentary behaviors during both structured and unstructured settings. Students with HI were engaged in more moderate to vigorous physical activity during PE than those with other disabilities.
Cushing, Chia and James (2008), Canada	41 children with sensorineural hearing loss and cochlear implants, aged 4-17	Equilibrium, static and dynamic balance	Bruininks-Oseretsky Test of Motor Proficiency (BOT-2)	With the exception of several children, overall results showed that children with implants performed at a level lower than their age level on the balance subtests, but their balance

Authors / Year / Location	Population	Variables	Assessments	Results
				significantly improved while wearing their implant.
Gheysen, Loots, and Van Waelvelde (2008), Belgium	79 children with and without cochlear implants, and children without HI, aged 4-12	Motor development	Movement Assessment Battery for Children (M-ABC), Körperkoordinationstest für Kinder (KTK), and One-leg standing test	Hearing children have significantly better scores and there was no overall significant difference in performance of the Deaf groups based on cochlear implants.
Gkouvatzi, Mantis, and Kambas (2010), Greece	34 children who were deaf or hard-of-hearing, aged 6-14	Reaction time, upper limb speed, visual-motor control and dexterity ability	BOT-2	No notable differences were present between children who were deaf when compared to children who were hard-of-hearing. However, there was a significant difference when compared by age, with children aged 13-14 performing better on upper limb speed, dexterity and visual-motor control.

Authors / Year / Location	Population	Variables	Assessments	Results
Gkouvatzi, Mantis and Pilianidis (2010), Greece	40 children who were deaf or hard of hearing and 39 hearing children, aged 6-14	The relationship between the degree of hearing loss and upper-limb coordination	BOT-2	There were significant differences in coordination between deaf and hard-of-hearing children when compared to hearing peers. Statistically significant variations in coordination were also present when comparing deaf and hard-of-hearing children as well as children of different ages.
Kurkova, Scheetz, and Stelzer (2010), Czech Republic	2 schools for the deaf in the U.S. and 2 in the Czech Republic	Comparison between countries regarding physical education curriculum, facilities, etc.	Questionnaires, observations and interviews	Schools in both countries were equipped for physical education provision with many similarities, and with a similar area of need for physical education cited by both Czech Republic and U.S. schools being the need for an improved student/teacher ratio.
Hartman, Houwen and Visscher (2011), Netherlands	42 children who are deaf with hearing loss ranging	Sports participation and motor skills performance	Sports participation questionnaire and the M-ABC,	Compared to normative samples, significant differences were found regarding manual dexterity, balance and ball skills, with children who participated in organized sports performing at a

Authors / Year / Location	Population	Variables	Assessments	Results
	from 80 to 120 dB, aged 6-12			higher level on balance and ball skill subtests
Walowska and Bolach (2011), Poland	105 children aged 10-12 with and without HI	HI effect on physical development of children and general fitness	Eurofit Physical Fitness Test Battery	Children with hearing impairments performed at a lower level in all components except for the static strength subtest.
Arsic, Slavnic, and Kovacevic (2012), Serbia	52 students with HI, aged 7-16	Sports activities and socialization	Comparative analysis	Deaf students' involvement in games and sports with the subsequent effect on socialization were discussed, assessing achievements such as taking part in play, playing various sports, understanding the rules, participating on a team, attending games and participating in a game.
de Sousa, de França Barros, and de Sousa Neto (2012), Brazil	43 children with profound hearing loss, aged 7-10	Postural control	Force platform and balance software	Results showed that when compared to their hearing peers, children with profound hearing loss had poorer balance abilities and less postural control.

Authors / Year / Location	Population	Variables	Assessments	Results
Ellis, Lieberman, and Dummer (2013), U.S.	Parents of 128 deaf children	Attitudes of parents of deaf children towards physical activity and fitness	Fitnessgram scores measured over a 4-year period, Likert questionnaire, parent-report of frequency and type of physical activities for their child	There was a positive relationship between parental values and their child's fitness levels and participation in physical activity.
Iwanska, Madej, and Urbanik (2013), Poland	300 students with and without HI, aged 12-16	Endurance levels, compared by power versus the time to decline for a total of 40 maximum effort take-offs	An inclined plane (simulating a jumping motion)	Results of this study found that female subjects had similar endurance levels and there was significant variation only between the males with hearing impairments and hearing males in the levels of maximal power.
Vidranski, Tomac, and Farkaš (2015), Croatia	16 students with cochlear implants, aged 6-18	Motor skill development	BOT-2	A large percentage of these students scored lower than average in all subtests. The largest significant differences in the motor skill categories for balance,

Authors / Year / Location	Population	Variables	Assessments	Results
				bilateral coordination and upper-limb coordination.
Malekabadizadeh, Barati, and Khorashadizadeh (2016), Iran	17 males with HI, 30 males with intellectual disability, and 42 typically developing peers, aged 7-12	Balance	BOT-2 Balance subtests	The children with hearing loss and intellectual disability performed similarly to each other, but at levels lower than typically developing children.
Schoffstall et al. (2016), U.S.	950 Deaf youth, aged 13-16	High-school extracurricular involvement effect on post-secondary enrollment	Data from the National Longitudinal Transition Study-2	Participation in extracurricular activities (including sports and athletics,) was positively correlated to independent living post-high school. Out of the students included in the study, the largest percentage (47%, or approximately 450 students) were involved in athletics as their extracurricular activity.

Authors / Year / Location	Population	Variables	Assessments	Results
Jernice and Nonis (2017), Singapore	Female students with (n=7) and without HI (n=17), aged 13-15	Fine and gross motor skills	McCarron Assessment of Neuromuscular Development (MAND	Significant differences were found in the kinesthetic integration component, implying lower levels of balance for children with hearing impairments.
Lobenius-Palmér, Sjöqvist, Hurtig-Wennlöf and Lundqvist (2018), Sweden	102 children with multiple disabilities, aged 7-20	Physical activity patterns	Accelerometers	Results found that the group with hearing impairments were the most physically active compared to the other subgroups- physical and visual impairments, autism spectrum disorder (ASD) and intellectual disability (ID).

DISCUSSION

Physical Activity Levels

The following sections reviews findings from recent literature. Physical activity levels for individuals with hearing impairments have noted that physical activity levels of children with hearing impairments are lower than typically developing peers (Lobenius-Palmér, Sjöqvist, Hurtig-Wennlöf, & Lundqvist, 2018). These children also spent a significantly larger amount of time sedentary than children without disabilities, with females with hearing impairments being more sedentary than males (Lobenius-Palmér, Sjöqvist, Hurtig-Wennlöf, & Lundqvist, 2018).

A similar study looking at the physical activity habits of elementary students concluded that when compared to students with visual impairments and physical disabilities, children with hearing impairments participate in more moderate-to-vigorous physical activity during physical education and recess time- though it is still less than the recommended total minutes for physical activity (Sit, McManus, McKenzie, & Lian, 2007). The conclusions that children with hearing impairments have higher levels of participation in physical activity that children with other disabilities align historical research such as Longmuir and Bar-Or (2000), who also drew comparisons between children with hearing impairments and children with disabilities such as muscular dystrophy, spina bifida, and cerebral palsy. Physical education participation and activity levels have also been used to find relationships between the number of students meeting the recommended amount of physical activity.

At a school for children with hearing impairments in Hong Kong, students with hearing impairments reached 16.6% of the recommended 420-minutes of moderate-to-vigorous physical activity during both physical education and recess (Sit, McManus, McKenzie, & Lian, 2007). Ellis, Lieberman and Dummer (2013) used a combination of questionnaires and Fitnessgram test items to analyze parental influence on the physical activity patterns of children with hearing impairments. There have been significant positive relationships between the physical fitness and activity levels of children who are deaf with their parent's attitudes regarding physical activity and sports (Ellis, Lieberman, & Dummer, 2013). In addition, higher values towards participation in sports were higher when both parents were deaf as well as their child's physical activity levels (Ellis, Lieberman, & Dummer, 2013). Parents who are aware of Deaf sport opportunities and are able to provide encouraging information that supports their child's belief regarding their physical capabilities may increase the positive perception of physical activity participation (Ellis, Lieberman, & Dummer, 2013).

These studies primarily used observational assessments (i.e., SOFIT), questionnaires and accelerometers to obtain data regarding physical activity patterns. Out of the studies reviewed, both Sit, McManus, McKenzie and Lian (2007) and Lobenius-Palmér, Sjöqvist, Hurtig-Wennlöf, and Lundqvist, (2018) completed research finding comparisons between students with different disabilities (i.e., HI, visual impairments, intellectual disabilities, autism spectrum disorder and physical disabilities) instead of in relation to typically developing peers.

Physical Fitness & Motor Development

In historical and recent literature, the physical fitness of children with hearing impairments as it compares to their hearing peers has been a well-researched topic. Goodman and Hopper (1992) reviewed ten research studies on this topic. Statistically significant variations in physical fitness levels were present in six out of ten of these studies (Goodman & Hopper, 1992). Similarly, three articles reviewed in this paper (between 2006-2018) noted a significant difference in physical fitness level subtests and seven studies found significantly poorer balance abilities for children with hearing impairments.

These studies utilized a variety of assessments to measure the physical fitness and motor development of children with hearing impairments were the BOT-2, the M-ABC (a standardized assessment including tests for manual dexterity, balance and ball skills), the KTK, The Eurofit Physical Fitness Test Battery, the MAND (including subtests such as jumping, heel-toe walking, hand strength, standing on one foot and finger-nose-finger assessments), and the Fitnessgram (Hartman, Houwen, & Visscher, 2011; Jernice & Nonis, 2017). Force platforms, balance software and lab-based tests were also utilized to collect data. Out of these tools, the BOT-2 was the most common with five of the articles utilizing it as a primary method of assessment.

Balance

Similar to early studies, balance components were the most frequent focus in studies assessing fitness and motor development of children with hearing impairments, as balance was measured in seven of the twenty articles included in this review.

These studies utilized a variety of assessments, with most containing subtests for static and dynamic balance. For example, de Sousa, de França Barros, and de Sousa Neto (2012) measured balance and postural control using a force platform and multiple experimental conditions to obtain data as opposed to the motor assessments utilized by the other studies included in the review (i.e., the BOT-2 and the M-ABC). These findings supported those of other studies showing that children with hearing loss displayed balance deficits (de Sousa, de França Barros, & de Sousa Neto, 2012). Gheysen, Loots and Van Waelvelde (2007) utilized three assessments- the M-ABC, KTK (a German assessment consisting of four dynamic balance subtests) and one-leg standing test (OSL)- to obtain information on static and dynamic balance. These researchers found significant difference for deaf children with cochlear implants when compared to hearing children and that on average, deaf children performed at significantly lower levels that hearing children on two out of the three total assessment scores (Gheysen, Loots & Van Waelvelde, 2007).

Also focusing the population of children with cochlear implants, Vidranski, Tomac, and Farkaš (2015) found these children scored worse on balance subtests than children without hearing impairments. However, results from Cushings, Chia and James (2008) showed that children with cochlear implants performed better on balance subtests while they were wearing their implants as opposed to when they were inactivated.

Jernice and Nonis (2018) had results showing that children with hearing impairments scored below-average and poorer than children without hearing impairments on subtests utilizing aspects of balance control. Hartman, Houwen and Visscher (2011), also measuring static and dynamic balance, with results showing that the most delays were present with static balance subtests. Notably, this study found no significant differences between Deaf children in relation to the scores of hearing children during the "dynamic balance while moving fast" subtest (Hartman, Houwen, & Visscher, 2011).

While most studies compared children with hearing impairments either to children with hearing impairments based on the use of a cochlear implant or to hearing peers, Malekabadizadeh, Barati, and Khorashadizadeh (2016) considered children with hearing impairments as well as children with intellectual disabilities when assessing balance. These children scored similarly to typically developing peers during the BOT-2's walking in a straight line subtest as well as when standing on one leg with eyes open (Malekabadizadeh, Barati, & Khorashadizadeh, 2016). The components testing dynamic and static balance had more differences in the performances of the children, with children with hearing impairments having worse balance, thus leading to the researcher's recommendation for physical activity programming to improve the balance capabilities of these children (Malekabadizadeh, Barati, & Khorashadizadeh, 2016).

Physical fitness

Deaf children have a higher prevalence of having an overweight BMI when compared to national averages, which may further affect components of health-related fitness, such as strength and endurance (Dair, Ellis, & Lieberman, 2006). A study by Walowska and Bolach (2011) looked at the physical fitness of 11-12-year-old children with moderate hearing impairments, with results showing that these children scored lower on all components of the general fitness test except for static strength compared to students without hearing impairments. Similarly, Hartman, Visscher and Houwen (2007) assessed 9-12-year-old deaf children and drew related conclusions: deaf children performed worse on physical fitness test items with non-significant improvements as they aged. Iwanska, Madej, and Urbanik (2013) focused on the endurance component of physical fitness, looking at relationships between age, gender and level of hearing impairment. Female students, hearing and hearing impaired, had similar performances for endurance and male students with hearing impairments performed with less power output that was sustained for a longer period of time when compared to their hearing peers (Iwanska, Madej, & Urbanik, 2013).

Ellis, Lieberman, and Dummer (2013) used the Fitnessgram to find correlations between parental attitudes and children's physical fitness, with the majority of their subjects scoring within the Healthy Fitness Zone. This contrasts earlier research by similar authors, as Fitipaldi, Ellis, Lieberman and Dummer (2005) considered the health-related fitness of deaf children to find that the children within the study achieved lower levels of healthy fitness levels and that physical fitness declined into adolescence.

Motor performance

In children who have profound deafness, delays in motor and postural development is common (Rajendran & Roy, 2011). Research by Hartman, Houwen, and Visscher (2011) supports this claim, as their results showed that both deaf children who participated in sports and those who did not participate had motor deficits in the three tested areas: ball skills, balance, and manual dexterity. Gkouvatzi, Mantis, and Kambas (2010) compared deaf children to children who were hard-of-hearing and while they found no significant differences in motor performance, they saw improved scores with the old group (children 13-14 years old).

Gheysen, Loots and Van Waelvelde (2007) assessed the motor development of deaf children with cochlear implants compared to children who are deaf or hard-of-hearing but did not have cochlear implants. When looking at vestibular function, it was noted that there wasn't a significant difference between performance on test items measuring balance between the two groups of students, though the scores from both groups were low (Gheysen, Loots, & Van Waelvelde, 2007). Vidranski, Tomac, and Farkaš (2015) also examined motor skill development of children with cochlear implants, with a large percent of subjects performing below average, especially when testing for gross motor skills (40% scored below average on upper-limb coordination and 53% on balance). In contrast, research by Jernice and Nonis (2017) found that students with hearing impairments were within normal values for gross motor proficiency when tested within a physical education setting using the Neuromuscular Development Index (NDI). However, there was significant differences became evident within kinesthetic integration component as students displayed mild difficulties with static and dynamic balance (Jernice & Nonis, 2017).

A study by Gkouvatzi, Mantis and Pilianidis (2010) measured upper-limb coordination using the BOT-2 to find differences in coordination based on the degree of hearing loss (categorized by deaf, hard-of-hearing and hearing). Similarly, Vidranski, Tomac, and Farkaš (2015) utilized the BOT-2 when assessing students with cochlear implants, observing significant differences during gross motor subtests including upper limb coordination and bilateral coordination. Hartman, Houwen, and Visscher (2011) results included significant deficits in hand-eye coordination of children with profound deafness. More children struggled with hand-eye coordination, which was measured by drawing, than with other tests involving coordination skills, such as catching a moving object (Hartman, Houwen, & Visscher, 2011).

Physical Education

Guidelines for physical education policy recommends that 50% of physical education be spent participating in moderate-to-vigorous physical activity (SHAPE America, 2014). In special education schools in Hong Kong, children with hearing impairments were active within their physical education class, yet showed limited time engaged in moderate-to-vigorous physical activity (41.9% of the total lesson, or 7.9 minutes) (Sit, McManus, McKenzie, & Lian, 2007). Previous research has shown that the use of a peer tutor can increase the total amount of time that children with hearing impairments spend participating in physical education (Lieberman, Dunn, van der Mars, & McCubbin, 2000).

A comparative study by Kurkova, Scheetz, and Stelzer (2010) looked into various characteristic of schools for the deaf in the U.S. and in the Czech Republic, finding that schools in both countries offered formal physical education classes one to two times a week, had the necessary facilities for physical education, and provides sports opportunities including local competitions with other schools and local sports. Research by Keilmann, Limberger and Mann (2007) noted that a child’s placement in public schools or schools for the deaf may further affect the child’s confidence and ability to make friends in their study regarding the physical and psychological health of children with hearing loss.

Out of the time frame criteria for the articles included in this review, there was a limited amount of research studying children with hearing impairments and physical education. Several articles and reviews provided a compilation of recommendations and guidelines for the successful inclusion of students with hearing impairments in a physical education class, including Schultz, Lieberman, Ellis, and Hilgenbrinck (2013), Hilgenbrink, Pyfer and Castle (2013), Palmer (2018). With regard to students with cochlear implants, Vidranski and Brozović (2015) completed a comprehensive review proposing guidelines, teaching strategies and modifications for physical education teachers to safely and successfully include students with cochlear implants.

Sport Programs and Organizations

Sports settings and activities allows children to socialize and develop communication skills as well as promotes character development during competition, including values such as team work, self-discipline, empathy and persistence (Arsic, Slavnic, & Kovacevic, 2012). For children with hearing impairments, participation in sports activities encourages socialization and communication with peers (Arsic, Slavnic, & Kovacevic, 2012). In addition, involvement in school or community extracurricular activities gives youth opportunities to solve problems, develop social and physical skills, establish supportive social networks and join peer groups (Schoffstall et al., 2016).

Children with hearing impairments who participated in organized sports have improved performances on motor skills such as ball skills (i.e., kicking, catching, throwing and rolling) and dynamic balance (Hartman, Houwen and Visscher, 2011). Participation in Deaf sport and physical activity opportunities has been seen to be more likely when the child has Deaf parents who are physically active (Ellis, Lieberman, & Dummer, 2013). Positive outcomes were seen with participation in extracurricular activities such as athletics for students who are deaf or hard-of-hearing correlating to enrollment in postsecondary education and independent living (Schoffstall et al., 2016).

In regards to young adults and adults with hearing impairments, Açak and Kaya (2016) looked into the self-esteem of 95 football players (ages 17+) using the Personal Information Form and Self-esteem Scale, ultimately concluding moderate levels of self-esteem for the athletes with no significant variations based on age, education and living-place variables. Participation in sports for children with hearing impairments has also resulted in significantly lower levels of continuous anger and increased ability to control anger when compared to peers with hearing impairments who were not involved in sports (Altin, 2015). Karakoc (2016) looked at the effects of participation in a Judo sports training program for adults with hearing impairments. When compared to adults with visual impairments, the individuals with hearing impairments had poorer scores with flexibility values and with the 30-second push-up test but significantly higher with the balance test (Karakoc, 2016).

CONCLUSION

Limitations

The articles reviewed highlighted various areas of need for children with hearing impairments as it pertains to their physical activity levels, physical fitness, gross motor development, and successful inclusion and participation in both physical education and organized sports. Several limitations were cited by the reviewed studies, including the small sample sizes of the research groups and the ability to control for confounding variables (Hartman, Houwen, & Visscher, 2011; Gheysen, Loots & Van Waelvelde, 2008; Vidranski, Tomac, & Farkaš, 2015). Both Gheysen, Loots and Van Waelvelde (2008) and Hartman, Houwen, and Visscher (2011) commented on the need for future research to be conducted with longitudinal studies.

Future Research

Future research focusing on the impact of cochlear implants on the vestibular system along with pre- and post-cochlear implantation data from standardized assessments on motor performance were also recommended (Cushings, Chia & James, 2008; Gheysen, Loots, & Van Waelvelde, 2008). Hartman, Houwen, and Visscher (2011) recognized research regarding the correlation between motor performance and sports participation of children with hearing impairments as an area of potential study. Ellis, Lieberman, and Dummer (2013) suggested further researching the effect of parent and educational influences on physical fitness and physical activity participation. Several studies recommended utilizing the current research to create programs and focused adapted physical education services for children with hearing impairments to meet their physical activity, physical fitness, balance, and upper-limb coordination needs (Gkouvatzi, Mantis, & Piliandis, 2010; Jernice, & Nonis, 2017; Lobenius-Palmér, Sjöqvist, Hurtig-Wennlöf, & Lundqvist, 2018; Malekabadizadeh, Barati, & Khorashadizadeh, 2016). While these studies presented the results and need for programs to counteract the motor delays presented by these children, few went on to suggest programs or draw conclusions as to why these differences were present in the first place, whether it be to variations in opportunities for participation, vestibular or cranial nerve damage related to the hearing loss.

In addition, few recent studies focused on the impact of peer interaction on physical activity, barriers to communication or the affective domain as it relates to students with hearing impairments. Children who are deaf or hard-of-hearing have been shown to interact less with peers, with the quality of the interaction correlated to their mode of communication and language ability (Anita, Kreimeyer, Metz, & Spolsky, 2011). As interactions, communication and relationships are important facilitators of social development for children, future research should address this area for children with hearing impairments and how it pertains to their ability to successfully communicate and socialize within sports and physical education settings (Anita, Kreimeyer, Metz, &

Spolsky, 2011). In addition, while several reviews provided recommendations to include students with hearing impairments in general physical education, there was limited amount of research regarding deaf schools and students' performance in physical education (Palmer, 2018).

Out of the 20 articles included in the review, the majority of the research was involved an international perspective, as only three articles (Dair, Ellis, & Lieberman, 2006; Ellis, Lieberman, & Dummer, 2013; and Schoffstall et al., 2016) originating in the United States. Other research from North America included an article from Cushings, Chia, and James (2008) in Canada and another in Brazil (de Sousa, de França Barros, & de Sousa Neto, 2012). Both Sit, McManus, McKenzie and Lian (2007) and Jernice and Nonis (2018) came from Asia: China and Singapore, respectfully. The majority of the articles (12 out of the 20) came from countries in Europe, including two from Poland, two from Greece, and one from each Germany, the Netherlands, Belgium, Czechia, Sweden, Serbia and Croatia. The variety in the cultural context of each country regarding physical activity levels, sport and education may impact the results of this review. However, the large amount of research performed in different countries provides a broad international perspective on the physical activity, fitness, and motor development of children with hearing impairments.

While there were twenty articles within the time frame of this review, historical research regarding children who are deaf or hard-of-hearing has been very minimal. A majority of articles on this subject up until 1990 have been unpublished dissertations (i.e., Burbank (1936) to Campbell (1983)), with a handful of books (such as Long (1932) and Myklebust (1960) and studies published through journals (i.e., Lindsey & O'Niel (1976) in *American Annals of the Deaf* and Geddes (1978) in *Perceptual Motor Skills*). The early 2000s had limited research regarding the physical activity, fitness levels, and motor development of children with hearing impairments. While initial research focused on what individuals who were deaf or hard-of-hearing could do in terms of motor development and balance, it is important for future research to expand on the general health perspectives of participation to physical activity as well as provide more information on and minimize barriers to physical activity that this population faces.

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