COMPARISON OF BALANCE BETWEEN YOUNG ADULTS WITH AND WITHOUT HEARING IMPAIRMENT

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By

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Dedication

To my family,

Bud Knudtson, Gigi Knudtson, Nicole Bullard

For everything they have done for me. For all their support, care, and love they have given me.

To my friends

For their help, support, and believing in me.

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Abstract

Comparison of Balance Between Young Adults With or Without Hearing Impairment

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Hearing impairment (HI) affects 1.4 per 1000 newborns in the United States (CDC, 2015). Damage to the vestibular system is one of the major causes of HI and is associated with balance impairment. Balance deficits may interfere with the development of motor skills. There is some discrepancy in the current literature on the development of balance in children and adolescents with HI. Few studies have investigated whether balance is impaired in young adults with HI and their results are inconsistent. The purpose of this study is to compare balance between young adults with and without HI.

Methods: A total of 70 participants were recruited for this study, 35 with HI (25.29 ± 2.71 years) and 35 without HI (24 ± 2 years). Balance outcomes were assessed using computerized dynamic posturography and the long forceplate (NeuroCom Internationa, Clackmas, OR, 2010). Balance tests included Sensory Organization Test (SOT), Motor Control Test (MCT), Adaptation Test (AT), and Unilateral Stance (US). Independent T-tests were used to analyze differences in balance between young adults with and without HI.

Results: Significant differences were found in the SOT composite score between those with and without HI ($t(68) = -4.99$; $p<0.05$). When the tests required the use of the vestibular system to maintain balance, the results indicate significant impairment for participants with HI. This was evident when balancing on an unstable surface with eyes open [EO] ($t(68) = -2.19$; $p<0.05$) and closed [EC] ($t(68) = -4.32$; $p<0.05$), as well as balancing on an unstable surface with incorrect visual information ($t(68) = -6.17$; $p<0.05$). A significant difference was also found in the single leg stance. The participants with HI showed significantly higher sway velocity (degree/sec) during EO and EC conditions on both the right and left leg ($t(68)$= Right leg EO: 3.32, Right leg EC: 5.40, Left leg EO: 2.84, Left leg EC: 6.33; $p<0.05$), which indicated unstable balance compared to controls. No difference was found between the two groups for the MCT and AT.

Conclusion: The results showed that there are differences in balance between young adults with and without HI. When a test required increased use of the somatosensory and vestibular system participants with HI had more sway and were able to balance on one leg for less time than young adults without HI.

Introduction

Between 1964 and 1994, the number of Americans aged 3 and up with hearing loss has doubled (Benson & Marano, 1995; Ries, 1994). In the United States, about 1.4 per 1,000 newborns are diagnosed with hearing loss (CDC, 2015). Hearing impairment is "a hearing loss that prevents a person from totally receiving sounds through the ear" (Bradford, Fleming, Hancock, Kleinert, Martinson, & Sheppard-Jones, 2000, p. 12). Hearing impairment covers a range from mild to profound hearing loss, and is used to describe people deaf or hard of hearing. Causes of hearing loss may include genetics, complications at birth, certain infectious diseases, chronic ear infections, drugs, exposure to excessive noise and aging (Deafness and Hearing Loss, 2015).

In addition, reports have found that 30% to 70% of children with hearing impairment have some level of vestibular dysfunction (Kegel, Maes, Baetens, Dhooge, & Van Waelvelde, 2012; Cushing, Gordon, James, Papsin, & Rutka, 2008, p. 12). Since a damaged vestibular system may lead to problems with balance, this may impede the development of dynamic and static balance reactions and coordination in children with hearing impairment (Chilosi, Comparini, Scusa, Berrettini, Forli, & Battini, 2010), which in turn, may interfere with the development of fundamental motor skills.

Balance deficits may cause poor postural control. Balance is defined as the ability to keep the body's center of gravity within the limits of the base of support (Pollock, Durward, Rowe, & Paul, 2000). Postural control is related to balance which requires maintaining stable posture during any activity. Balance relies on three main systems: vestibular, visual and somatosensory. The vestibular system provides sensory information of equilibrium; therefore, a damaged vestibular system may lead to balance problems (Watson & Black, 2008).

Those with poor postural control may have high risk of falling. The majority of studies have found that children with HI have poor equilibrium compared to peers without HI. Furthermore, children with HI demonstrate significantly higher sway causing unstable postural control. Studies indicate that children with HI demonstrate postural immaturity; however, their postural control improves with age. Yet, there are no studies in young adults.

Furthermore, participating in physical activity has been found to hinder motor developmental delays, and improve balance skills (Hartman, Houwen, & Visscher, 2011; Majlesi, Farahpour, Azadian, & Amini, 2014). Physical activity is an important area of the psychomotor domain, which is characterized by developing the proper skills to master a physical skill (Winnick, Lieberman, & Volding, 2004). Lack of physical activity may lead to sedentary lifestyle, which causes decreased health-related quality of life. Research has that children with hearing impairment are found to avoid being involved in social activity, which may lead to avoidance of participating in physical activity (Hogan, 2009). In addition, Hopper (2007) reports that children with HI have lower fitness levels compared to children with normal hearing. This may cause children with HI to be behind in motor and balance skills. It is critical for scientific studies to determine effective treatments to improve postural stability and control in individuals with hearing impairment.

Training the proprioception system has been found to improve somatosensory skills, this in turn contributes to balance effectiveness. By maintaining or improving balance skills, people with HI may be able to maintain stable postural control as well as people to those with normal hearing. In addition, although studies have used the NeuroCom to compare balance differences between children with HI and control group (Suarez, S., Angeli, Suarez, B., Rosales, & Carrera, 2007 and Huang, 2011); these studies have not yet investigated balance skills in persons with hearing impairments after adolescence. Therefore, it is important to examine balance in young adults with hearing impairments using reliable and valid tools.

This research study focuses on the balance outcomes in young adults with HI. The purpose of this study is to compare balance between young adults with and without HI. The main hypothesis is that there is a significant difference in balance. The second hypothesis is that person with HI who are active will have better balance than those who are inactive.

Clinical Implications

Participants with HI in this study made a new contribution to the clinical and practical fields. The findings in this study showed that there were statistically significant differences in balance between the hearing impaired and control groups. Knowledge gained from this study may help clinicians understand balance deviations in the hearing impairment population. Furthermore, this finding may assist clinicians in making recommendations regarding exercise intervention/rehabilitation to improve balance skills.

Hypotheses

Hypothesis 1: There will be significant differences in balance in persons with HI relative to those with normal hearing.

Hypothesis 2: Persons with HI who are active have better balance scores than those who are inactive.

Operational Definition

1. Postural control: the ability to maintain stable and upright posture during any activity (Pollock et al., 2000).

2. Balance: the ability to maintain balance by keeping the body's center of gravity (COG) over the base of support (BOS) (Pollock et al., 2000). Balance is measured by using a NeuroCom Balance Master EquiTest and Long Forceplate. The balance differences were examined in two variables: sway velocity (degrees/sec) and equilibrium.

3. Equilibrium: The Sensory Organization Test (SOT) measures participant's COG displacement per seconds.

4. Sway Velocity: The Unilateral Stance (US) measures the ratio of distance traveled by the COG (degree) to the time of the trials (seconds). Zero indicates no sway; twelve represent a fall. (NeuroCom International Clinical Integration Manual, 2010, p. 98)

5. Latency: The Motor Control Test (MCT) measures participant's ability to recover motor response (milliseconds) of COG over BOS. (NeuroCom International Clinical Integration Manual, 2010, p. 38)

6. Sway Energy: The Adaptation Test (AT) measures participant's ability to maintain postural control on support surface of toes up and toes down transition. ((NeuroCom International Clinical Integration Manual, 2010, p. 52)

7. Physical activity: A body movement that uses muscles and expends energy such as walking, running, or any recreational activities (CDC, 2015). Physical activity level is measured through a physical activity questionnaire which includes the participant's history of involvement in organized sports and current physical activity, classified as hours per week.

Assumptions

1. NeuroCom Balance Master EquiTest and Long Forceplate is a valid and reliable instrument to measure balance in young adults with hearing impairment.

2. Modified Physical Activity Questionnaire (PAQ) is a valid and reliable instrument to measure physical activity level in young adults with hearing impairment.

3. Participants answered the questions on the information sheet and modified physical activity questionnaire honestly and accurately.

4. Participants performed maximum effort during all balance tests.

Delimitations

1. All the participants with hearing impairment are diagnosed by an audiologist.
2. Participants recruited have no cognitive, cardiovascular, physical, and visual impairment.
3. Participants completed the test once to minimize familiarization during the test.

Limitation

1. Majority of the participants are college students and the age is not diverse.
2. Majority of the HI participants are more active than inactive.
3. Validity of physical activity levels is unknown as this information was self-reported.

Independent and Dependent Variables

Independent Variables:

1. Hearing Impairment

2. Normal Hearing

Dependent Variables:

1. <u>Balance</u>

    a. Adaptation Test

    b. Motor Control Test

    c. Sensory Organization Test

    d. Unilateral Stance

2. <u>Physical Activity</u>

Literature Review

Hearing Impairment (HI)

The organ of the ear is composed of three parts: the outer, middle and inner ear. Hearing impairment is the result of damage to one or more parts of this hearing system. Hearing impairment is defined as any type or degree of hearing loss, ranging from mild to profound (Ross, 2006). Hearing impairment may be present at birth, but it also can be acquired after birth either suddenly or progressively. It may be caused by a variety of factors including genetics, prenatal infections such as maternal rubella, oxygen deprivation at birth, prematurity, head trauma, ear infections and diseases such as meningitis (Ross, 2006). Hearing loss may be unilateral (one ear) or bilateral (both ears), and the hearing loss decibels (dB) may be symmetrical or asymmetrical, where one ear has equal or more substantial hearing loss than the other.

There are several devices that can assist with hearing impairment. People who are hard of hearing may use a hearing aid to help intensify sounds. People who are deaf either may not recognize sounds well with a hearing device, or they may have no hearing, rendering a hearing aid useless for this population. However, people with severe-to-profound hearing loss may be eligible for a cochlear implant. A cochlear implant is not like a hearing aid that amplifies sounds; instead, it is an electrical device that stimulates the auditory nerve in the inner ear.

Classification of HI

Hearing loss is measured by (dB), which is the intensity of the sound, and by hertz (Hz), which is the frequency of the sound. The normal range of frequencies is between 20 and 20,000 Hz. A person with hearing loss may have difficulty understanding certain vowel or constant sounds. Hearing ranges from -10 dB (normal hearing) to 120 dB (profound hearing loss). As the number of decibels increase, the degree of hearing loss increases. Hearing loss is labeled as slight (16-25 dB), mild (26-40 dB), moderate (41-55 dB), moderate-to-severe (56-70 dB), severe (71-90 dB) and profound (> 91 dB). Hard of hearing is defined as a hearing loss below 55 dB, while those who are deaf have a hearing loss of 55 dB or greater. Worldwide, there are approximately 440 million children who have hearing loss above 85 dB and about 800 million children who have hearing loss above 50 dB (Newton, Macharia, Mugwe, Ototo, & Kan, 2001; Smith et al., 1996).

In addition, hearing loss can be classified as conductive, sensorineural, or mixed (Hopper, 2007). Conductive hearing loss is due to damage or obstruction in the outer or middle ear. Sensorineural hearing loss is due to damage of the inner ear. Mixed hearing loss is a combination of both. People with conductive hearing loss do not have severe hearing loss. Hearing aids and medical interventions can usually help people with this kind of hearing loss. All frequencies of hearing are affected in conductive hearing loss. Sensorineural hearing loss, on the other hand, affects the ability to hear certain frequencies more than others and the hearing loss can range from mild to profound. Sounds may be distorted even with a hearing device or it may be impossible to hear at all. This is due to damage to sensory hair cells (cilia) in the inner ear or to the nerve fibers that supply the inner ear *(*Bevan, 1988*).* Since sensorineural hearing loss is caused by this kind of damage, it can affect the vestibular system as well. The vestibular system provides sensory information of motion, equilibrium, and spatial orientation; so therefore, vestibular dysfunction may lead to vertigo, dizziness, and equilibrium problems (Watson & Black, 2008).

Balance & Postural Control

Balance is defined as the ability to maintain the body's center of gravity (COG) within the base of support (BOS). Balance is associated with postural control. Postural control is a person's ability to maintain, achieve, or restore a state of balance during any posture or activity (Pollock et al., 2000). There are two types of balance: static and dynamic. Static balance is when a person is still in one position, while dynamic balance is when a person is upright while in motion. The ability to balance in both of these situations requires controlling the body's center of gravity and the part of the body that serves as the base of support. If the body's center of gravity is displaced out of the base of support, then a fall can occur.

People effectively maintain balance by receiving input from three main sensory systems: vestibular, somatosensory and visual. The vestibular system uses the head's position to determine spatial orientation, motion, and equilibrium. The somatosensory system uses the extensor muscles and joint systems to give proprioceptive information about how the body is moving. The visual system sends visual information to the brain about the body's position in its surroundings. The brain receives, interprets, and processes information from all three of these systems in order to maintain balance in the body. Therefore, if there is a problem with the input from one of these systems, the body's ability to maintain balance may be affected.

HI, Balance, & Postural Control

The inner ear is part of the balance system, therefore damage to the vestibular afferent fibers that leads to a hearing impairment (Marchetti, Siegel & Tecklin, 1991) can also cause balance deficits (Jafari & Malayeri, 2011; Potter & Silverman, 1984; Rajendran et al., 2012). Previous studies have found that children with congenital or severe-to-profound hearing loss may demonstrate balance deficits, delayed postural control, and motor development delays (Kegel, Dhooge, Peersman, Rijckaert, Baetens, & Cambier, 2010; Derlich, Krecisz, & Kucyoski, 2011; Potter & Silverman, 1984; Rine et al., 2004). Furthermore, deficits in balance may interfere with sensory organization (Jafari & Malayeri, 2011), general dynamic coordination, eye coordination (Kegel et al., 2010; Sousa , Barros, & Neto, 2012), and gaze (Rajendran et al., 2012).

In addition, children who are hearing impaired may have progressive balance or motor deficits (Rine et al., 2000). Hartman and colleagues (2011) conducted a study with elementary school children with severe-to-profound hearing loss, motor skills were assessed using three subtests of the Movement Assessment Battery: manual dexterity, ball skills, and balance. The children were found to have significantly more motor problems than children with normal hearing. The majority of children with hearing impairment with motor problems performed poorly on eye-hand coordination and static balance. Similarly Butterfield (1990) conducted a study on fundamental motor skills, using the Ohio State University Scale of Intra-gross Motor Assessment, with children aged 3 and 14 years old with 60 dB or greater hearing loss. Butterfield found that the children with hearing impairment demonstrated delays in kicking, jumping, catching, and hopping. Similarly, Dummer, Haubenstricker, and Stewart (1996) assessed fundamental motor skills in students aged 4-18 years with 55 dB or greater hearing loss using The Test of Gross Motor Development. This study found that children with hearing impairment showed some delay in object control skills, including stationary bounce, catch, kick, two-hand strike and overhead throw. Overall these results indicate that children with hearing impairment have delays of 1 to 3 years in these skills (Dummer et al., 1996).

Another study, Kegel et al. (2012), assessed motor impairments in children with hearing impairment aged 3 to 12 years by using the Movement Assessment Battery for Children- Second Edition (M ABC-2). The M ABC-2 is an assessment to identify and describe the motor impairments (Brown & Lalor, 2009). The test includes 3 areas: manual dexterity, ball skills ability, and balance. This study found that most children with hearing impairment not only possess balance deficits, but also perform weakly in manual dexterity and ball skills ability. The authors concluded that this is due to an inability to use proper postural control, which, in turn, causes delayed motor development (Kegel et al., 2012). Also, Kegel et al. stated that persons who have acquired hearing loss are more likely to have a motor disorder because their hearing loss is associated to neurological damage.

Postural control in children with hearing impairment aged 8-11 years was examined by Suarez and colleagues. These researchers looked at how the children with HI used sensory information for postural control compared to children with normal hearing (Suarez et al., 2007). The Postural Control Test that was conducted was based upon altered sensory conditions, there were two conditions: standing on a firm surface with eyes open and standing on a foam pad with eyes closed. The researchers found that the children performed poorly in postural control, displaying increased sway, while standing on a foam pad with eyes closed. According to Suarez and colleagues, children with hearing impairment depend on both visual and somatosensory information for effective postural control due to damaged vestibular system.

Similarly, Huang, Hsu, Kuan, & Chang (2011) compared static balance control in adolescents with cochlear implants and adolescents with normal hearing. This study used the stabilometry test, Gravicoder GS-7, which monitors individuals' ability to maintain postural control under different conditions. The test included 4 conditions: firm surface with eyes open; firm surface with eyes closed; foam pad with eyes open; and foam pad with eyes closed. Adolescents with hearing impairment performed significantly worse than adolescents with normal hearing in static balance control during the foam pad with eyes closed condition. Also, adolescents with normal hearing performed slightly better than those with hearing impairment on the firm surface with eyes open. Interestingly, adolescents with hearing impairment performed significantly better on the foam pad with eyes open than hearing adolescents. The results demonstrated that adolescents with hearing impairment performed better when only somatosensory input was disrupted, but performed significantly worse when both visual and somatosensory inputs were eliminated or disrupted.

Rine and colleagues looked at both static and dynamic balance skills in young children, 3 to 5 years old, with sensorineural hearing loss and found that they exhibited development delays in both areas (Rine, Robinsone, Rice, O'h, 1999). This study included single-leg stance and certain Peabody Developmental Motor Scale skill areas such as catching a ball. Results showed that the children with sensorineural hearing loss scored at or below the 20th percentile on static and dynamic balance compared to children with normal hearing. In a similar study, Cushing, Papsin, Rutka, James, Blaser,

& Gordon (2009) used the balance subsets of the Bruininks-Oseretsky Test Proficiency 2 (BOT2) to examine static and dynamic balance skills in children aged 4 to 17 years with sensorineural, profound hearing loss. The BOT2 includes nine balance subtest tasks including standing on one leg on a line with eyes opened and closed, standing on a balance beam with eyes opened and closed, and standing heel to toe on a balance beam. The results from this study demonstrated that the majority of children with profound sensorineural hearing loss demonstrated abnormalities in static and dynamic balance skills compared to children with normal hearing.

Years before, Lindsey and O'Nea1 (1976) conducted a similar study with a population of 8-year-old boys, some of whom had hearing loss of 30 dB or greater and some of whom had normal hearing. They used 6 static balance tests and 10 dynamic balance tests. This study found that 8-year old boys with hearing impairment scored significantly lower in static and dynamic balance compared to 8-year-old boys with normal hearing. Lindsey and O’Neal stated that visual input elimination caused children with hearing impairment to perform significantly worse on the static balance test compared to children with normal hearing. However, Lindsey and O’Neal also found that some children with hearing impairment did as well as the children with normal hearing in both static and dynamic balance tests. Their study showed that children who are hearing impaired, but with normal vestibular function have normal motor and balance skills, and that children who are hearing impaired with abnormal vestibular function have normal motor skills except for balance skills. They also showed that children who are hearing impaired with sensory organization deficits have poor motor and balance skills.

These findings were replicated in later studies. Crowe and Horak (1988) also stated that children who are hearing impaired with sensory organization deficits have motor and balance deficits. Rine et al. (1999) found that children with abnormal vestibular dysfunction exhibited poorer gross motor skills than children with sensorineural hearing loss without sensory organization deficits.

Although it has been shown that children with vestibular impairments lag behind hearing children in motor development, investigators found that not all children with hearing impairment have balance deficits (Boyd, 1967). Potter and Silverman (1984) proposed that children who became deaf after birth were more likely to have balance deficits than those who were born deaf. Similarly, Said (2013) examined balance skills in children with hearing impairment using the balance subsets of the Bruiniks-Oseretsky Test of motor proficiency, the modified Clinical Test of Sensory Interaction for Balance, one leg stance, and tandem stance. This study found that children with hearing impairment scored lower in all balance skills tests compared to children with normal hearing, but that children with acquired hearing loss (e.g. through meningitis) performed worse than children with congenital hearing loss. However, the scores were not statistically associated with etiology and balance. Also, the youngest group of children with hearing impairment scored the lowest in the balance subsets compared to older age groups.

Though Potter and Silverman (1984) and Said (2013) found that children with acquired hearing loss have balance deficits, other studies have found different results. Dummer et al. (1996) found that balance skills in both children with hearing impairment and in children with normal hearing improved with increasing age. Increasing age is associated with more mature movement patterns in typical development (Dummer et al.

1996). Siegel et al. (1991) conducted a study of balance skills in children with hearing impairment by using the balance subtest of the Bruininks-Oseretsky Test of Motor Proficiency to determine if balance deficits were present and if the deficits were age-related. This study included three groups of children age 4.5-6.5 years old, 8 years old, and 10 years old with bilateral sensorineural hearing loss. They found that the older age group had significantly higher scores than the youngest group; however, the older age group obtained a lower mean score than the standard mean score on the balance subtest. Siegel et al. (1991) stated that the children did not demonstrate any differences among balance scores and balance subtest standard scores between the age groups; so therefore, the authors concluded balance deficits were not age-related.

Static and dynamic balance skills in the hearing population are well developed by adolescence. Butterfield and Ersing (1986) investigated if balance skills in children with hearing impairment are also age-related. Both of these studies found that balance skills in children with hearing impairment whose ages ranged from 3 to 14 years old did improve with age. Similarly, Kaga (1999) stated that persons with vestibular impairment demonstrated poor postural control during childhood; however, they were able to develop postural control skills similar to individuals with normal hearing with age. However, one report, Siegel et al. (1991), rejected the idea that balance deficits decreased with age. Siegel et al. found that even though the older children had significantly higher scores than the younger children, the mean score of the older age group was not significantly different than the standard score and concluded that balance skills were not age-related.

Some studies have shown differences among children with hearing impairment and balance skills, while other studies have pointed to other aspects of HI that affect balance. These include different types of hearing loss. Kegel et al. (2012) conducted a study on children with bilateral or unilateral moderate (41-55 dB) hearing loss to profound (91+ dB) hearing loss. The result indicates that those with moderate hearing loss performed motor and balance skills in a manner similar to children with profound hearing loss. As a result, Kegel et al. stated that children with moderate bilateral or unilateral hearing loss are at the same risk for motor and balance deficits as children with profound hearing loss.

In another study, Rine (2000) found that children with sensorineural hearing loss have progressive motor development delays and postural control deficits, but children with conductive hearing loss do not exhibit any delays or deficits. However, at least one researcher reported contrasting results, Huang et al. (2011) stated that vestibular loss does not correlate to balance skills and that people with vestibular loss do not have typical balance problems on a daily basis. According to Huang et al. (2011), type of hearing loss does not influence the balance function, but the process of the central nervous system does.

Although there are several factors that affect children's postural control and motor developmental skills, Dummer and colleagues stated that children who are deaf and lag behind in motor development are likely to experience environmental factors, in addition to their HI, that contributed to their motor development delay (Dummer, Haubenstricker, & Stewart, 1996). Environmental factors include type of school (mainstreamed or deaf institute) and opportunities for participating in physical activity. Moreover, this study state that children with hearing impairment who went to mainstreamed school are found to be more likely to avoid social interaction, which cause them to be less likely to be involved in physical activity. On the other hand, those who went deaf school was found to be more likely to be involved in physical activity. Dummer and colleagues (1996) used the Test of Gross Motor Development (TGMD) to evaluate fundamental motor skills of children with hearing impairment aged 4 to 10 years who were attending a school for the deaf. This study found that a group of 4-year-old children with hearing impairment scored higher on object-control and locomotor skills than children with normal hearing. But a group of children with hearing impairment aged 5 to 10 years scored lower on the object-control and locomotor subscales of the TGMD compared to children with normal hearing. Furthermore, children with hearing impairment who participated in sports scored higher on subscales of the TGMD (Dummer et al, 1996). Hence, the authors concluded that participating in early intervention and in physical activity is beneficial for improving motor skills.

Physical Activity

Physical activity (PA) refers to body movements that use muscles and expends energy, such as walking, household chores, running or any recreational activities. It is important to be physically active to promote health-related quality of life, a multidimensional concept including physical and psychosocial dimensions (Rajendran et al., 2012), and to reduce the risk of secondary conditions such as chronic diseases like heart disease.

Current CDC guidelines recommend that children aged 6-17 years participate in at least 60 minutes of moderate physical activity every day and muscle strengthening activities three times a week (Centers for Disease Control and Prevention, 2014). In addition, adults aged 18-64 years should participate in at least 150 minutes of moderate-intensity physical activity every week and muscle strengthening activities two times a week, or 75 minutes of vigorous-intensity physical activity every week and muscle strengthening activities twice a week. Moderate-intensity activities include walking or playing tennis, while vigorous-intensity activities include running or playing basketball. Participating in regular physical activity helps develop fitness, motor skills and a healthy lifestyle.

Correlation between physical activity and postural control in HI

Although it is well established that physical activity is necessary for a healthy life, children with hearing impairment are likely to experience social-emotional development issues due to difficulty with communication, which may cause them to avoid participating in social or physical activities (Hogan, 2009). Hogan (2009) and Rajendran et al. (2012) have shown an association between children with hearing impairment and decreased health-related quality of life because they avoid participating in social activities. In addition, poor fitness may further deter children with a hearing impairment from participating in physical activity (Cairney & Veldhuizen, 2013). Rajendran et al. (2012) stated that children with hearing impairment demonstrate lower levels of postural control skills, motor skills, and health-related quality of life.

It has been hypothesized that inactivity can cause poor motor functioning, which, in turn, leads to a lack of motor skills and poor fitness (Cairney & Veldhuizen, 2013). Since literature reports that children who are deaf have lower fitness levels compared to children with normal hearing (Hopper, 2007), lack of physical fitness may be another reason children with hearing impairment are behind in motor and balance skills compared to children with normal hearing (Dair, Ellis, & Lieberman, 2006 & Ellis, Lieberman, Fittipauldi-Wert, & Dummer, 2005). Research has demonstrated that if children with hearing impairment participate in physical activity or sports, that their motor and balance deficits will decrease (Hartman et al., 2011).

Motor skill or balance deficits may cause children with hearing impairment to be inactive and face difficulties in some sports activities such as bike riding or walking on a balance beam (Butterfield, 1990); however, overall, those who are physically active are more likely to have a better quality of life (Winnick et al., 2004). Lieberman, Dunn, Mars, & McCubbin (2000) conducted a direct observation study to examine children with hearing impairment’s engagement in physical activity using the System for Observing Fitness Instruction Time (SOFIT). This study found that children with hearing impairment are only engaged in moderate to vigorous physical activity (MVPA) 22% of the physical education lesson time. This is far less than the recommended physical education time. Chow, McKenzie, & Louie (2009) found that students without disabilities in grades 7-12 only engage in MVPA 36% of the class time. The study showed that students without disabilities did not meet the 50% physical education time criterion either; however, they spent more time in MVPA than those with disabilities. It is critical for children with hearing impairment to meet the MVPA criterion in physical education to avoid problems with motor and balance skills and fitness deficiencies (Hartman et al., 2011).

Literature indicates that balance deficits may lower physical activity levels, and it has been found that children with hearing impairments have significantly more problems with balance compared to children with normal hearing (Hartman et al. 2011). The Hartman et al. (2011) study showed that persons with hearing impairments who were involved in physical activity possessed greater levels of balance and motor performance; however, this report also showed that these levels of balance were lower than in people with normal hearing. Furthermore, physical activity leads to increased social and psychological growth (Brown & Brown, 1996; Malina & Bouchard, 1991). To improve balance and to increase overall physical activity in persons with hearing impairment, studies have looked at the effects of different intervention programs.

Intervention

Participating in balance and body awareness programs have been shown to significantly improve balance skills in children with hearing impairment (Majlesi et al., 2014). Majlesi et al. (2014) conducted a study with children with hearing impairment who were between the ages of 8 to 14 years offering a 12-session balance intervention that focused on improving somatosensory skills by training the proprioception system. The result showed that their intervention was effective in improving static balance and decreasing sway.

In another study, Rajendran et al. (2012) conducted a six-week intervention of vestibular-specific neuromuscular training program in children with hearing impairment aged 6 to 11 years old. The Test of Gross Motor Development-2, Pediatric Reach Test, One Leg Standing Test, postural sway meter, and PedsQL Generic Core Scale were used in the neuromuscular training program. The program focused on developing visual and somatosensory abilities and enhancing fundamental motor skills. This exercise intervention program was found to significantly improve postural control and motor skills, and this improved the children’s PedsQL Generic Core Scale scores which correspond to health-related quality of life. Similarly, Rine’s (2004) study of a balance intervention, which focused on enhancement of sensory integrative and postural control skills for children with hearing impairment, revealed improvement of balance control and halted progressive motor delay. This study showed that the children with hearing impairments who exercised had less delay in motor development than children with hearing impairment who did not exercise. This indicated that exercise intervention can minimize motor developmental delay.

Effgen (1981) conducted an exercise program that focused on static balance activities in children with hearing impairment aged 7 to 11 years; however, this study found no significant difference in static balance compared to normal hearing children. However, this program was only for 10 days, which suggests that duration may affect the result. Studies recommend that exercise intervention can address balance and motor deficits in children with hearing impairments (Rajendran et al., 2012). Interventions that focus on visual and somatosensory effectiveness in postural control have been found to arrest progressive motor delay (Rine et al., 2004) and improve balance and gaze stability in people with vestibular impairment (Braswell, 2006; Herdman, Schubert, Das, & Tusa, 2003). According to Dummer et al. (1996), if children with vestibular impairment participate in intervention at an early age, they may develop basic motor skills at the same rate as children with normal hearing.

Interventions help individuals with vestibular impairment learn how to recognize and control postural control. Krebs, Gill-Body, Riley, & Parker (1993) conducted an eight-week vestibular treatment with adults with bilateral vestibular dysfunction. This study included visual training by using with or without head movement, gait with different support size and surface, and goal oriented movement tasks. The results showed improvement of motor skills and postural control in static and dynamic balance. Hence, the author concluded that vestibular treatment focusing on visual and somatosensory improves postural control along with motor skills. Therefore, it is critical to provide proper treatment for individuals with vestibular impairment to diminish the negative impact of balance and/or motor deficits and to improve their health-related quality of life.

Summary

Physical activity is crucial for promoting a healthy lifestyle and preventing secondary conditions associated with a sedentary lifestyle such as obesity, fatigue, depression or low physical function and fitness levels (Warburton, 2006). Evidence has shown that better balance scores are related to greater engagement in physical activity (Hartman et al., 2011). Furthermore, balance skills depend upon using visual, somatosensory, and vestibular systems. Consequently, interventions that focus on visual and somatosensory effectiveness in postural control have the potential of improving individual's balance and motor abilities.

Although it is well documented that children with hearing impairments have balance deficits which may interfere with motor skill development (Horak, 1990; Lindsey & O'Neal, 1976; Rine et al. 2000; Said, 2013), balance skills in children with hearing impairment do improve with increasing age until adolescence (Riach & Hayes, 1987; Schwab & Kontorinis, 2011). However, few studies have investigated whether balance is altered in young adults with hearing impairments, and how physical activity levels in this population are affected. The purpose of this study is to compare balance in young adults with and without hearing impairment. Additionally, this study will investigate the relationship between balance and physical activity in young adults with hearing impairment.

Methods

Participants

A total of 70 individuals participated in this study. Thirty-five people with hearing impairment (19 male, 16 female, mean age 25.29 ± 3.18 years) and thirty-five people with normal hearing (16 male, 19 female, mean age 24 ± 4.38 years). Inclusion criteria for all participants was 18-30 years old and the inclusion criteria for participants with hearing impairment was a diagnosis of 40-120 dB (moderate to profound) hearing loss range. Participants were excluded from the project if any of the following exclusion criteria were met: a history of cognitive, physical, and visual impairments, any medical conditions that inhibit participation in physical activity, and an acute injury or surgery within the past 6 months. Also, the control group had no history of hearing or balance problems. Recruitment was done through fliers and word of mouth at California State University, Northridge (CSUN) and the surrounding community.

Research Setting

The study was performed at the Center of Achievement at CSUN. All data collection was completed during one visit.

Variable Outcomes and Instrumentation

Each participant completed four balance tests using the following assessment tools: the Sensory Organization Test (SOT), the Motor Control Test (MCT), the Adaptation Test (AT), and Unilateral Stance (US) on the NeuroCom Balance Master (NeuroCom International, Clackamas, OR, 2010). The NeuroCom Balance Master is a computerized posturalgraphic balance assessment machine.

Static and dynamic balance was measured by the SOT, MCT, AT, and US. The SOT measured the equilibrium for six conditions, including a combination of eyes open and eyes closed, fixed surface and moving surface and fixed sway and sway referenced visual surrounding. Figure 1 shows the six conditions. The equilibrium score calculates how well the participant's is able to maintain their sway within the theoretical limits of stability of 12.5 degrees during each sensory condition. If a person has little sway the score is near 100%, increased sway decreases the score (NeuroCom International Clinical Integration Manual, 2010, p. 24). This test assessed the role of the three major balance systems: visual, proprioception, and vestibular by measuring the sway velocity (degree/second) of recovery from balance perturbations. The NeuroCom Balance Manage Software converted the speed of adjustment to repair balance to norm-reference equilibrium score which was calculated (% average of degree/second).

The MCT measured the latency (milliseconds) score during three task conditions, including small, medium, and large unexpected translations of forward and backward direction on the support surface. This assessed the participant’s ability to quickly recover their balance from the unexpected floor movement, and measured the participant’s reaction time. The AT measured the reaction time and the participants’ ability to adapt to conditions of toes up and toes down movement of the support surface through sway velocity (degrees/second). Both of the conditions consisted of five trials to measure the participants’ ability to maintain postural control. The Unilateral Stance (US) measured sway velocity (degrees/second) under four conditions. The conditions used a combination of 3 trials of each standing on one leg at a time with eyes open and closed.

The balance tests took approximately 30 minutes to complete. Individuals followed the instructions given by the researcher and all assessments were completed by the same researcher. Participants were allowed to take as many breaks as they needed.

Physical activity was investigated with the Modified Physical Activity Questionnaire (Modified PAQ). The Modified PAQ is composed of 10 questions for assessing participants' history and current involvement in physical activity. The questionnaire took approximately 5 minutes to complete.

Data Collection Procedures

Participants completed data collection once. Prior to any data collection, participants were asked to sign informed consent form. After obtaining consent, the participants were asked to complete the information sheet, anthropometric data, and four balance tests. In addition, the hearing impairment group was asked to fill out the Modified PAQ, A brief description of each balance test was provided. Balance tests were performed in random order for each participant throughout the data collection procedure.

Statistical Analysis

All data from the questionnaires were imported into Microsoft Excel to create the graphs and charts. Visual analysis was used to investigate the association between balance and the following variables: the cause of deafness, gender, age, hearing loss in dB, mainstreamed/deaf school, history and current physical active level. Independent t-tests were used to analyze differences in balance between young adults with and without HI. All statistical analyses were calculated using the SPSS in SOT, AT, MCT, and US balance tests (SPSS software, version 17, SPSS Inc. Chicago, IL).

The relationship between balance and current physical activity level for individuals with HI was explored using point by serial correlation analysis. The groups of participants with HI were divided into two groups; those who met the national guidelines for physical activity established by the CDC and those who did not. The CDC physical activity guideline include 150 minutes of moderate-intensity aerobic activity with muscle strengthening activities on 2 or more days every week or 75 minutes of vigorous-intensity aerobic activity with muscle strengthening activities on 2 or more days every week (CDC, 2015). A significance level of $p < 0.05$ was adopted for all statistical tests.

Human Subjects Protocol

This study protocol was submitted and approved by the Human Subjects Review Board of California State University, Northridge. All participants read and signed an informed consent form before any data was collected. Potential risks to participants, including fatigue or fall, were minimized by wearing a harness, allowing breaks, and active spotting by the research assistant.

Results

The purpose of this study was to compare balance in young adults with and without hearing impairment. A total of 70 individuals, 35 with hearing impairment and 35 individuals with normal hearing participated in this research study group. The two groups were similar gender and age, a summary of the participants' profile data are presented in Table 1.

Participants with HI showed significantly poorer balance compared to those without HI on SOT and US tests. This supports the main hypothesis that persons with hearing impairment have impaired balance relative to those with normal hearing.

Second, it was hypothesized that people with hearing impairment who are more active have better balance scores than those who are less active. Of the 35 participants, 22 participants met and 13 did not meet the physical activity guideline. There were no significant differences between current physical activity and balance scores.

Balance analysis

Independent t-test revealed that there were statistically significant differences in balance between the two groups on some sections of the Sensory Organization Test (SOT) and the Unilateral Stance (US), but no statistically significant differences were found for the Motor Control Test (MCT) and Adaptation (AT) tests.

The SOT measures the ability to use input cues to the sensory system to maintain balance. The composite score, which is weighed by the average of the six conditions, was significantly different between the two groups ($t = -4.99$, $p<0.05$). When looking closer at the different conditions we found that there were no significant differences in conditions 1 to 3. Condition 1 requires the use of somatosensory system without any visual elimination or sway reference surface; Condition 2 and 3 require the use of somatosensory system with visual elimination/disruption. On the other hand, when the tests required the use of the visual and vestibular system to maintain balance, the results indicate significant impairment in participants with hearing impairment. This was evident in Condition 4 which required balancing on an unstable support surface with eyes open [EO] ($t(68) = -2.19$, $p<0.05$), as well as Condition 5 which required balancing on an unstable surface with eyes closed [EC] ($t(68) = -4.32$, $p<0.05$), and Condition 6 which required balancing on an unstable surface with incorrect visual information ($t(68) = -6.17$, $p<0.05$).

During the Unilateral Stance test, the participants with HI showed significantly higher sway velocity (degree/sec) in all four conditions: Left EO ($t(68) = 3.32$, $p<0.05$); Left EC ($t(68) = 5.40$, $p<0.05$); Right EO ($t(68) = 2.84$, $p<0.05$); Right EC ($t(68) = 6.33$, $p<0.05$), which indicated unstable balance compared to the controls. The sway velocity is measured by the degree of center of gravity displacement per second. The higher number indicates the higher degree of sway velocity.

The MCT and ADT measure the ability to quickly recover from unexpected surface translations. The MCT Composite Score is weighed by the average latency (milliseconds). The ADT test measures the average of degrees in sway energy per second. No difference was found between the two groups for the MCT and AT test. Comparison of all four balance tests between the hearing impaired and control groups is shown in Table 3.

A summary of the demographic data in hearing impairment group are presented in Table 2. There were no significant differences found between individuals with HI current physical activity and balance test. However, there was a low correlation between individuals with HI current physical activity with SOT condition 4 ($r=.138$) and US eyes closed ($r=.113$). The point by serial correlation analysis measured the strength of association of coefficient value of small ($0.1 < | r | < .3$), medium ($0.3 < | r | < .5$), and large ($| r | > .5$) correlation (Cohen, 1988). Correlation between HI's current physical activity and balance tests are shown in Table 4.

It was of interest to investigate the association between balance tests which showed significantly deficits for participants with HI (SOT 4, SOT 5, SOT 6, and US) with cause of deafness, gender, age, hearing loss in dB, mainstreamed/deaf school, history and current physical active level. Visual analysis was used to assess the association. There was no association between SOT 4 and US with all the variables. However, there was an association between several variables and SOT Condition 5 and 6 including involvement in sports, hearing loss (dB), type of school, and the cause of deafness. The comparisons between each variable with SOT 5 and SOT 6 are shown in Graph 1 to 12.

Discussion

The primary objective of this study was to compare balance in young adults with and without hearing impairment. There were two hypotheses in this study, the main hypothesis was that there would be a significant difference between the two groups in the various balance measures. Second, it was hypothesized that people with hearing impairment who are active have better balance than those who are inactive.

According to the statistical analysis, the study findings support the first hypothesis. Results demonstrated that persons with hearing impairment have poor balance compared to the control group. The second hypothesis was not supported. There was no correlation found between individuals with HI's balance skills and current physical activity. However, those who were involved in sports during elementary to high school exhibited greater postural stability during the Sensory Organization Also, the cause of hearing loss was found to be mildly associated with physical activity level and balance skills. There was no association between physical activity level and Unilateral Stance assessment. Still, those who were involved in sports performed better than those who did not.

Balance

Statistical analysis showed that there were significant differences in balance between groups with and without hearing impairment. This result supported previous study results (Jafari & Malayeri, 2011; Potter & Silverman, 1984; Rajendran et al., 2012) that damaged vestibular system has a significant influence on postural control in young adults with HI. The participants with hearing impairment performed poorly in the Sensory Organization Test (SOT) and Unilateral Stance (US). These balance tests require individuals to utilize information from one of the balance systems: visual, somatosensory, and visual. The group with hearing impairment demonstrated significant sway when their somatosensory input was disrupted compared to the control group. Furthermore, when visual information was eliminated, sway velocity was significantly higher in the HI group than the control group.

In addition, the result in this study has shown that the deficits in balance interfere with sensory organization. Specifically, group with hearing impairment demonstrated unstable postural control in a condition where only their somatosensory information was disrupted without visual elimination or disruption. This indicates that individuals with hearing impairment were not able to fully utilize information from their visual system when their somatosensory information was disrupted. The balance results of the present study were similar to those in many other studies involving children with HI (Cushing et al. 2009; Hartman et al., 2011; Jafari & Malayeri, 2011; Kegel et al., 2012; Lindsey and O'Nea1, 1976; Rine et al., 2011; Suarez et al., 2007). These studies found that people with HI depend on both visual and somatosensory information for effective postural control.

All individuals with hearing impairment have a damaged vestibular system; therefore, it was believed that individuals depend on either somatosensory or visual system to have a stable posture. Surprisingly, the results in this study found that the hearing impairment group cannot depend on only one of the balance systems. When only the somatosensory information was disrupted, young adults with HI had significantly higher sway. This indicates that individuals with HI depend on both visual system and somatosensory system and require a stable support surface for effective balance control.

The control group, on the other hand, demonstrated stable postural control when their visual and/or somatosensory system was disrupted or eliminated.

Physical Activity and Other Variables

Some participants with HI did as well as the control group in balance tests, which indicated that not all young adults with HI have balance deficits. The information sheet and physical activity questionnaire were used to determine if there were any differences in balance related to each of the variables.

Although there was no significant difference in participants with HI's current physical activity and balance scores, there was low correlation between current physical activity with SOT condition 4 and US eyes closed condition. Though, physical activity in childhood may be associated with balance, current physical activity levels did not show a strong relationship.

In addition, there were differences found between SOT condition 5 and SOT condition 6 with the following variables: type of school, history involvement in organized sports, cause of deafness, and hearing level (dB). The variable, type of school supports Dummer et al. (1996) study that individuals who went to deaf school demonstrated better balance scores than those who went to mainstreamed school. Because children with hearing impairment are more likely to be involved in social interactions in deaf schools than those who went to mainstreamed schools, they may be motivated to participate in physical activity which may positively influence balance skills. Moreover, history involvement revealed results similar to other studies (Dummer et al., 1996 & Hartman et al., 2011) that concluded those involved in physical activity at an early age possessed better postural control than those who were not involved in sports throughout their childhood. In addition, the finding in SOT condition 5 and condition 6 are supported by other studies (Potter and Silverman, 1984 & Said, 2013), which concluded that individuals with acquired hearing loss were more likely to have impaired balance skills than those with congenital hearing loss. Furthermore, the present study revealed a correlation between those who are physically active and the cause of deafness. Active participants with acquired hearing loss exhibited poorer balance scores than active participants with congenital hearing loss. This indicated that etiology was correlated with balance. Additionally, the present study found that those with less severe hearing loss exhibited better balance skills than those with more severe hearing loss. This result conflict with the previous study (Kegel et al., 2012), which concludes that those with moderate hearing loss have balance skills equal to those with profound hearing loss.

Overall, the environmental factors and factors related to deafness affected individuals with hearing impairment's postural control stability in Sensory Organization Test. On the other hand, these do not appear to be related to balance in Unilateral Stance. In addition, the result in this study revealed that those who were involved in physical activity possess better postural control than those who were not.

Future Research

Only a few studies have investigated balance skills in young adults with hearing impairment. The results of this study have raised additional research questions which should be addressed in future studies. The physical activity questionnaire was not as effective to monitor individual's current physical activity level. Future studies should employ physical activity monitoring. In addition, future studies could examine the impact of long-term intervention/rehabilitation on improving balance skills in adults with HI.

Conclusion

The results of this study showed that there are differences in balance skills between young adults with and without HI. In particular, when a test required the use of the vestibular system, the balance abilities of participants with HI were less than adults without HI. This study revealed that vestibular dysfunction in young adults has a significant effect on balance when their somatosensory and/or visual systems are disrupted or eliminated. Previous research stated that balance in children with vestibular impairment improves with age and the development of visual, somatosensory and vestibular organs, however this study included young adults with HI where these three main systems had time to develop. Despite increasing age balance deficits are apparent in this population. Specific programs designed to improve balance skills for people with HI may have the long term effect of decreasing the risk of falling and improving overall mechanical body functioning.

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Appendix A
Tables

Table 1 Summary of participants' profile.

Variable	Hearing Impairment N=35	Control N=35
Age	25.29	24
Gender	19 Males; 16 Females	16 Males; 19 Females
Body Mass Index	24.27	25.01
Weight	157.34	156.91
Height	67.11	65.77

Table 2 Summary of HI group demographic data.

	N	Minimum	Maximum	Mean	Std. Deviation
Age	35	19	30	25.29	2.71
Gender	35	1	2	1.46	0.51
Hearing Level	35	1	5	3.54	1.36
Cause of Deafness	35	0	1	0.4	0.5
Current Physical Activity Level	35	1	4	2.57	0.1
Years Participated in Sports	35	0	20	9.91	4.67
Type of School	35	0	1	0.34	0.48

Table 3 Independent T-Test: HI and Control.

Variables	Group		P-Value	T-Value
	Hearing Impairment (N=35)	Control (N=35)		
	Mean ± SE	Mean ± SE		
SOT Condition 1	93.99 ± 0.24	94.05 ± 0.24	0.86	-0.17
SOT Condition 2	92.95 ± 0.35	92.44 ± 0.32	0.28	1.09
SOT Condition 3	88.80 ± 1.75	91.22 ± 0.59	0.20	-1.31
SOT Condition 4	78.39 ± 2.07	83.85 ± 1.39	0.03 *	-2.19
SOT Condition 5	51.5 ± 2.90	66.03 ± 1.71	0.00 *	-4.32
SOT Condition 6	42.05 ± 3.41	67.76 ± 2.39	0.00 *	-6.17
SOT COMP	69.57 ± 1.66	79.31 ± 1.03	0.00 *	-4.99
US Left EO	1.12 ± 0.07	0.86 ± 0.02	0.00 *	3.32
US Left EC	4.75 ± 0.39	2.40 ± 0.20	0.00 *	5.40
US Right EO	1.30 ± 0.15	0.88 ± 0.02	0.01 *	2.84
US Right EC	5.37 ± 0.47	2.29 ± 0.15	0.01 *	6.33
AT_TU1	75.34 ± 3.45	68.86 ± 3.63	0.20	1.30
AT_TU2	67.66 ± 3.30	62.17 ± 2.89	0.22	1.25
AT_TU3	60.97 ± 2.71	58.66 ± 2.40	0.52	0.64
AT_TU4	54.17 ± 1.97	54.03 ± 2.05	0.96	0.05
AT_TU5	54.91 ± 2.08	52.86 ± 2.17	0.50	0.68
AT_TD1	52.17 ± 2.46	48.71 ± 2.90	0.37	0.91
AT_TD2	45.40 ± 1.63	44.11 ± 2.21	0.64	0.47
AT_TD3	42.66 ± 1.53	41.17 ± 1.60	0.50	0.67
AT_TD4	40.34 ± 1.51	40.83 ± 1.45	0.82	-0.23

AT_TD5	39.77 ± 1.49	39.66 ± 1.41	0.96	0.06
MCT_MB	117.97 ± 3.44	123.37 ± 2.23	0.19	-1.32
MCT_ML	115.34 ± 2.82	114.43 ± 3.95	0.85	0.19
MCT_MF	125.09 ± 4.44	132.23 ± 3.66	0.22	-1.24
MCT_FL	120.14 ± 3.44	123.60 ± 2.40	0.41	0.82
MCT_COMP	123.54 ± 6.72	113.77 ± 7.18	0.32	0.99

Table 4 Correlation between HI's current physical activity and balance tests

Correlations

		Group	SOT_4	SOT_5	SOT_6	SOT_COMP	MCT_COMP	AT_TU	AT_TD	US_EC	US_EO
Group	Pearson Correlation	1	-.091	-.315	-.254	-.277	.006	-.055	.012	.429*	.021
	Sig. (2-tailed)		.604	.065	.141	.108	.975	.752	.943	.010	.904
	N	35	35	35	35	35	35	35	35	35	35
SOT_4	Pearson Correlation	-.091	1	.409*	.287	.546**	.051	.292	.206	-.458**	-.118
	Sig. (2-tailed)	.604		.015	.094	.001	.773	.089	.235	.006	.498
	N	35	35	35	35	35	35	35	35	35	35
SOT_5	Pearson Correlation	-.315	.409*	1	.822**	.936**	-.124	.103	.122	-.359*	-.497**
	Sig. (2-tailed)	.065	.015		.000	.000	.478	.558	.484	.034	.002
	N	35	35	35	35	35	35	35	35	35	35
SOT_6	Pearson Correlation	-.254	.287	.822**	1	.898**	-.014	-.057	.084	-.420*	-.430**
	Sig. (2-tailed)	.141	.094	.000		.000	.937	.747	.632	.012	.010
	N	35	35	35	35	35	35	35	35	35	35

SOT_COMP	Pearson Correlation	-.277	.546**	.936**	.898**	1	-.082	.154	.202	-.438**	-.405*
	Sig. (2-tailed)	.108	.001	.000	.000		.642	.376	.245	.009	.016
	N	35	35	35	35	35	35	35	35	35	35
MCT_COMP	Pearson Correlation	.006	.051	-.124	-.014	-.082	1	-.178	-.303	-.048	-.290
	Sig. (2-tailed)	.975	.773	.478	.937	.642		.306	.076	.784	.091
	N	35	35	35	35	35	35	35	35	35	35
AT_TU	Pearson Correlation	-.055	.292	.103	-.057	.154	-.178	1	.633**	-.035	.154
	Sig. (2-tailed)	.752	.089	.558	.747	.376	.306		.000	.841	.377
	N	35	35	35	35	35	35	35	35	35	35
AT_TD	Pearson Correlation	.012	.206	.122	.084	.202	-.303	.633**	1	.143	-.008
	Sig. (2-tailed)	.943	.235	.484	.632	.245	.076	.000		.411	.964
	N	35	35	35	35	35	35	35	35	35	35
US_EC	Pearson Correlation	.429*	-.458**	-.359*	-.420*	-.438**	-.048	-.035	.143	1	.159
	Sig. (2-tailed)	.010	.006	.034	.012	.009	.784	.841	.411		.363

	N	35	35	35	35	35	35	35	35	35	35
US_EO	Pearson Correlation	.021	-.118	-.497**	-.430**	-.405*	-.290	.154	-.008	.159	1
	Sig. (2-tailed)	.904	.498	.002	.010	.016	.091	.377	.964	.363	
	N	35	35	35	35	35	35	35	35	35	35

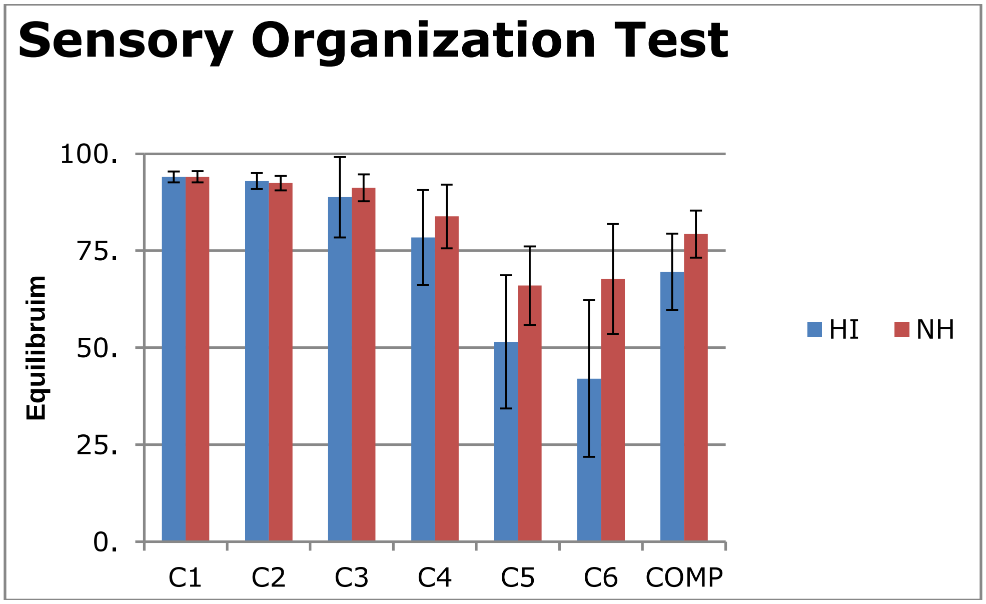
*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix B

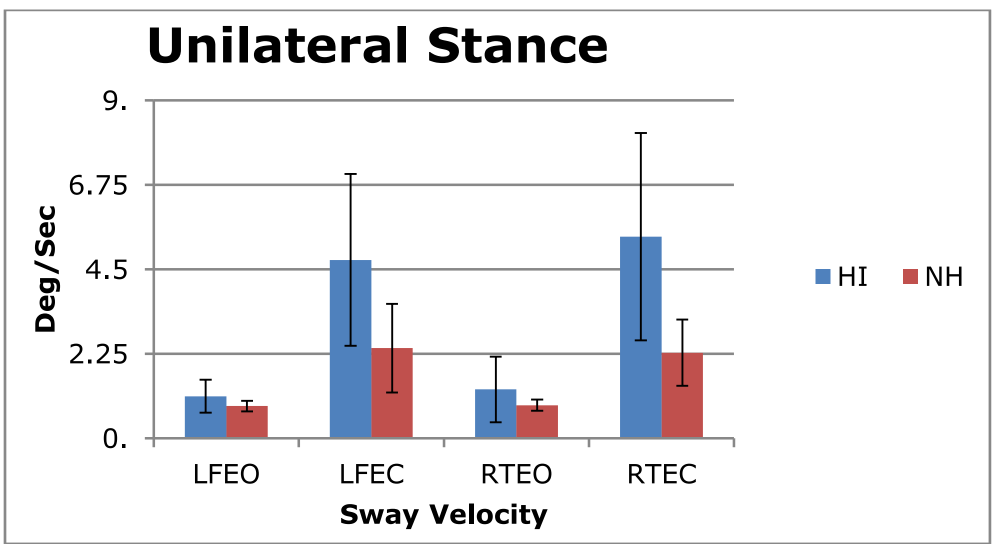
Graphs

Graph 1 Comparison of SOT scores.



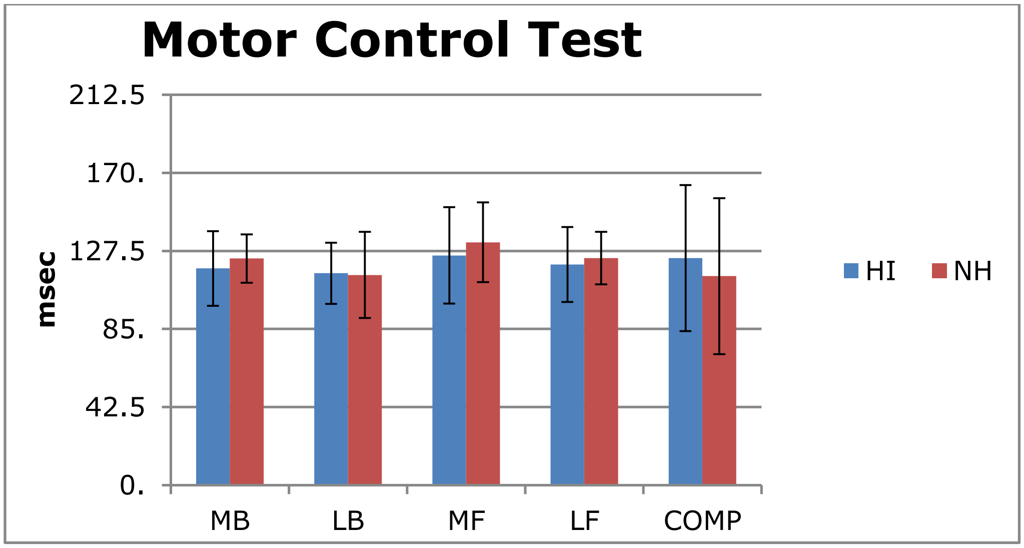
HI: Hearing Impaired; NH: Normal Hearing; C: Condition; COMP: Composite Score.

Graph 2 Comparison of US scores.



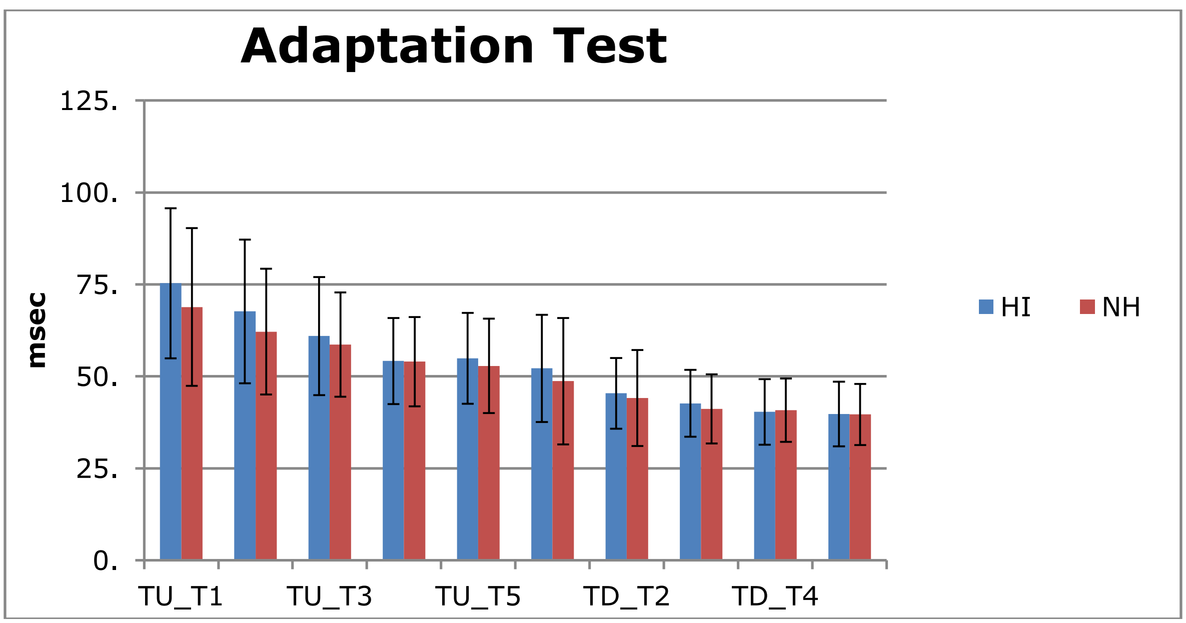
HI: Hearing Impaired; NH: Normal Hearing; Deg/Sec: degrees/second; LFEO: Left Eyes Open; LFEC: Left Eyes Closed; RTEO: Right Eyes Open; RTEC: Right Eyes Closed.

Graph 3 Comparison of MCT scores.



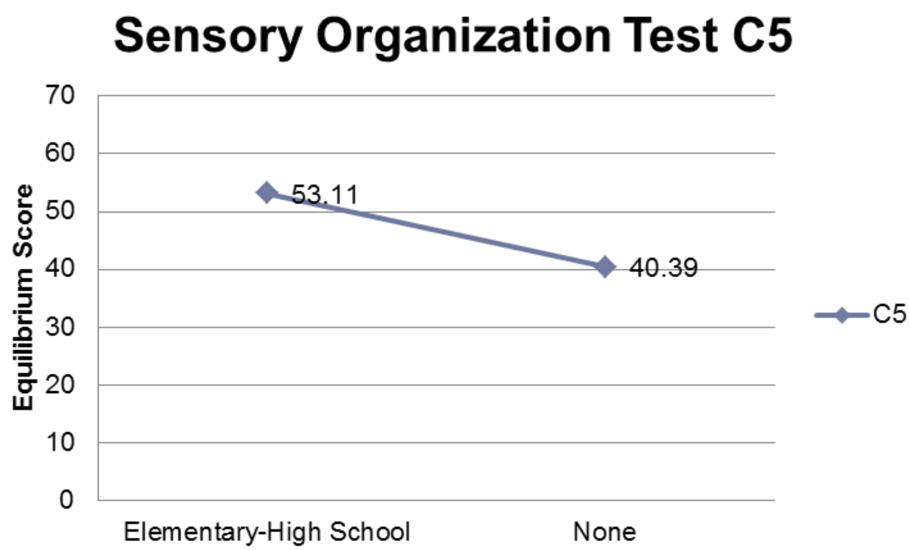
HI: Hearing Impaired; NH: Normal Hearing; msec: Millisecond; MB: Medium Backward; LB: Long Backward; MF: Medium Forward; LF: Long Forward; COMP: Composite Score.

Graph 4 Comparison of AT scores.



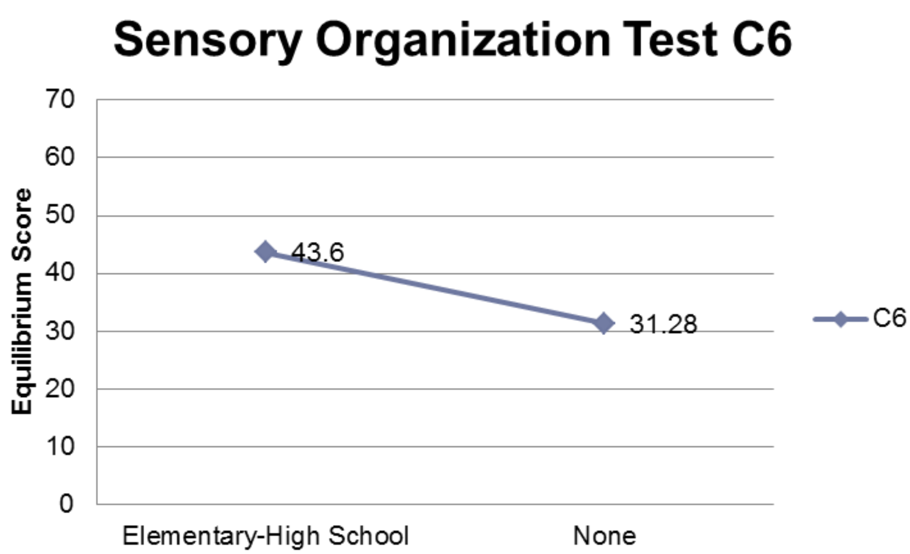
HI: Hearing Impaired; NH: Normal Hearing; msec: Millisecond; TU: Toes up; TD: Toes Down.

Graph 5	Association between history involvement in physical activity and SOT Condition 5 with hearing impairment population.



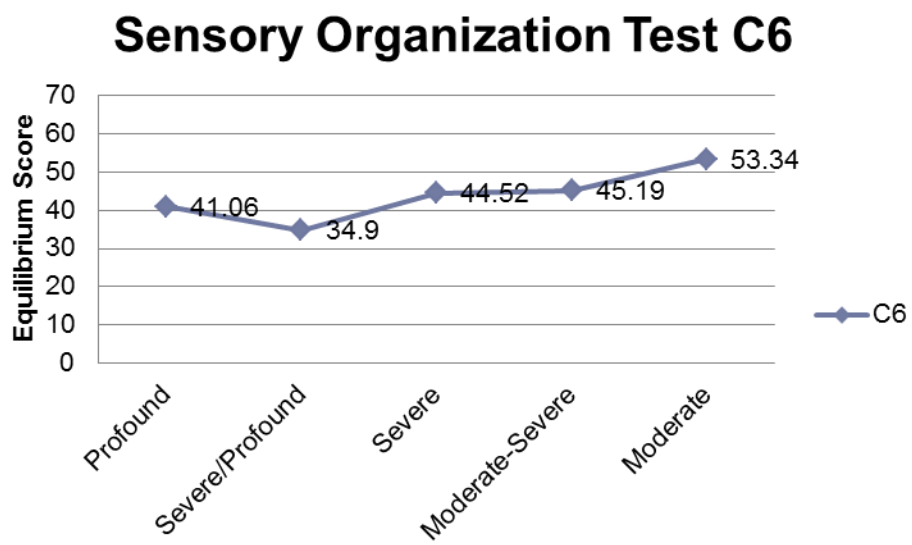
C5: Condition 5.

Graph 6	Association between history involvement in physical activity and SOT Condition 6 with hearing impairment population.



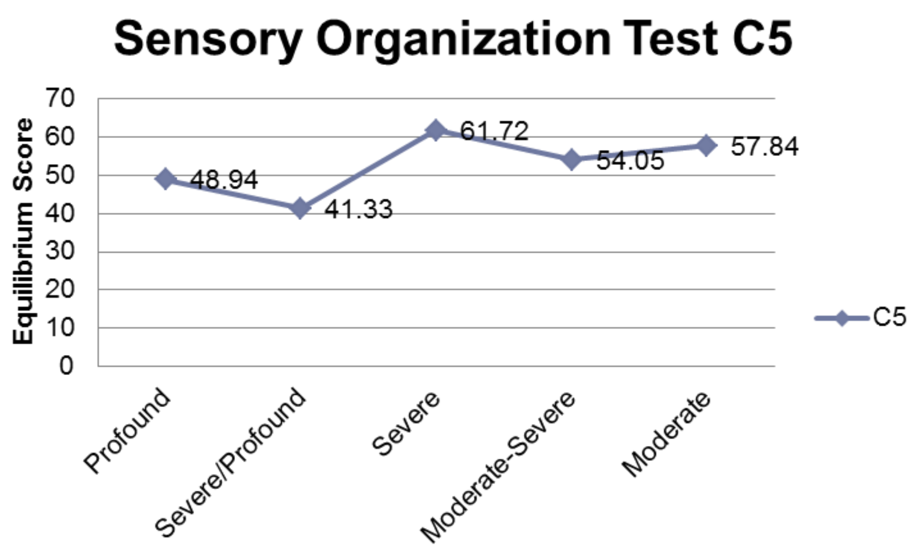
C6: Condition 6.

Graph 7 Association between hearing level and SOT Condition 5 with hearing impairment population



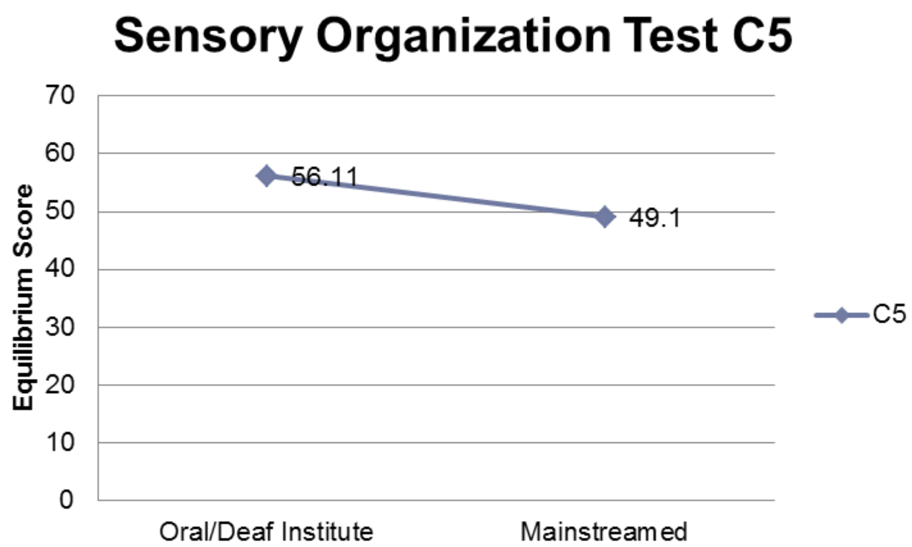
C5: Condition 5.

Graph 8 Association between hearing level and SOT Condition 6 with hearing impairment population.



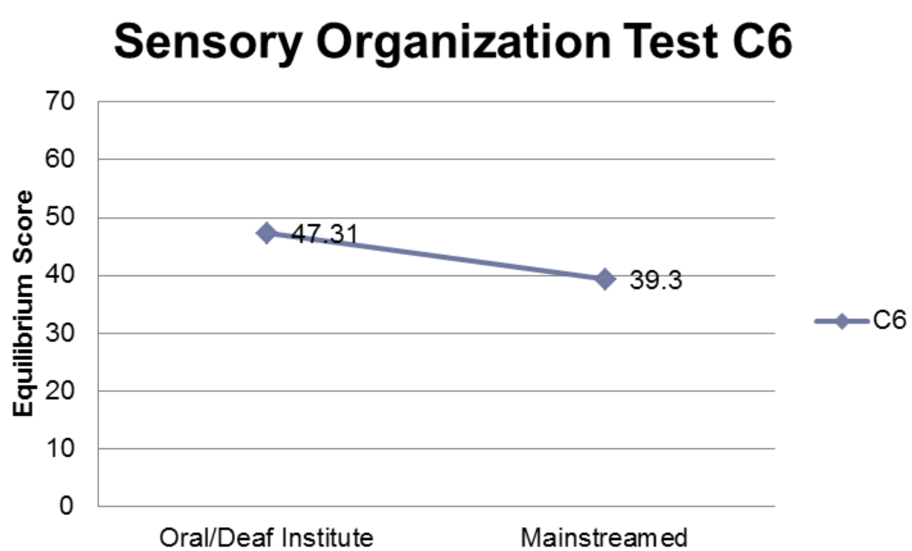
C6: Condition 6.

Graph 9 Association between deaf or mainstreamed school and SOT Condition 5 with hearing impairment population.



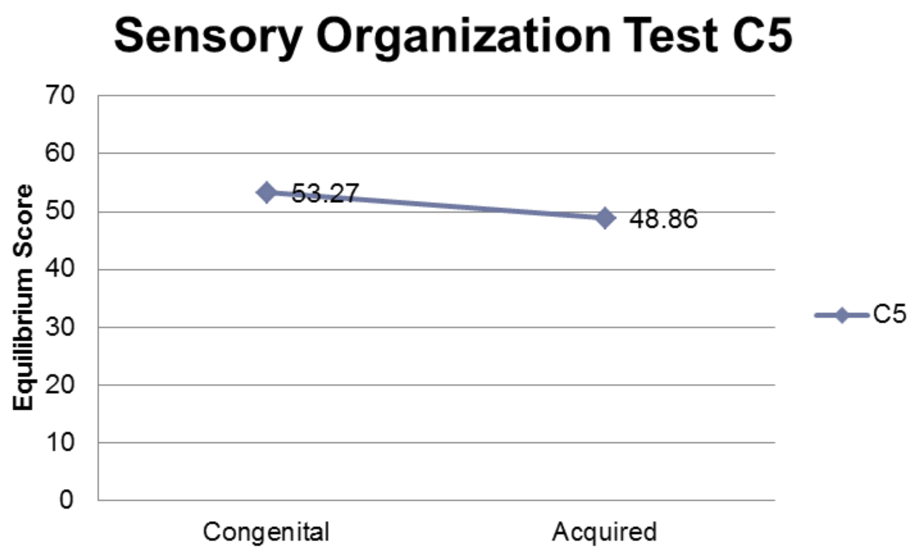
C5: Condition 5.

Graph 10 Association between deaf or mainstreamed school and SOT Condition 6 with hearing impairment population.



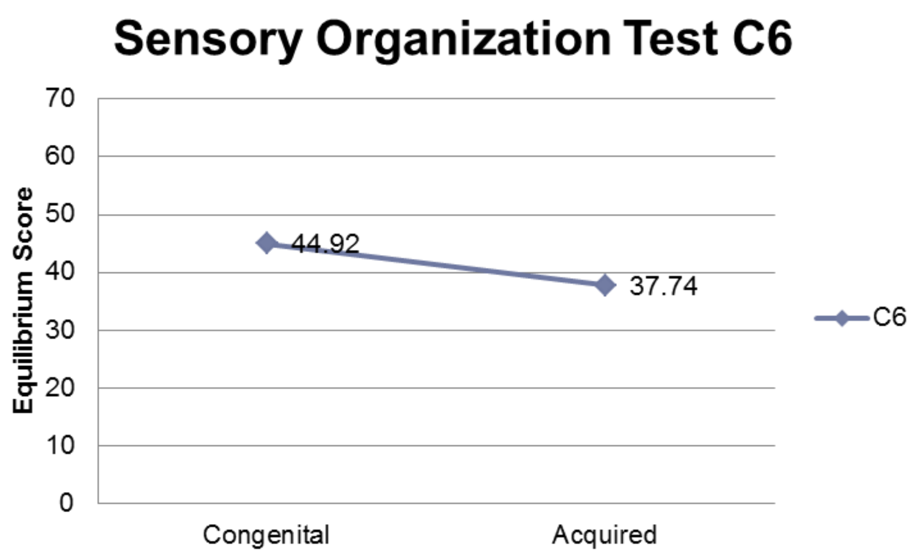
C6: Condition 6.

Graph 11 Association between cause of deafness and SOT Condition 5 with hearing impairment population.



C5: Condition 5.

Graph 12 Association between cause of deafness and SOT Condition 6 with hearing impairment population.

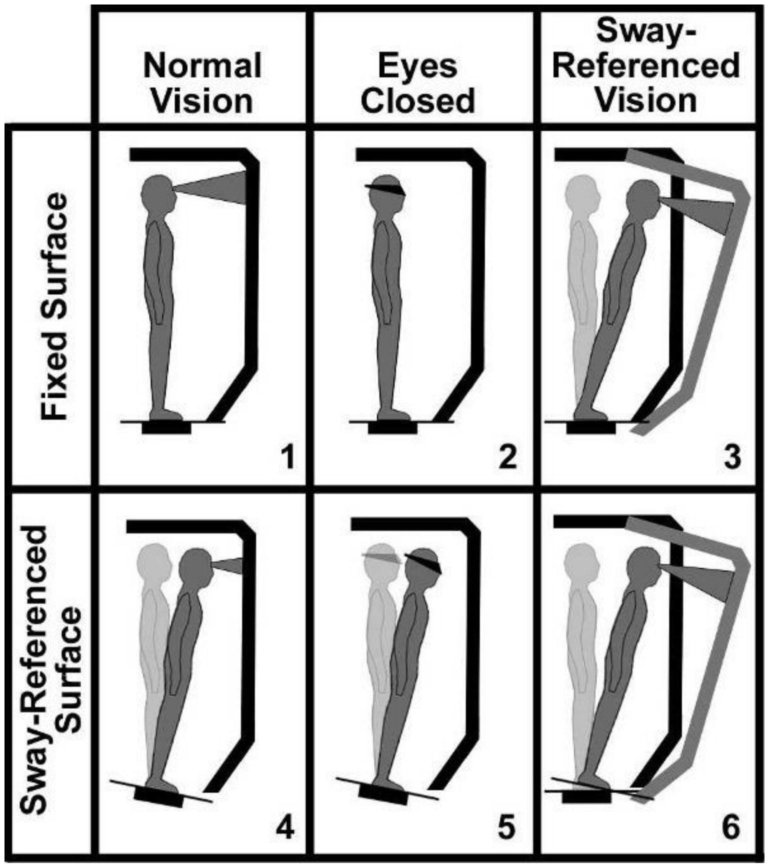


C6: Condition 6.

Appendix C

Figures

Figure 1 Sensory Organization Test



(NeuroCom, 2012)

Appendix D

California State University, Northridge
CONSENT TO ACT AS A HUMAN RESEARCH PARTICIPANT

You are being asked to participate in a research study titled "**Comparison of Balance Between Young Adults With and Without Hearing Impairment**, a study conducted by Alexis Knudtson as part of the requirements for the M.S. degree in Kinesiology, Adapted Physical Activity. Participation in this study is completely voluntary. Please read the information below and ask questions about anything that you do not understand before deciding if you want to participate. A researcher listed below will be available to answer your questions.

RESEARCH TEAM

Researcher:
Alexis Knudtson
Department of Kinesiology
18111 Nordhoff St.
Northridge, CA 91330-8229
(916) 759-7350 via text
alexis.knudtson.256@my.csun.edu

Faculty Advisor:
Dr. Teri Todd
Department of Kinesiology
18111 Nordhoff St.
Northridge, CA 91330-8229
(818)677-2182
teri.todd@csun.edu

PURPOSE OF STUDY

The purpose of this study is to compare balance between young adults with hearing-impairment and young adults with normal hearing. Moreover, this study will investigate the relationship between physical activity and balance in young adults with hearing impairment.

SUBJECTS

Inclusion Requirements

Hearing-impairment group: You are eligible to participant in this study if you are

- Diagnosed with hearing impairment within 40-91+ dB (moderate – profound) hearing loss (self-reported)
- Aged between 18-30 years old
- Completion of PAR-Q
- Ability to participant in mild physical activity exercise
- Ability to understand instructions and adhere to study protocol

Control group: You are eligible to participant in this study if you are

- Subjectively normal hearing ability (self-reported)
- Aged between 18-30 years old
- Completion of PAR-Q
- Ability to understand instructions and adhere to study protocol
- Ability to participant in mild physical activity exercise

Exclusion Requirements

Hearing-impaired group: You are not eligible to participant in this study if you have

- Cognitive, physical and visual impairments
- Any medical conditions that inhibits participation in physical activity
- An acute injury or surgery within the past 6 months

Control group: You are not eligible to participant in this study if you have

- Cognitive, physical and visual impairments
- Any medical conditions that inhibits participation in physical activity
- An acute injury or surgery within the past 6 months

Time Commitment

This study is a one-time study and testing sessions will last approximately 1.5 hours.

PROCEDURES

You will visit Center of Achievement, CSU Northridge one time for the study. You will be informed of the procedure for this study and the risks associated with the balance test. You will be asked to sign this consent form as well as a "Bill of Rights" and PAR-Q. Afterwards, you will be asked to complete an information sheet (age, sex, hearing) and anthropometric (weight, height, BMI). Your physical activity level will be assessed using the Physical Activity and Physical Fitness: PAQ questionnaire. After completing the physical activity level questionnaire, you will perform the first balance test using the NeuroCom Balance Manager system: SMART EquiTest. You will wear a safety harness and stand on a platform on either a stable or unstable support surface for 20 seconds with eyes open and closed. Then you will complete the second balance test using NeuroCom Balance Manager system: Long Forceplate. You will stand on a platform with one leg at a time with eyes open and closed. You will be able to rest in between each test for 1 minute. If you feel any abnormal discomfort, the balance test will be terminated upon your request. This visit will approximately last for 1.5 hours.

RISKS AND DISCOMFORTS

The possible risks and/or discomforts associated with the procedures described in this study include: falling, dizziness, injury, fatigue, and anxiety/fear during balance test. You will be allowed to rest when necessary to prevent fatigue or dizziness during the balance test. You will be using a safety harness for all tests and you will be actively spotted by a research assistant. CPR/AED and first aid certified research assistants will aid in procedures. If you show signs or symptoms that appear to put you at risk, data collection procedure will cease immediately and you will be referred to your primary physician at your own cost. Emergency services (911) will be contacted. This study involves no more than minimal risk. There are no known harms or discomforts associated with this study beyond those encountered in normal daily life.

BENEFITS
Subject Benefits
You may not directly benefit from participation in this study.

Benefits to Others or Society
The knowledge from this study may help clinicians understand balance deviations for people with hearing impairment. Furthermore, this finding may lead clinicians to make recommendations in exercise intervention to focus on improving balance skills and prevent any further poor physical skills or motor skills.

ALTERNATIVES TO PARTICIPATION
The only alternative to participation in this study is not to participate.

COMPENSATION, COSTS AND REIMBURSEMENT
You will not be paid for your participation in this research study.

You will not be reimbursed for any out of pocket expenses, such as transportation fees. Parking passes will be provided by the Center of Achievement.

WITHDRAWAL OR TERMINATION FROM THE STUDY AND CONSEQUENCES
You are free to withdraw from this study at any time. **If you decide to withdraw from this study you should notify the research team immediately**. The research team may also end your participation in this study if you do not follow instructions, miss the scheduled visit, or if your safety and welfare are at risk.

CONFIDENTIALITY
Subject Identifiable Data
All identifiable information that will be collected about you will be removed and replaced with a code. A list linking the code and your identifiable information will be kept separate from the research data and stored on a password protected hard drive, which will be stored in the office of Center of Achievement. This will be placed in a locked file cabinet in a locked office in Dr. Todd's office in the Center of Achievement. Only the primary investigator, Alexis Knudtson, and faculty advisor, Dr. Todd, will have access to these files.

Data Storage
All research data will be stored electronically on a secure computer with password protection in the office at the Center of Achievement.

Data Access
Only the researcher, Alexis Knudtson and faculty advisor, Dr. Todd will have access to your study records. Any information derived from this research project that personally

identifies you will not be voluntarily released or disclosed without your separate consent, except as specifically required by law. Publications and/or presentations that result from this study will not include identifiable information about you.

Data Retention
The researchers intend to keep the research data for approximately three years and then it will be destroyed.

Mandated Reporting
Under California law, the researcher(s) is/are required to report known or reasonably suspected incidents of abuse or neglect of a child, dependent adult or elder, including, but not limited to, physical, sexual, emotional, and financial abuse or neglect. If any researcher has or is given such information, he or she may be required to report it to the authorities.

IF YOU HAVE QUESTIONS
If you have any comments, concerns, or questions regarding the conduct of this research please contact the research team listed on the first page of this form.

If you have concerns or complaints about the research study, research team, or questions about your rights as a research participant, please contact Research and Sponsored Projects, 18111 Nordhoff Street, California State University, Northridge, Northridge, CA 91330-8232, or phone 818-677-2901.

VOLUNTARY PARTICIPATION STATEMENT
You should not sign this form unless you have read it and been given a copy of it to keep. **Participation in this study is voluntary.** You may refuse to answer any question or discontinue your involvement at any time without penalty or loss of benefits to which you might otherwise be entitled. Your decision will not affect your relationship with California State University, Northridge. Your signature below indicates that you have read the information in this consent form and have had a chance to ask any questions that you have about the study.

I agree to participate in the study.

____ ________________
Participant Signature Date

____
Printed Name of Participant

____ ________________
Researcher Signature Date

____
Printed Name of Researcher

Appendix E

CALIFORNIA STATE UNIVERSITY, NORTHRIDGE

EXPERIMENTAL SUBJECTS
BILL OF RIGHTS

The rights below are the rights of every person who is asked to be in a research study. As an experimental subject I have the following rights:

1) To be told what the study is trying to find out,

2) To be told what will happen to me and whether any of the procedures, drugs, or devices is different from what would be used in standard practice,

3) To be told about the frequent and/or important risks, side effects or discomforts of the things that will happen to me for research purposes,

4) To be told if I can expect any benefit from participating, and, if so, what the benefit might be,

5) To be told the other choices I have and how they may be better or worse than being in the study,

6) To be allowed to ask any questions concerning the study both before agreeing to be involved and during the course of the study,

7) To be told what sort of medical treatment (if needed) is available if any complications arise,

8) To refuse to participate at all or to change my mind about participation after the study is started. This decision will not affect my right to receive the care I would receive if I were not in the study.

9) To receive a copy of the signed and dated consent form.

10) To be free of pressure when considering whether I wish to agree to be in the study.

If I have other questions I should ask the researcher or the research assistant, or contact Research and Sponsored Projects, California State University, Northridge, 18111 Nordhoff Street, Northridge, CA 91330-8232, or phone (818) 677-2901.

X____

Signature of Subject Date

Appendix F

CALIFORNIA STATE UNIVERSITY, NORTHRIDGE

MODIFIED PHYSICAL ACTIVITY QUESTIONNAIRE (M-PAQ)

1. During the past 7 days, on how many days were you physically active for a total of at least 60 minutes per day? Add up all the time you spent in any kind of physical activity that increased your heart rate and made you breathe hard some of the time.
    - □ 0 days.. 0
    - □ 1 day.. 1
    - □ 2 days.. 2
    - □ 3 days.. 3
    - □ 4 days.. 4
    - □ 5 days.. 5
    - □ 6 days.. 6
    - □ 7 days.. 7
    - □ REFUSED 77
    - □ DON’T KNOW 99

2. In a typical week do you do any **low**-intensity physical activity such as walking or light-weight training for **at least 10 minutes continuously**?
    - □ NO
    - □ YES

    a. In a typical week, on how many days do you do **low**-intensity physical activity?
    |___|___| ENTER NUMBER OF DAYS
    (1 AND 7 NUMBERS OF DAYS)

    b. How much time do you spend doing **low**-intensity physical activity?
    |___|___|___| ENTER NUMBER OF MINUTES OR HOURS

3. In a typical week do you do any **moderate**-intensity sports, fitness, or recreational activities that cause a **small increase** in breathing or heart rate such as fast-paced walking, bicycling, or baseball for **at least 10 minutes continuously**?
    - □ NO
    - □ YES

    a. In a typical week, on how many days do you do **moderate**-intensity sports, fitness or recreational activities?
    |___|___| ENTER NUMBER OF DAYS
    (1 AND 7 NUMBERS OF DAYS)

b. How much time do you spend doing **moderate**-intensity sports, fitness or recreational activities on a typical day?
|___|___|___| ENTER NUMBER OF MINUTES OR HOURS

4. In a typical week do you do any **vigorous**-intensity sports, fitness, or recreational activities that cause large increases in breathing or heart rate like running or basketball for at least 10 minutes continuously?
    - NO
    - YES

    a. In a typical week, on how many days do you do **vigorous**-intensity sports, fitness or recreational activities?
    |___|___| ENTER NUMBER OF DAYS
    (1 AND 7 NUMBERS OF DAYS)

    b. How much time do you spend doing **vigorous**–intensity sports, fitness or recreational activities on a typical day?
    |___|___|___| ENTER NUMBER OF MINUTES OR HOURS

5. In a typical week do you do any exercises to **strengthen or tone** your muscles, such as push-ups, sit-ups, or weight lifting?
    |___|___| ENTER NUMBER OF DAYS
    (1 AND 7 NUMBERS OF DAYS)

6. The following question is about sitting at work, at school, at home, getting to and from places, or with friends, including time spent sitting at a desk, traveling in a car or bus, reading, playing cards, watching television, or using a computer. Do not include time spent sleeping.

    How much time do you usually spend sitting on a typical day?
    |___|___|___| ENTER NUMBER OF MINUTES OR HOURS

7. Now I will ask you first about TV watching and then about computer use. Over the **past 30 days**, on average how many **hours per day** did you sit and watch TV or use a computer?

    Would you say:
    - Less than 1 hour
    - 1 hour
    - 2 hours
    - 3 hours
    - 4 hours

□ 5 hours or more
□ You do not watch TV or use computer

8. Did you consider yourself active during your school (not including recess)?
   □ HIGH SCHOOL
   □ MIDDLE SCHOOL
   □ ELEMENTARY SCHOOL
   □ NO

9. Did you participate in school sports or physical activity clubs?
   □ NO
   □ YES

   a. How many years did you participate in school sports or physical activity clubs?
      _____ COLLEGE
      _____ HIGH SCHOOL
      _____ MIDDLE SCHOOL
      _____ ELEMENTARY SCHOOL

   b. In what school sports or physical activity clubs did you participate?
      □ BASEBALL/SOFTBALL
      □ BASKETBALL
      □ SOCCER
      □ CHEERLEADING
      □ DANCE
      □ FOOTBALL
      □ GOLF
      □ GYMNASTICS
      □ HOCKEY
      □ LACROSSE
      □ SWIMMING/DIVING
      □ WATER POLO
      □ TENNIS
      □ TRACK AND FIELD
      □ VOLLEYBALL
      □ WRESTLING
      □ OTHER (SPECIFY): ______________________________

10. Have your dizziness or balance problems caused you to change or cut back on any of the activities such as exercising or taking walks?

- ☐ NO
- ☐ YES

Appendix G
CALIFORNIA STATE UNIVERSITY, NORTHRIDGE

INFORMATION SHEET

1. Are you

    □ Male

    □ Female

2. What is your age?

    _______ years

3. Hearing Levels

    □ Hearing (Skip to question #9)

    □ Deaf (Skip to question #5)

    □ Hard-of-Hearing

4. What type of hearing loss?

    □ Bilateral

    □ Unilateral

5. When were you diagnosed?

    □ Birth

    □ Other (SPECIFY):

____

    □ Unknown

6. What degree of hearing loss?

□ Normal hearing (-10 to 20 dB)

□ Mild (21 to 40 dB)

□ Moderate (41 to 55 dB)

□ Moderately-severe (56 to 70 dB)

□ Severe (71 to 90 dB)

□ Profound (91+ dB)

7. Do you wear any hearing devices?

□ Hearing aids

□ Cochlear Implant

□ No

8. Did you attend to deaf school?

□ Yes

For how long: ____

□ No

9. Do you have any additional impairment/disability?

No

Yes (Specify): ________________________________

10. Do you have any known deficits in balance or motor skills?

□ No

□ Yes (Specify): ________________________________