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Hearing Health in Utah Special Olympics Athletes Compared to Special Olympics Athletes Worldwide: A Prevalence Study in Individuals with Intellectual Disabilities

Lisa Moses Mullins
Brigham Young University - Provo

HEARING HEALTH IN UTAH SPECIAL OLYMPICS ATHLETES COMPARED TO SPECIAL OLYMPICS ATHLETES WORLDWIDE: A PREVALENCE STUDY IN INDIVIDUALS WITH INTELLECTUAL DISABILITIES

by

Lisa Moses Mullins

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of a thesis submitted by

Lisa Moses Mullins

This thesis has been read by each member of the following graduate committee and by majority vote has been found to be satisfactory.

Date	David L. McPherson, Chair
Date	Ron W. Channell
Date	Shawn Nissen

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Date

David L. McPherson
Chair, Graduate Committee

Accepted for the Department

Ron W. Channell
Graduate Coordinator

Accepted for the College

K. Richard Young
Dean, David O. McKay School of Education

ABSTRACT

HEARING HEALTH IN UTAH SPECIAL OLYMPICS ATHLETES COMPARED TO SPECIAL OLYMPICS ATHLETES WORLDWIDE: A PREVALENCE STUDY IN INDIVIDUALS WITH INTELLECTUAL DISABILITIES

Lisa Moses Mullins

Department of Audiology and Speech-Language Pathology

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The Special Olympics Healthy Athletes initiative promotes wellness of the athletes with intellectual disabilities and education for medical professionals. Healthy Athletes has created a hearing screening program, Healthy Hearing, to help athletes with intellectual disabilities get the otological and audiological care they need. This program promotes a healthy hearing lifestyle and educates medical professionals regarding the need of health care for the intellectually disabled population. The physiologic, otologic, and audiologic abnormalities often occurring in the intellectually disabled population bring special attention for the need to determine the prevalence rate of hearing loss among the athletes participating in Special Olympics events. Investigation of the prevalence of hearing loss in 1450 athletes participating in the 2004 Summer Games and Fall Sports Classic and 2005 Fall Sports Classic in Utah, USA and the 2005 World

Winter Games in Nagano, Japan was made. A total pure-tone failure rate of 31.1% among athletes in all four games was found, however follow-up was recommended for 34.7% of athletes. Athletes were found to have a greater prevalence of cerumen management problems than the general population and 34% of those passing the pure-tone hearing screen needed cerumen removal. Due to inherent audiological and otological complications found in individuals with intellectual disabilities, regular cerumen management and sensory testing for athletes are recommended.

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Introduction

In 1962, Eunice Kennedy Shriver started a movement that has significant global influence. She believed that individuals with intellectual disabilities were much more physically and socially capable than what society believed. She was inspired by the strength and fortitude her sister, Rosemary, showed despite her intellectual disability. At first, Shriver created a day camp for 35 boys and girls with intellectual disabilities to come to her home for physical fitness training. By 1968, Shriver, in partnership with physical education specialists from Southern Illinois University, the Chicago Park District, and other interested groups, created the First International Special Olympics Games or the Chicago Special Olympics. This athletic event included 1000 athletes from 26 US states and from Canada. Today, Special Olympics, Inc. has grown to include 1.7 million children and adults with intellectual disabilities in over 150 countries with more than 200 programs (Special Olympics, History, n.d.).

Intellectual disabilities are often linked to sensory impairments including vision, hearing, or combined sensory impairments. Increased medical complications such as increased dental caries, obesity, and limb deformations are often apparent. Special Olympics has created athletic programs and wellness initiatives to benefit individuals over eight years of age with intellectual disabilities. As part of the organization's athlete wellness initiative, Healthy Athletes, the following programs have been implemented: Healthy Hearing, Fit Feet, FUNfitness, Health Promotion, Opening Eyes, and Special Smiles. The Healthy Athletes programs have been established to help improve the overall health and well-being of the Special Olympics athletes through providing health screening services as well as opportunities for professionals to become educated about

the overall health needs of individuals with intellectual and developmental disabilities (Special Olympics, Healthy Athletes, n.d.).

Healthy Hearing began in 1999 as a specific program targeting the intellectually disabled population to help provide additional hearing health care for the athletes. The specific purposes of Healthy Hearing are to:

> Screen the hearing of athletes and notify athletes and their coaches if follow-up care is needed, provide corrective (hearing aids) and preventative (custom swim earplugs) services where possible, and study the prevalence of hearing loss in athletes competing in Special Olympics events. (Special Olympics, Healthy Hearing, n.d.)

Currently, Healthy Hearing has determined an estimated hearing impairment prevalence rate of 30% among the athletes screened worldwide. Hearing screening failure rate estimates include 25% of athletes ages 8–17 years, 50% of athletes ages 35–50 years, and 70% of athletes ages 51–70 years (Special Olympics, 2005). The aim of this study was to determine the prevalence and types of hearing losses in the Special Olympics athletes competing in events in the state of Utah compared to Special Olympics athletes from other regions worldwide.

Review of Literature

Intellectual Disability

Definition

The World Health Organization (WHO) defines mental retardation as an intellectual disability. It is a specific condition where the brain is incompletely developed or development suddenly stops before the age of 18 years. It affects neural areas that

control cognition, language, motor, and social abilities. This disorder can occur with or without other concomitant physical or mental disorders (WHO, 2001).

Causes

Intellectual disabilities may result from a variety of factors, including genetic factors such as trisomy 21 syndrome, which is known as Down syndrome. Prenatal damage from substance abuse, as seen in fetal alcohol syndrome (FAS), and injuries during the birth process, resulting in anoxia, have an effect on the development of the central nervous system (CNS). Sometimes even a CNS infection such as encephalitis, a dietary factor relating to a mineral deficiency (i.e. iodine), or a reaction to a food component (i.e. phenylketonuria) can impede the developmental processes of the CNS resulting in an intellectual disability (WHO, 2001).

Prevalence

According to WHO, the prevalence estimates of intellectual disability globally are between 1% and 3%. This estimate varies according to the country. Developing countries have a higher prevalence estimate due to the greater number of injuries, early childhood CNS infections, and incidents of asphyxia at birth (WHO, 2001).

Associated Disorders

Down syndrome. Down syndrome is the most common genetically caused intellectual disability with an occurrence of 1/600 to 1/1100 live births annually (Iino, Imamura, Harigai, & Tanaka, 1999; Kanamori, Witter, Brown, & Williams-Smith, 2000; Pulsifer, 1996; Shott, Joseph, & Heithaus, 2001; Van Buggenhout et al., 1999). This disorder results from an abnormality on chromosome 21 in the form of trisomy (i.e. the presence of a third chromosome), trisomy translocation (i.e. transposition of two

segments between two different chromosomes, usually a portion of the 14th chromosome being replaced by an extra portion of the 21st chromosome), or mosaicism (i.e. some tissue groups have a normal chromosomes and other groups carry trisomy 21; Stedman's Medical Dictionary, 2005). Common features of the disorder include flattened facial features, short limbs, a depressed nose bridge, congenital hearing difficulties, dental problems, and congenital heart abnormalities (Northern & Downs, 2002; Pulsifer, 1996). Due to current medical aid, longevity in individuals with Down syndrome is increasing. One report stated that in British Columbia, over 50% of individuals with Down syndrome survive past age 50 years, 40% to age 60 years, and about 13% to age 68 years (Van Allen, Fung, & Jurenka, 1999).

Fetal alcohol syndrome. Fetal alcohol syndrome, often overlooked or underdiagnosed, is now one of the leading causes of intellectual disability in the Unted States with an occurrence of 1/500 to 1/1200 live births. In the United States, FAS incidence is particularly high among the Native American and African American populations (Pulsifer, 1996). Features commonly seen in individuals with FAS include microcephaly, short palpebral fissures, an underdeveloped or flat philtrum, and a thin upper lip. Other craniofacial anomalies sometimes appearing include micrognathia, cleft palate, and abnormal pinna construction. Infants often exhibit low birth weight or failure to thrive. Mild intellectual disability is probably the most serious CNS dysfunction regarding this disease. Fetal alcohol syndrome can occur with sensory deficits as well: hearing loss, poor visual acuity, delays in receptive and expressive language, and optic nerve hypoplasia. Other internal physiologic anomalies that occur in individuals with FAS include congenital heart problems, diverticula in the bladder, renal hypoplasia, and

anomalies in the genitourinary tract. This specific disorder can be prevented by maternal abstinence of alcohol consumption during pregnancy (Church & Abel, 1998; Church & Gerkin, 1988; Lewis & Woods, 1994; Northern & Downs, 2002; Pulsifer, 1996).

Cytomegalovirus disease. Cytomegalovirus disease (CMV) is the most common congental infection with rates of 3–12 per 1000 live births in the US and many other developed nations. Sequelae of CMV include encephalopathy with additional complications in motor functioning, cognitive development often resulting in intellectual disability (microcephaly, hepatosplenomegaly, intracranial calcifications), and visual and hearing impairments (Pass, 2005). Although approximately 90% of infants born with CMV do not present with overt symptoms at birth, approximately 15% will present with some symptoms discovered during follow-up by age two years (Griffiths & Walter, 2005).

Hearing Loss

Prevalence of Hearing Loss in the Typical Population

According to a recent report compiled by the American Speech-Language-Hearing Association (ASHA), about 28 million people in the United States have some reduced hearing acuity. Eighty percent of those with reduced hearing sensitivity have an irreversible hearing loss. Currently, estimates for children ages 0 to 17 years hearing loss prevalence rates range from 1.1% to 3.5% (Boyle, Decoufle, & Yeargin-Allsopp, 1994; Boyle et al., 1996). Additionally, other prevalence rates state that 4.6% of adults between the ages of 18 and 44 years have a hearing loss while 14% of the adults between the ages of 45 and 64 years have a hearing loss. Those numbers rise dramatically in the population

over 65 years where 54% of those individuals have a hearing loss. It is reported that the third most chronic condition in the older adult population is hearing loss (ASHA, n.d.).

Prevalence of Hearing Loss in Individuals with Intellectual Disabilities

Intellectual disability and hearing loss are often associated. An extensive longitudinal study in the metropolitan Atlanta, Georgia area relating to part of the National Health and Nutrition Examination Survey has concluded that for children ages 3 to 10 years, about 30% of children with hearing impairments will have other developmental disabilities. When compared to four other developmental disabilities (intellectual disability, cerebral palsy, seizure disorder, and vision impairment), intellectual disability was the most common disability coinciding with 26.3% of all hearing impairment cases, and including 86.4% of the developmental disabilities. Etiologies found to be concurrent with the hearing impairment were idiopathic, genetic disorders (Aarskog and congenital syndromes, familial, and trisomy 8p and 10p), teratogens, birth defects, infections (otitis media and meningitis), and ototoxic drugs (Van Naarden, Decoufle, & Caldwell, 1999). Appendix A includes an index of disorders in which hearing loss and intellectual disability are co-occurring characteristics.

Down syndrome. Down syndrome is one of the most common etiologies that coincides between intellectual disability and hearing impairment. Common otologic difficulties associated with Down syndrome include abnormal pinna type with the external auditory meatus being atypically lower than that of age-matched individuals, and the external auditory canal is often narrow in diameter, thus making it easier for obstructions caused by cerumen build-up to occur (Mazzoni, Ackley, & Nash, 1994; Shott et al., 2001). The middle ear may easily contract otitis media because the tensor veli

palatini, which helps the eustachian tube open, has an abnormal contraction direction. This problem does not allow proper aeration of the middle ear through the eustachian tube (Roizen, 1996). These structural malformations may increase the risk of chronic otitis media by up to three times, thus resulting in an elevated risk of conductive hearing loss that could otherwise be prevented or treated quickly. In addition, the ossicles may actually become fused as a result of persistent otitis media or from other ossicular malformations. An added cause of conductive hearing loss may result from unabsorbed mesenchyme tissue near the round window (Shott, 2000). The cochlear sprial, located in the inner ear, may also be reduced in length as compared to normal individuals (Roizen, 1996). Knowledge of these structural malformations can help physicians take increased precautions to guard the hearing health of individuals with Down syndrome.

Loss of hearing sensitivity is an important factor in decreased communication skills for both the typical population and the intellectually disabled population. The development of language in children with Down syndrome is highly related to the degree of hearing loss in the child. Children with Down syndrome whose hearing threshold is moderately impaired are more likely to produce less intelligible utterances. Hearing thresholds in children with Down syndrome must be examined regularly and hearing aids may need to be implemented in order for the child to develop good language and hearing skills (Laws, 2004).

Often, it is the damage done as a child that leads to increased hearing damage in adults with Down syndrome. Both conductive and sensorineural hearing losses occurring in early adulthood are reported in approximately 70% of the population with Down syndrome. The cognitive and linguistic difficulties that are associated with Down

syndrome impair communication. When paired with the impaired hearing caused by the physical abnormalities, communication impairment is exacerbated (Smith D. S., 2001).

A study was conducted by Van Buggenhout et al. (1999) on a group of intellectually disabled individuals having Down syndrome comparing age (in years) and IQ level. Ages were separated into five groups: ≤ 29 years, 30–39 years, 40–49 years, 50–59 years, and ≥ 60 years. The IQ level was split into four groups: profound, < 20–25; severe, 20–25 to 35–40; moderate, 35–40 to 50–55; and mild, 50–55 to 70. Using a combination of pure-tone audiometry (play audiometry), speech audiometry with pictures, and behavioral audiometry, researchers found that 65 of the 90 individuals (72.2%) had moderate, severe, or profound hearing losses.

In a group of 38 individuals with Down syndrome living in residential care centers in British Columbia, Van Allen et al. (1999) found that 44.7% of the individuals had some type of hearing concern. These problems were chronic otitis media (44.7%), hearing loss (25.0%), chronic mastoiditis (18.4%), and mastoidectomy (15.8%). The major concern with the presence of chronic otitis media in this population is the possibility of its development into mastoiditis and a permanent conductive hearing loss.

Fetal alcohol syndrome. Hearing loss is manifested in four different ways in individuals with FAS: (a) delayed auditory system maturation, (b) sensorineural hearing loss, (c) conductive hearing loss from recurrent serous otitis media, and (d) central hearing loss (Church & Abel, 1998). These significant problems extend into adulthood causing other difficulties and intervention needs to be sought early and often to help these individuals (Church, Eldis, Blakley, & Bawle, 1997). In a study conducted by Church and Gerkin (1988), 14 children with FAS were examined periodically during child and

adolescent development for hearing difficulties. All of the children participating in the study had six or more incidents of otitis media during their lifetime. Of the 14 children, 13 of them had recurrent serous otitis media. In comparison to the general pediatric population, this occurrence of serous otitis media was statistically significant; $\chi^2 = 66.97$, $p < .001$ [*sic*]. In this group of 13 children, five of them required the repetition of myringotomy surgeries including the use of pressure equalization tubes. Four of the children also had a significant bilateral hearing loss. This relatively high sensorineural hearing loss in the children could be related to the alcohol-induced ototoxicity in the neuroectoderm. It is also possible for the sensorineural hearing loss to be influenced by alcohol's damaging effects on the organ of Corti. Alcohol has the capacity to damage the sensory epithelium of the auditory mechanism during crucial pre-natal developmental periods of the cochlea. Significant sensorineural hearing losses are often seen in frequencies above 2000 Hz although this can vary and may include only low frequencies or be a consistently flat hearing loss across frequencies (Church & Abel, 1998).

An additional study by Rossig, Wasser, and Oppermann (1994) found conductive losses in 22 of 36 children with FAS ages 2 months to 17 years (mean age: 6;11 years), sensorineural losses in 2 of the 36 children (mean age: 13;4 years), and a central hearing loss in 6 of the 36 children, three of which had an additional conductive loss (no conductive loss mean age: 7;1 years; conductive loss mean age: 6;5 years). This high prevalence of conductive loss (75%) among children with FAS with causes from serous otitis media is much greater than the 12% incidence found in the general pediatric population. Additionally, the prevalence of sensorineural hearing loss of 6% in this group is greater than the 2% incidence in the general pediatric population.

Cytomegalovirus disease. Sensorineural hearing loss is one of the biggest concerns with CMV. It affects between 40–60% of infants born with CMV symptoms at birth and 7–15% of infants born without CMV symptoms (Griffiths & Walter, 2005; Pass, 2005). In the United Kingdom, approximately 12% of the childhood sensorineural hearing loss cases are attributed to CMV. Development of hearing loss may be delayed until after neonatal hearing screenings and often occurs during speech and language development. In children known to have CMV, it is imperative that annual or semi annual hearing screenings be conducted during childhood development. The hearing loss is noted as being progressive in 50% of cases and fluctuating in 20% of cases. Treatment of this hearing loss using ganciclovir as a preventative agent is currently being researched (Griffiths & Walter, 2005).

Other intellectual disabilities in comparison to Down syndrome. In recent years extensive research performed in The Netherlands concerning sensory impairments and the intellectually disabled population have helped further knowledge in this field. Evenhuis, Theunissen, Denkers, Verschuure, and Kemme (2001) determined that hearing loss is more present in the Down syndrome population in comparison to other groups with mild to profound intellectual disabilities. Individuals younger than age 50 years with Down syndrome had a greater prevalence of hearing impairment compared to those having mild to moderate intellectual disability without Down syndrome (64% versus 21%). Those in the age 50 years and older group also had a greater prevalence of hearing loss compared to the younger group. Mild to moderate impairment in Down syndrome individuals compared to non-Down syndrome individuals was 93% and 77%

respectively. The only group in which the impairment did not increase with age was the severe to profound group (Down syndrome: 80% and non-Down syndrome: 88%).

A comparison of the occurrence of serous otitis media between FAS and Down syndrome individuals has been made by Church & Gerkin (1988). In the FAS group researched, incidence of serous otitis media for the 14 children examined was 93%. At the same ear, nose, and throat clinic, 107 children with Down syndrome were examined having a serous otitis media incidence of 62%. The difference in the incidence of serous otitis media between the two groups was statistically significant; $\chi^2 = 4.02$, $p = .04$ [*sic*]. A note of caution accompanies this statement of the significance of these results because of the large difference in the number of participants in the FAS group ($n = 14$) compared to that of the Down syndrome group ($n = 107$).

Hearing Examination Techniques

Otoscopy

The physical examination of the ear mechanism includes an examination of the auricle, external auditory canal, and the exterior portion of the tympanic membrane. This first portion of the audiological examination requires that the ear canal does not collapse and that cerumen does not occlude the external auditory canal and impede other tests from revealing accurate results (American Speech-Language-Hearing Association Audiologic Assessment Panel 1996, 1997). The position and appearance of the auricle should be observed. The appearance of the auricle can often signal to examiners other anomalies that may cause problems for the individual; problems such as microtia, or an abnormal formation of the auricle, should be noted (Jordan & Roland, 2000).

After the initial observation of the external auditory canal diameter, a proper fitting speculum on an otoscope can be inserted to observe the portion of the external auditory canal that cannot otherwise be observed. The external auditory canal should be examined specifically for impacted cerumen, foreign bodies (i.e. insects, toys, and other objects), soft or bony growths (i.e. osteoma, hyperostosis, and exostosis), and signs of infection (i.e. effusion and otitis externa; Ginsberg & White, 1994).

Examination of the tympanic membrane includes observation of the color, position of the ossicles and tympanic membrane, and any other abnormalities that might be seen that could possibly affect the hearing acuity of the individual. The color should be a "pearly" white, as redness may suggest inflammation of the tympanic membrane, which should be examined further through other portions of the audiologic examination. The entire tympanic membrane should be visualized. Anatomical landmarks that should be observed are the short process, manubrium, and umbo of the malleus; the pars flaccida; and the cone of light. Scarring, perforations, effusion, bulging, and any other anomalies should be carefully noted. Considering that all of these problems occur in a very delicate and important area of the auditory system, it is suggested that the individual be referred to an otolaryngologist for cerumen removal and medical care as needed (Ginsberg & White, 1994; Jordan & Roland, 2000).

Otoacoustic Emissions

Otoacoustic emissions (OAEs) are echoes created in the cochlea by sound stimuli, sent by reverse transmission through the middle ear structures, and recorded in the external auditory canal using a microphone. The measurement of OAEs reflects outer hair cell (OHC) transmission and not inner hair cell (IHC) transmission in the cochlea.

Most congenital and acquired sensory losses affect the OHC transmission and will therefore affect the OAE test results. Ears presenting with middle ear pathology or a threshold ≥ 30 dB HL will typically not create a response to testing stimuli. Individuals with moderate to profound hearing losses with present OAEs will show a neurological pathology because the factor causing the hearing loss is beyond the cochlea on the auditory pathway (Robinette & Glattke, 2000). Two types of evoked OAEs are used clinically: transient evoked otoacoustic emissions (TEOAEs) and distortion product otoacoustic emissions (DPOAEs). TEOAEs use a broadband click stimuli produced at around 84 dB SPL. DPOAEs utilize a two frequency stimuli at the ratio of 1.2 : 1. The emission recorded is the cubic difference tone ($f_{dp} = 2f1 – f2$; Kemp, 2002). Uses for OAEs include screening the peripheral auditory system in infants, distinguishing between sensory and neural components of a hearing loss, monitoring the effects of ototoxic drug use, and testing a fluctuation of hearing acuity in individuals (Norton & Stover, 1994). Currently, DPOAEs, specifically, are used in Special Olympics Healthy Hearing screenings (Herer & Montgomery, 2001).

Tympanometry

Tympanometry is a portion of the exam that identifies, through admittance measurements, possible middle ear pathology that may become a factor in conductive hearing loss such as eustachian tube dysfunction and tympanic membrane pathologies (Evenhuis, 1996). As recommended by ASHA, performance of tympanometry is suggested during screening procedures (American Speech-Language-Hearing Association Audiologic Assessment Panel 1996, 1997). When coupled with other physiologic

measurements and subjective measurements, tympanometry can be a helpful tool in determining conductive hearing losses in Special Olympics athletes.

Pure-tone Screening

The use of pure-tone audiometry assesses hearing threshold for a single frequency. Threshold is the intensity at which the individual can hear pure-tone stimuli 50% of the time presented. Pure-tone audiometry can be easily adapted for individuals having intellectual disabilities who can answer yes and no questions. The ASHA recommended method and Hughson-Westlake technique for determining thresholds are often used. The Hughson-Westlake technique was specifically developed to reduce the possibility of perseveration and inhibition from being included in testing of the individual. The ASHA recommended method is a slight variation of the Hughson-Westlake method. Implementation of pure-tone testing helps determine possible sensorineural components an individual's threshold might contain (ASHA, 1978; Martin & Clark, 2003; Roeser, Buckley, & Stickney, 2000). Where appropriate, Healthy Hearing guidelines allow for pure-tone threshold testing at 500, 1000, 2000, and 4000 Hz (Herer & Montgomery, 2001).

Pure-tone screening is a form of audiometry that allows for quick determination of hearing within normal limits. Most often, a training tone is presented at assumed supra-threshold levels (approximately 50 dB HL for individuals with normal hearing) to allow the individual the opportunity to know what tone to listen for. ASHA defines hearing impairment as a unilateral or bilateral sensorineural or conductive hearing loss greater than 20 dB HL. ASHA's guidelines for hearing screenings state that it is to be performed at 25 dB HL on adults at 1000, 2000, and 4000 Hz (American Speech-

Language-Hearing Association Audiologic Assessment Panel 1996, 1997). Healthy Hearing guidelines screen only at 2000 and 4000 Hz due to interference from lower frequency noise at 500 and 1000 Hz (Herer & Montgomery, 2001).

Statement of the Problem

This study included the screening areas of otoscopy (ear canal screen), DPOAEs, tympanometry, pure-tone screen, and, where applicable, pure-tone threshold testing as set forth in the Healthy Hearing guidelines (Herer & Montgomery, 2001). Specific problems elucidated during research include the areas of hearing screening administration, athlete demographical characteristics, and regional differences between hearing health. In the process of the hearing screenings, are too many athletes being over referred thus creating an extra sensitive program that is not specific enough? Are changes in hearing status from one screening to the next secondary to transient changes in hearing (conductive pathology) or screening conditions and procedures? Do specific hearing loss characteristics follow specific athlete demographics (age, region of origin, gender)? What are the characteristics of the athletes' hearing losses? What proportion of the athletes have sensorineural losses in comparison to athletes having conductive or mixed losses? If conductive losses are prevalent, are the conditions occasional or recurrent, transient or long-term? The purpose of this specific study is to determine the prevalence and types of hearing losses, and changes in hearing health of Special Olympics athletes competing in events in the state of Utah in comparison to other Special Olympics athletes from different regions throughout the world.

Method

Participants

Participants in the study were separated into two groups: Special Olympics athletes from the state of Utah and Special Olympics athletes from regions throughout the world.

Athletes from the State of Utah

Special Olympic athletes were screened at the Healthy Hearing screening during one or more of the following sport events: the Summer Games at Brigham Young University in Provo, Utah, June 3–5, 2004; the Fall Sports Classic at the University of Utah in Salt Lake City, Utah, October 8 and 9, 2004; and/or the Fall Sports Classic at the University of Utah in Salt Lake City, Utah, October 6–8, 2005. Some athletes participated in more than one or two screening sessions. Also noted is that three Utah athletes were also participants in the Nagano 2005 screening period. All athletes included in the study were eight years or older in age. Each athlete had previously passed the requirements to become involved in Special Olympics athletic events. Special Olympics requires the athletes to have a previously diagnosed intellectual disability to participate under the title of *athlete*. This means the athlete's disability includes a cognitive delay that has been determined by generally accepted measures such as intelligence quotient or the individual has a closely related developmental disability that affects the individual's learning and adaptive skills. These skills must diminish the individual's ability "to adapt to the daily demands of a normal social environment" (Special Olympics, Eligibility, n.d.).

Athletes at the Summer 2004 games were initially screened with the ear canal screen, DPOAEs, tympanometry, and pure-tone screening at 2000 and 4000 Hz at 25 dB HL.

Athletes at the 2004 Fall Sports Classic followed a slightly different protocol. All athletes were screened with otoscopy and DPOAEs. Those who passed the DPOAE screen were discharged from further screening. Those athletes who did not pass the DPOAE screen were then sent on to tympanometry and pure-tone screening areas for further screening. The decision tree schematic in Figure 1 was used to determine if a referral were needed, and if so, the type of referral. According to this decision tree, athletes not passing either otoscopy or tympanometry were given a medical referral. Athletes who did not pass the pure-tone screening were given an audiological referral. In some cases, the athletes could have received both referrals. Specific referral criteria have been established by Special Olympics (Herer & Montgomery, 2001).

Athletes at the 2005 Fall Sports Classic followed the same procedure as the 2004 Fall Sports Classic screening with additional pure-tone threshold testing at 500, 1000, 2000, and 4000 Hz upon failure at the pure-tone screen. This was conducted in a quiet, though not sound treated room. Results from this portion of the screening are not included in this study.

In some cases, testing for an athlete may have been incomplete due to scheduling conflicts with athlete sport events or other unknown factors. In these situations, it was determined that these athletes receive a “fail” for their screening so they may be notified that further testing needs to be completed to rule out possible hearing problems.

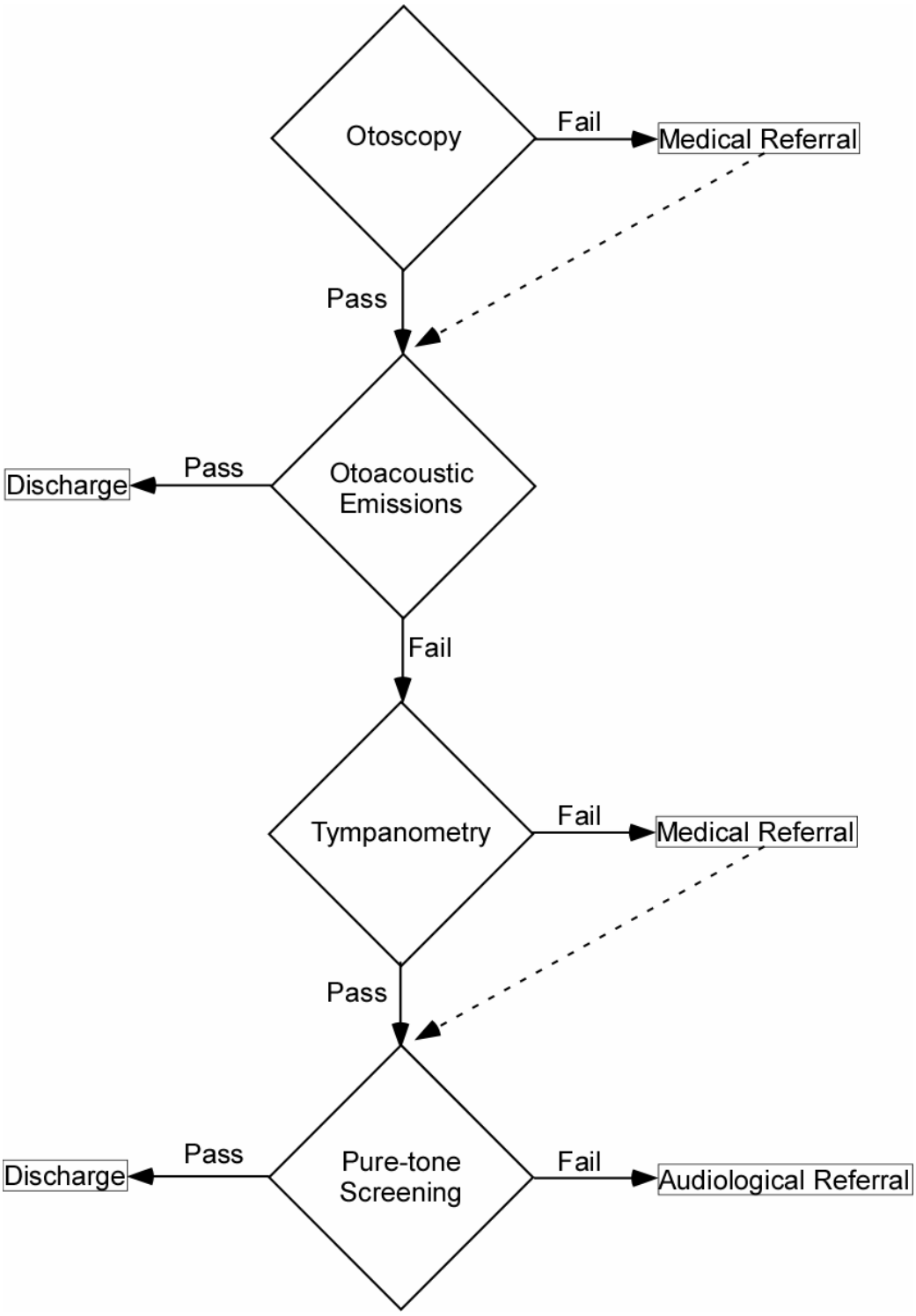

Figure 1. *Healthy Hearing screening decision tree used to determine the type of referral for participating athletes and the need for follow-up contact.*

At the conclusion of each testing, an athlete "report card" was sent to the athlete's coach from the state clinical director for Healthy Hearing. This report card stated whether the athlete passed the hearing screening or if further follow-up from an ear, nose, and throat (ENT) physician or an audiologist was needed. It is unknown in many cases if the athlete's caregivers ever became aware of the recommendations that were made.

Athletes from Different World Regions

Special Olympic athletes from around the world were screened at the Healthy Hearing screening at the 2005 World Winter Games in Nagano, Japan. Athlete testing information was gathered according to region, and where possible, country of origin. Included in Appendix B is a list of the seven world Special Olympics regions and the participating countries in each region. Athletes tested at this venue had previously been found eligible for athletic participation in Special Olympics in their home countries. All athletes tested were eight years of age or older. Athletes at this screening were screened with the same protocol as the 2005 Utah Fall Sports Classic screening. This screening also had the capabilities of performing pure-tone threshold testing in a sound treated booth, which was transported to the Nagano testing facility, however, results from this portion of the screening are not included.

Procedures

Instruments

An audiometric screening was conducted. This screening procedure was developed by Drs. Gilbert Herer and Judy Montgomery, Global Clinical Directors for the Healthy Hearing division of Healthy Athletes. The portions of the screening examination

includes ear canal screen (otoscopy), OAE screen (DPOAE), tympanometry, pure-tone screening, and where possible, pure-tone threshold testing.

Ear canal screen. The otoscopic evaluation was conducted using a standard rechargeable Welch Allyn diagnostic otoscope with corresponding disposable specula. Results from observations were recorded as Normal, Partially Blocked, or Blocked, with an additional seven observation options needing ENT follow-up available with screener discretion: (a) refer for medical exam of retracted eardrums, (b) reports upper respiratory infection or allergy, (c) foreign object in ear canal, (d) perforation of ear drum, (e) unusual ear canal, (f) atretic ear, or (g) refer for cerumen removal.

Otoacoustic emissions screen. DPOAEs were recorded using the Biologic handheld AuDX screener with corresponding disposable single-use foam tips (pediatric, adult, and jumbo sizes; Special Olympics, Healthy Hearing, n.d.). DPOAE recordings were made according to the presence or absence of the signal at specific frequencies. Results from the DPOAE screen were distinguished as Pass or Refer (No Pass). Refer results may occur from excess cerumen in the ear canal, middle ear pathology, or a cochlear hearing loss greater than about 25–30 dB HL. Additional observations the screener could make regarding the DPOAE testing were (a) cannot achieve seal, (b) canal blocked by cerumen, (c) excessive noise, and (d) athlete refused testing.

Tympanometry. Tympanometric measures were taken using a handheld rechargeable or battery-powered GSI 37 Auto Tymp tympanometer from Grason-Stadler, Inc. (GSI) with accompanying Grason Associates, Inc. single use eartips (Grason-Stadler, 1996; Herer & Montgomery, 2001). Tympanometric data were recorded with a Pass or No Pass screener response. A Pass screener response was determined if the apex of the

curve or the main body of the tympanometric curve were within the box on the tympanometer's LCD screen, whereas a No Pass included all responses where the apex and/or main body of the tympanometric curve were without the box on the tympanometer's LCD screen. This included all tympanometric curves not containing an apex (Jerger type B; Martin & Clark, 2003). If the athlete did not pass unilaterally or bilaterally, screeners could note if there was an ENT ear exam recommended, or any of the following: (a) evidence of middle ear pathology, (b) large ear canal volume, (c) could not achieve seal, or (d) athlete refused testing.

Pure-tone audiometry. Pure-tone air conduction screening was conducted using a standard portable audiometer with TDH-50 Telephonics supra-aural earphones with a GSI 17 Audiometer provided by Special Olympics. Screening was completed at 2000 and 4000 Hz at 25 dB HL. Screeners were instructed to present a training tone at an assumed supra-threshold level near 50 dB HL to familiarize the athlete with the tone and then present the test pure-tone at 25 dB HL (Herer & Montgomery, 2001). Results were recorded as Pass or No Pass. Additional observations and comments the screeners could make include: (a) hearing evaluation recommended, (b) good conditions for screening, (c) could not train to respond, (d) poor earphone fit, and (e) excessive noise.

In screening sessions where pure-tone threshold testing was available for athletes not passing the initial pure-tone screening either unilaterally or bilaterally, screeners were instructed to test athletes at 500, 1000, 2000, and 4000 Hz bilaterally. The method of testing used during the study was the ASHA recommended method (ASHA, 1978; Martin & Clark, 2003; Roeser et al., 2000). Athlete unmasked threshold results, if within the limits of the audiometer, were recorded as a numeric value in dB HL.

Screeners

Personnel doing the actual testing consisted of different groups of students and professionals. For the Summer 2004 and Fall 2005 games, screening personnel consisted of undergraduate and graduate students from Brigham Young University, Utah State University, and the University of Utah with one to three ASHA certified audiologists supervising testing. All students were trained to use the instrumentation, record results, and instructed regarding interaction with the athletes prior to testing them. Screening personnel for the Fall 2004 games consisted of professionals in audiology and speech-language pathology who were being trained as trainers for their own states or countries in addition to undergraduate and graduate students from Brigham Young University, Utah State University, the University of Utah, and Idaho State University. All screeners were trained to use the instrumentation and correctly record results, and instructed regarding interaction with the athletes prior to testing the athletes. The Nagano 2005 games screening personnel consisted of ear, nose, and throat (ENT) physicians and audiology and speech-language pathology professionals, many of whom were state or national coordinators for Healthy Hearing, from throughout the world specifically invited by the Global Clinical Directors to participate in the screenings. All screeners received previous training to perform the screenings, use the instrumentation, and record results.

Statistical Analysis

Two sets of data were compiled for this study. The data from the Utah screening sessions (Summer 2004, Fall 2004, and the Fall 2005 games) were compared to each other and also as a whole group in comparison to data from the Nagano 2005 World Winter Special Olympic Games. Individual changes were noted in athletes participating

in more than one screening session, as seen in the Utah screenings. In addition, the data were evaluated for the efficacy of the hearing screening regarding the number of athletes referred due to instrumental or environmental factors. The results from these four screenings were then analyzed using descriptive, nonparametric statistics and chi-square tests with a Bonferroni correction factor.

Variables included in the screening database were age and gender differences; outcomes from ear canal screen, OAEs, tympanometry, pure-tone screen, and classification of the hearing loss identified (sensorineural and conductive/mixed); degree of hearing loss; screening location; and change in athlete hearing status during the screenings. Variables relating to the demographics of the population included gender, age, and region of origin.

Results

Screening Results

The following is a description of the screening results from the Summer 2004, Fall 2004, Fall 2005, and Nagano 2005 games. A screening period is defined as the group of screening days during a Special Olympics sport event (i.e. Summer 2004), whereas a screening session is defined as the actual time period when an athlete was administered the screening protocol. All percentages have been rounded to the nearest tenth. Where appropriate, chi-square tests using a Bonferroni correction factor ($p \leq 0.001$) have been used. All results reported using unilateral and bilateral differentiations include complete and incomplete testing, whereas all results reported using chi-square tests include only complete test results.

Utah Athlete Statistics

Special Olympics athletes from the state of Utah had the option of being tested in four different hearing screening periods, three of which were located in Utah. Although it appears that 689 Utah athletes were tested, 493 athletes were actually tested due to additional testing at subsequent games or during the same hearing screening period at the same games. Tables 1 through 3 show the breakdowns in number of athletes tested during each testing period with the number of screening sessions participated.

Table 1 describes the number of Utah athletes participating in each hearing screening period and the number of screening sessions total (1, 2, 3, or 4) athletes screened in that specific period participated in. The Summer 2004 games was the most widely attended screening period with many athletes participating in subsequent screening periods.

Table 2 defines how many athletes participated in which screening period according to the number of times the athlete was tested. Ninety-eight of the athletes that participated in multiple screening sessions participated in both the Summer 2004 and Fall 2004 games.

Information given in Table 3 is a detailed breakdown of pure-tone screening results for those athletes participating in multiple testing sessions. As noted, the results of athletes who failed to complete necessary testing during their screening session were automatically designated as a "fail." It was found that 14 athletes had their hearing screened twice during a testing period, 12 of which occurred at the Summer 2004 games. Of the 14 athletes who were tested twice during a single screening period, 2 athletes had differing results during the same screening period. The total number of athletes with

Table 1

Utah Athlete Participation and Number of Screening Sessions According to Games

Games	Total athlete screenings	Total no. of screening sessions participated in			
		1	2	3	4
Summer 2004	309	176	84	42	7
Fall 2004	250	121	91	34	4
Fall 2005	127	42	48	32	5
Nagano 2005*	3	—	3	—	—

* = Only three of the 54 athletes screened from the USA were from Utah.

Table 2

Total Number of Screening Sessions Participated in by Games

1 Test	#	2 Tests	#	3 Tests	#	4 Tests	#
a	176	a, a	6	a, a, b	3	a, a, b, c	2
b	121	a, b	60	a, a, c	1	a, b, c, c	1
c	42	a, c	22	a, b, c	32		
d	0	a, d	1				
		b, c	42				
		c, c	1				
		c, d	2				
Total	390		115		36		3

Note. a = Summer 2004, b = Fall 2004, c = Fall 2005, d = Nagano 2005

Table 3

Pure-tone Pass/Fail Results for Utah Athletes Participating in Multiple Testing Sessions

2 Tests	#	3 Tests	#	4 Tests	#
Fail a, Fail a*	4	Fail a, Fail a, Fail b*	1	Fail a, Fail a, Pass b, Fail c*	1
Fail a, Pass a*	1	Fail a, Fail a, Pass b*	1	Fail a, Fail a, Pass b, Pass c*	1
Fail a, Fail b	19	Fail a, Fail a, Fail c*	1	Fail a, Pass b, Fail c, Fail c*	1
Fail a, Pass b	14	Fail a, Pass a, Fail b*	1		
Fail a, Fail c	7	Fail a, Fail b, Fail c	11		
Fail a, Pass c	3	Fail a, Fail b, Pass c	2		
Fail a, Pass d	1	Fail a, Pass b, Fail c	2		
Pass a, Pass a*	1	Fail a, Pass b, Pass c	8		
Pass a, Fail b	6	Pass a, Fail b, Pass c	1		
Pass a, Pass b	21	Pass a, Pass b, Pass c	8		
Pass a, Fail c	3				
Pass a, Pass c	2				
Fail b, Fail c	12				
Fail b, Pass c	2				
Pass b, Fail c	4				
Pass b, Pass c	12				
Pass b, Pass d	2				
Pass c, Pass c*	1				
Total	115		36		3
Re-screen*	7		4		3
Changing results	34		15		3

Note. a = Summer 2004; b = Fall 2004; c = Fall 2005; d = Nagano 2005
* = Testing situations where athletes participated in re-screen during same games.

fluctuating screening results (pass then fail or fail then pass) was 52/154 (33.8%). Of that group of athletes with changing screening results, the total number of athletes who failed then passed their hearing screen was 33/52 (63.5%) and the total number of athletes who passed the hearing screen and then failed at a later testing was 13/52 (25.0%). The total number of athletes who fluctuated between failing, passing, and then failing again at subsequent screening sessions was 5/52 (9.6%) and only 1/52 (1.9%) athletes passed, failed, and then passed the screening at a later date.

Screening Results According to Games

Screening results for all four screening areas are presented in Table 4. Results for tympanometry and pure-tone screen are calculated twice: once with only those athletes participating in the original testing and again with all athletes who passed OAE screening and were assumed to have been able to pass the tympanometry and pure-tone screenings. This was the case for the Fall 2004 and 2005 and Nagano 2005 games. The Summer 2004 games produced a higher fail rate in each screening area than the three other games. The total failure rate for all four games combined was 31.1% (450/1450 athletes) when only complete data were used. However, when incomplete data were included, the total failure rate was 34.7% (528/1521 athletes). Figure 2 presents the schematic of athlete pass/fail for each of the different screening areas for all Utah athletes combined. Figure 3 presents the schematic of athlete pass/fail for each of the different screening areas for Nagano 2005 athletes. Figure 4 presents the schematic of athlete pass/fail for each of the different screening areas for all four screening periods combined. Each of these figures include incomplete data.

Table 4

Screening Pass/Fail Results by Special Olympics Games

Screening Measure	Summer 2004		Fall 2004		Fall 2005		Nagano 2005	
Ear Canal Screen								
Pass	143	(47.0%)	151	(61.4%)	62	(50.8%)	563	(63.8%)
Fail	161	(53.0%)	95	(38.6%)	60	(49.2%)	319	(36.2%)
Total no.	304		246		122		882	
OAE								
Pass	54	(19.7%)	78	(32.2%)	42	(32.8%)	509	(56.7%)
Fail	220	(80.3%)	164	(67.8%)	86	(67.2%)	388	(43.3%)
Total no.	274		242		128		897	
Tympanometry*								
Pass	—	—	103	(63.2%)	52	(61.2%)	171	(44.2%)
Fail	—	—	60	(36.8%)	33	(38.8%)	216	(55.8%)
Total no.	—		163		85		387	
Pure-tone Screen*								
Pass	—	—	70	(49.6%)	27	(35.1%)	177	(52.8%)
Fail	—	—	71	(50.4%)	50	(64.9%)	158	(47.2%)
Total no.	—		141		77		335	
Tympanometry**								
Pass	172	(63.5%)	181	(75.1%)	94	(74.0%)	680	(75.9%)
Fail	99	(36.5%)	60	(24.9%)	33	(26.0%)	216	(24.1%)
Total no.	271		241		127		896	
Pure-tone Screen**								
Pass	97	(36.2%)	148	(67.6%)	69	(58.0%)	686	(81.3%)
Fail	171	(63.8%)	71	(32.4%)	50	(42.0%)	158	(18.7%)
Total no.	268		219		119		844	

* = Those failing OAE screening

** = All athletes calculated, with assumption that all athletes passing OAE screen would have passed tympanometry and pure-tone screen.

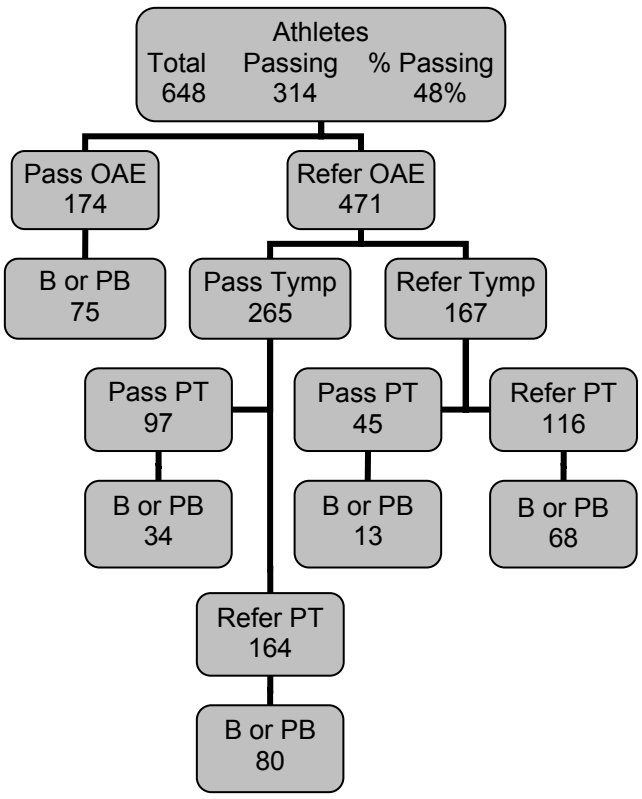

Figure 2. *Flow chart of combined Utah 2004–2005 results.*

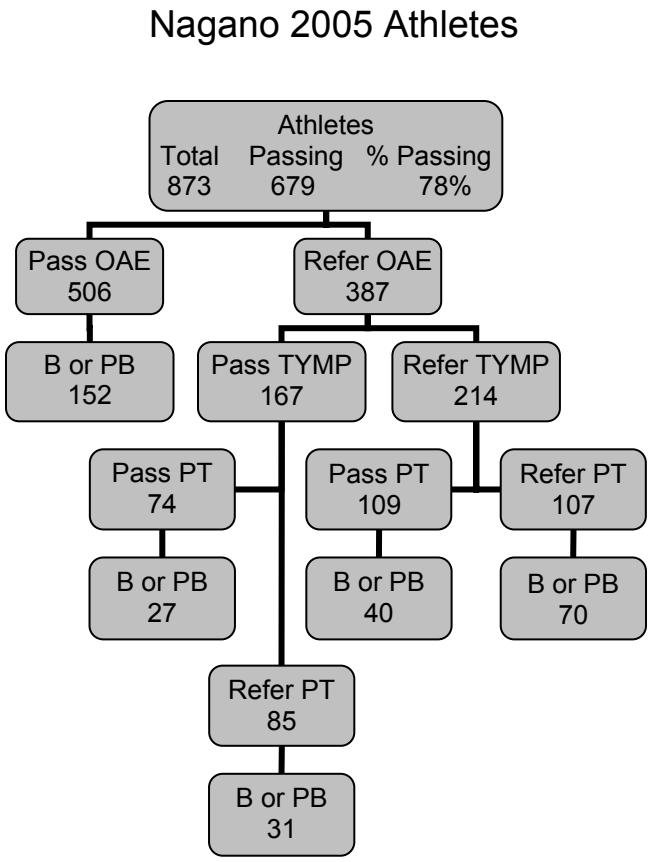

Figure 3. *Flow chart of Nagano 2005 results.*

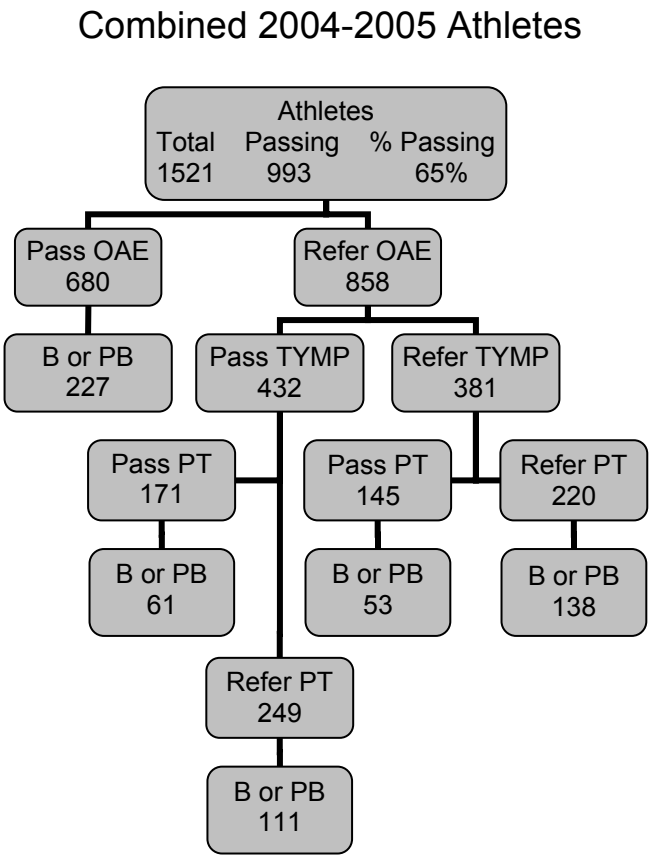

Figure 4. *Flow chart of combined results for all for testing periods.*

A chi-square analysis revealed differences between ear canal screening results from the four screening periods [$\chi^2(3, N = 1450) = 30.46, p < 0.001$]. Further chi-square analyses (see Table 5) between the four games elucidate statistically significant differences in ear canal screening in the following pairs of games: Summer 2004 and Fall 2004 and Summer 2004 and Nagano 2005 ($p \leq 0.001$). The Summer 2004 games had a pass rate of only 47%, whereas the pass rates of the Fall 2004 and Nagano 2005 games were 61.4% and 63.8%, respectively.

A chi-square test regarding OAE screening showed differences between the four screening sessions [$\chi^2(3, N = 1450) = 144.57, p < 0.001$]. Further chi-square analyses (see Table 5) between the four games revealed statistically significant differences in OAE screening in the following pairs of games: Summer 2004 and Nagano 2005, Fall 2004 and Nagano 2005, Fall 2005 and Nagano 2005 ($p \leq 0.001$). All three games held in Utah had significantly less athletes pass the OAE screen in comparison to the Nagano 2005 games.

Statistically significant differences between tympanometry results for the four screening sessions were revealed using a chi-square test [$\chi^2(3, N = 1450) = 16.93, p < 0.001$]. Additional chi-square analyses (see Table 5) between the four games suggest differences in tympanometry screening results are statistically significant between Summer 2004 and Nagano 2005 ($p \leq 0.001$) with Summer 2004 pass results being far fewer than the Nagano 2005 results. However, it is noted that the pass percentages for Fall 2004, Fall 2005, and Nagano 2005 lie within a range of 1.9%.

A chi-square analysis showed significant differences between pure-tone screening results for the four screening sessions [$\chi^2(3, N = 1450) = 201.18, p < 0.001$]. Additional

Table 5

Chi-square Analysis of Differences Between Game Results Per Screening Measure

Screening Measure	Game x Game	χ^2	*df*	*p*
Ear Canal Screen				
	Summer 2004 x Fall 2004	10.67	1	0.001*
	Summer 2004 x Fall 2005	0.36	1	0.549
	Summer 2004 x Nagano 2005	25.77	1	< 0.001*
	Fall 2004 x Fall 2005	3.31	1	0.039
	Fall 2004 x Nagano 2005	0.40	1	0.529
	Fall 2005 x Nagano 2005	7.18	1	0.007
OAE				
	Summer 2004 x Fall 2004	9.94	1	0.002
	Summer 2004 x Fall 2005	7.54	1	0.006
	Summer 2004 x Nagano 2005	113.85	1	< 0.001*
	Fall 2004 x Fall 2005	0.00	1	0.997
	Fall 2004 x Nagano 2005	82.43	1	< 0.001*
	Fall 2005 x Nagano 2005	24.86	1	< 0.001*
Tympanometry				
	Summer 2004 x Fall 2004	7.53	1	0.006
	Summer 2004 x Fall 2005	3.88	1	0.049
	Summer 2004 x Nagano 2005	15.67	1	< 0.001*
	Fall 2004 x Fall 2005	0.01	1	0.919
	Fall 2004 x Nagano 2005	0.03	1	0.866
	Fall 2005 x Nagano 2005	0.12	1	0.726
Pure-tone Screen				
	Summer 2004 x Fall 2004	46.24	1	< 0.001*
	Summer 2004 x Fall 2005	15.10	1	< 0.001*
	Summer 2004 x Nagano 2005	196.31	1	< 0.001*
	Fall 2004 x Fall 2005	2.69	1	0.101
	Fall 2004 x Nagano 2005	18.51	1	< 0.001*
	Fall 2005 x Nagano 2005	32.06	1	< 0.001*

* = $p \leq 0.001$

chi-square analyses (see Table 5) between the four games suggests statistically significant differences ($p \leq 0.001$) in pure-tone screening results between all games except Fall 2004 and Fall 2005. Pass results from the Nagano 2005 games were more than double that of the Summer 2004 games, and still significantly greater than that of the Fall 2004 and 2005 games.

Screening Results According to Region

Each of the four screening areas was analyzed in relation to the Special Olympics region the athletes represented. Regions included in this study are Africa, Asia Pacific, East Asia, Europe/Eurasia, Latin America, Middle East/North Africa, and North America (Special Olympics, Program Locator, n.d.). Countries comprising these seven regions are indicated in Appendix B.

Regional ear canal screen results. Table 6 presents the results from the ear canal screening for each of the seven Special Olympics regions. Results were compiled according to pass (bilateral) and fail (unilateral, bilateral, and any failure). A failure represents a partially blocked or completely blocked ear canal. The overall fail rate is 36.4%. The East Asia region has the largest fail rate (49.1%) and the Africa region had the least failure rate (19.0%). Also noted, is except for the Africa region, all other regions are approximately within one standard deviation for percent fail of each other. Significant differences were found between the seven regions for ear canal screen $[\chi^2(6, N = 1450) = 28.54, p < 0.001]$. Table 7 presents the chi-square analysis of differences between regions for ear canal screen results. Significant differences ($p \leq 0.001$) were found for the following regional comparisons: Africa–East Asia, Africa–North America, and Europe/Eurasia–North America.

Table 6
Ear Canal Screen Pass/Fail Results by Special Olympics Region

	Pass		Fail						
									Total no.
Region	Bilateral		Unilateral		Bilateral		Either		screened
A	34	(81.0%)	7	(16.7%)	1	(2.4%)	8	(19.0%)	42
B	63	(61.8%)	19	(18.6%)	20	(19.6%)	39	(38.2%)	102
C	55	(50.9%)	18	(16.7%)	35	(32.4%)	53	(49.1%)	108
D	222	(65.7%)	53	(15.7%)	63	(18.6%)	116	(34.3%)	338
E	85	(68.5%)	20	(16.1%)	19	(15.3%)	39	(31.5%)	124
F	38	(62.3%)	11	(18.0%)	12	(19.7%)	23	(37.7%)	61
G	422	(54.8%)	148	(19.2%)	200	(26.0%)	348	(45.2%)	770
All	919	(59.5%)	276	(17.9%)	350	(22.7%)	626	(40.5%)	1545
M	131	(63.6%)	39	(17.3%)	50	(19.1%)	89	(36.4%)	221
SD	144	(9.8%)	50	(1.3%)	69	(9.3%)	119	(9.8%)	261

Note. A: Africa; B: Asia Pacific; C: East Asia; D: Europe/Eurasia; E: Latin America; F: Middle East/North Africa; G: North America

Table 7

Chi-square Analysis of Differences Between Regional Ear Canal Screen Results

Region–Region	χ^2	*df*	*p*
A–B	4.15	1	0.042
A–C	10.42	1	0.001*
A–D	3.55	1	0.059
A–E	1.98	1	0.159
A–F	3.28	1	0.070
A–G	10.35	1	0.001*
B–C	2.29	1	0.130
B–D	0.25	1	0.617
B–E	0.71	1	0.400
B–F	0.01	1	0.921
B–G	1.70	1	0.192
C–D	6.88	1	0.009
C–E	6.74	1	0.009
C–F	1.76	1	0.185
C–G	0.45	1	0.505
D–E	0.23	1	0.635
D–F	0.08	1	0.782
D–G	10.72	1	0.001*
E–F	0.37	1	0.544
E–G	7.57	1	0.006
F–G	1.13	1	0.288

Note. A: Africa; B: Asia Pacific; C: East Asia; D: Europe/Eurasia; E: Latin America; F: Middle East/North Africa; G: North America

* = $p \leq 0.001$

Regional OAE results. Results from the OAE screening are presented in Table 8 for each of the seven Special Olympics regions. The mean failure rate is 42.1%. The Asia Pacific region had the largest failure rate (49.0%) and the Africa and East Asia regions had the least failure rate (31.0% and 33.9% respectively). Also noted, all regions except Africa and East Asia are approximately within one standard deviation for percent fail of each other. A chi-square analysis found significant differences in OAE results between the seven regions [$\chi^2(6, N = 1450) = 114.42, p < 0.001$]. Chi-square tests for OAE results are presented in Table 9 Interestingly, all regions were significantly different ($p \leq 0.001$) from North America in this screening area as North America had a significantly greater number of athletes fail OAEs.

Regional tympanometry results. Tympanometry results for each of the seven Special Olympics regions are presented in Table 10. The mean failure rate is 53.4%. The East Asia region has the largest failure rate (69.4%) and the North America region has the least failure rate (38.2%). It is noted that both the East Asia and North America regions are also not within one standard deviation of the mean unlike the other five regions. Significant differences in tympanometric results between the seven regions are apparent using a chi-square analysis [$\chi^2(6, N = 1450) = 31.34, p < 0.001$]. As noted in Table 11, North American tympanometry pass results were significantly greater than East Asia and Europe/Eurasia ($p < 0.001$)

Regional pure-tone screen results. Pure-tone screening results of pass or fail are presented in Table 12 for each of the Special Olympics regions. The mean failure rate is 51.3%. The Africa region has the least failure rate (33.3%) and the East Asia region has the greatest failure rate (65.7%). Also noted, all regions failure rates are within one

Table 8

OAE Screen Pass/Fail Results by Special Olympics Region

Region	Pass		Fail						Total no. screened
	Bilateral		Unilateral		Bilateral		Either		
A	29	(69.0%)	4	(9.5%)	9	(21.4%)	13	(31.0%)	42
B	53	(51.0%)	23	(22.1%)	28	(26.9%)	51	(49.0%)	104
C	72	(66.1%)	10	(9.2%)	27	(24.8%)	37	(33.9%)	109
D	196	(55.8%)	60	(17.1%)	95	(27.1%)	155	(44.2%)	351
E	68	(54.4%)	18	(14.4%)	39	(31.2%)	57	(45.6%)	125
F	33	(54.1%)	11	(18.0%)	17	(27.9%)	28	(45.9%)	61
G	232	(31.3%)	136	(18.3%)	374	(50.4%)	510	(68.7%)	742
All	683	(44.5%)	262	(17.1%)	589	(38.4%)	851	(55.5%)	1534
M	98	(54.5%)	37	(15.5%)	84	(30.0%)	120	(42.1%)	219
SD	82	(12.2%)	47	(4.8%)	131	(9.5%)	178	(6.8%)	252

Note. A: Africa; B: Asia Pacific; C: East Asia; D: Europe/Eurasia; E: Latin America; F: Middle East/North Africa; G: North America.

Table 9

Chi-square Analysis of Differences Between Regional OAE Screen Results

Region–Region	χ^2	d. f.	*p*
A–B	3.27	1	0.070
A–C	0.03	1	0.875
A–D	2.16	1	0.142
A–E	2.20	1	0.138
A–F	1.74	1	0.070
A–G	24.53	1	< 0.001*
B–C	4.40	1	0.036
B–D	0.59	1	0.444
B–E	0.15	1	0.699
B–F	0.05	1	0.820
B–G	15.66	1	< 0.001*
C–D	3.16	1	0.075
C–E	2.82	1	0.093
C–F	1.89	1	0.169
C–G	49.97	1	< 0.001*
D–E	0.03	1	0.862
D–F	0.01	1	0.910
D–G	61.63	1	< 0.001*
E–F	0.01	1	0.906
E–G	25.27	1	< 0.001*
F–G	12.78	1	< 0.001*

Note. A: Africa; B: Asia Pacific; C: East Asia; D: Europe/Eurasia; E: Latin America; F: Middle East/North Africa; G: North America

* = $p \leq 0.001$

Table 10

Tympanometry Screen Pass/Fail Results by Special Olympics Region

Region	Pass		Fail						Total no. screened
	Bilateral		Unilateral		Bilateral		Either		
A	5	(41.7%)	2	(16.7%)	5	(41.7%)	7	(58.3%)	12
B	20	(40.0%)	20	(40.0%)	10	(20.0%)	30	(60.0%)	50
C	11	(30.6%)	8	(22.2%)	17	(47.2%)	25	(69.4%)	36
D	68	(43.9%)	38	(24.5%)	49	(31.6%)	87	(56.1%)	155
E	31	(54.4%)	12	(21.1%)	14	(24.6%)	26	(45.6%)	57
F	15	(53.6%)	6	(21.4%)	7	(25.0%)	13	(46.4%)	28
G	350	(61.8%)	119	(21.0%)	97	(17.1%)	216	(38.2%)	566
All	500	(55.3%)	205	(22.7%)	199	(22.0%)	404	(44.7%)	904
M	71	(46.6%)	29	(23.8%)	28	(29.6%)	58	(53.4%)	129
SD	125	(10.6%)	41	(7.5%)	34	(11.2%)	75	(10.6%)	198

Note. A: Africa; B: Asia Pacific; C: East Asia; D: Europe/Eurasia; E: Latin America; F: Middle East/North Africa; G: North America.

Table 11

Chi-square Analysis of Differences Between Regional Tympanometry Results

Region–Region	χ^2	*df*	*p*
A–B	0.05	1	0.824
A–C	0.13	1	0.724
A–D	0.02	1	0.878
A–E	0.23	1	0.629
A–F	0.12	1	0.730
A–G	1.18	1	0.277
B–C	0.45	1	0.501
B–D	0.10	1	0.752
B–E	1.67	1	0.196
B–F	0.84	1	0.358
B–G	7.88	1	0.005
C–D	1.62	1	0.203
C–E	4.14	1	0.042
C–F	2.57	1	0.109
C–G	12.13	1	< 0.001*
D–E	1.45	1	0.228
D–F	0.55	1	0.458
D–G	14.62	1	< 0.001*
E–F	0.03	1	0.872
E–G	0.80	1	0.372
F–G	0.40	1	0.528

Note. A: Africa; B: Asia Pacific; C: East Asia; D: Europe/Eurasia; E: Latin America; F: Middle East/North Africa; G: North America

* = $p \leq 0.001$

Table 12

Pure-tone Screen Pass/Fail Results by Special Olympics Region

Region	Pass		Fail						Total no. screened
	Bilateral		Unilateral		Bilateral		Either		
A	8	(66.7%)	1	(8.3%)	3	(25.0%)	4	(33.3%)	12
B	19	(39.6%)	13	(27.1%)	16	(33.3%)	29	(60.4%)	48
C	12	(34.3%)	3	(8.6%)	20	(57.1%)	23	(65.7%)	35
D	74	(50.3%)	28	(19.0%)	45	(30.6%)	73	(49.7%)	147
E	25	(45.5%)	9	(16.4%)	21	(38.2%)	30	(54.5%)	55
F	10	(38.5%)	3	(11.5%)	13	(50.0%)	16	(61.5%)	26
G	223	(37.8%)	115	(19.5%)	252	(43.7%)	367	(62.2%)	590
All	371	(40.6%)	172	(18.8%)	370	(40.5%)	542	(59.4%)	913
M	53	(48.7%)	16	(15.2%)	26	(36.1%)	41	(51.3%)	94
SD	78	(13.1%)	19	(6.6%)	20	(13.6%)	39	(13.1%)	116

Note. A: Africa; B: Asia Pacific; C: East Asia; D: Europe/Eurasia; E: Latin America; F: Middle East/North Africa; G: North America

standard deviation of the mean except Africa, which lies below one standard deviation, and East Asia, which lies above one standard deviation. Of the four screening areas, pure-tone screen results demonstrated the least amount of differences between regions when chi-square analysis was performed [$\chi^2(6, N = 1450) = 12.63, p = 0.013$], thus resulting in statistically insignificant differences (see Table 13).

Screening Results According to Age

Four different age groups were created to determine if differences appeared between age groups. These age groups were 8–20 years, 21–35 years, 36– 50 years, and 51 years and older. The total number of athletes in each age group ranged from 541 athletes (21–35 year group) to 30 athletes (51+ years group). Demographic information regarding athlete gender and age according to region is presented in Figures 5–7. Figure 5 presents the number of males versus females by region. The greatest number of females were from the North America region and no females from the Middle East/North Africa region participated in the screenings. Figure 6 presents the number of athletes from each age group (8–20 years, 21–35 years, 36–50 years, and 51+ years) by region. The greatest number of athletes were between 21 and 35 years of age, with the 8 to 20 years group leading in five of the seven regions, and the fewest number of athletes were age 51 years and older. Figure 7 presents the number of athletes from each age group separated by sex according to region. The number of males per age group for each region was greater than the number of females for the same age group. Only two regions, East Asia and North America, had comparable amounts of females participating from each age group. Pass/fail results from each of the screening areas according to age group are noted in Table 14. A chi-square analysis of each age group by screening area is noted in Table 15.

Table 13

Chi-square Analysis of Differences Between Regional Pure-tone Screen Results

Region–Region	χ^2	*df*	*p*
A–B	0.98	1	0.322
A–C	3.06	1	0.080
A–D	0.70	1	0.404
A–E	1.07	1	0.301
A–F	2.10	1	0.148
A–G	2.98	1	0.084
B–C	0.84	1	0.360
B–D	0.12	1	0.733
B–E	0.05	1	0.830
B–F	0.27	1	0.603
B–G	0.62	1	0.433
C–D	2.91	1	0.088
C–E	1.00	1	0.318
C–F	0.00	1	0.992
C–G	0.22	1	0.643
D–E	0.17	1	0.677
D–F	1.31	1	0.252
D–G	6.56	1	0.010
E–F	0.33	1	0.567
E–G	0.87	1	0.351
F–G	0.00	1	0.999

Note. A: Africa; B: Asia Pacific; C: East Asia; D: Europe/Eurasia; E: Latin America; F: Middle East/North Africa; G: North America

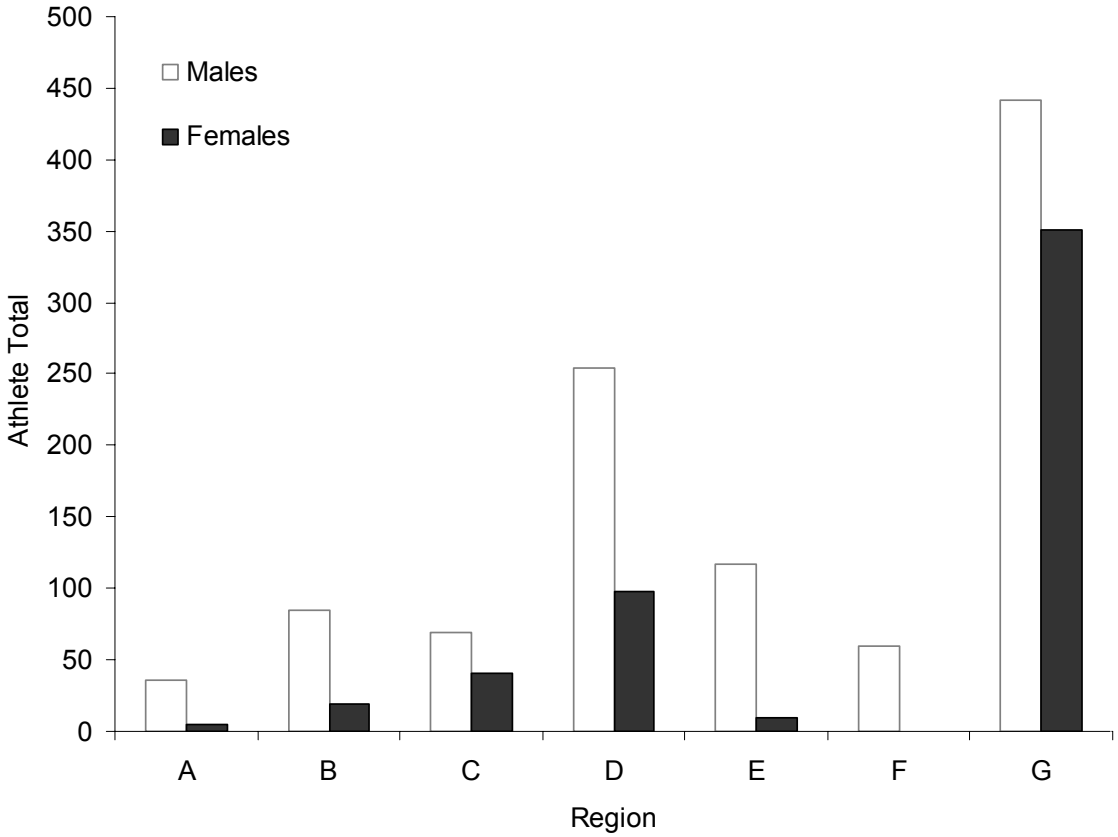

Figure 5. *Total number of athletes from each region according to athlete sex.*

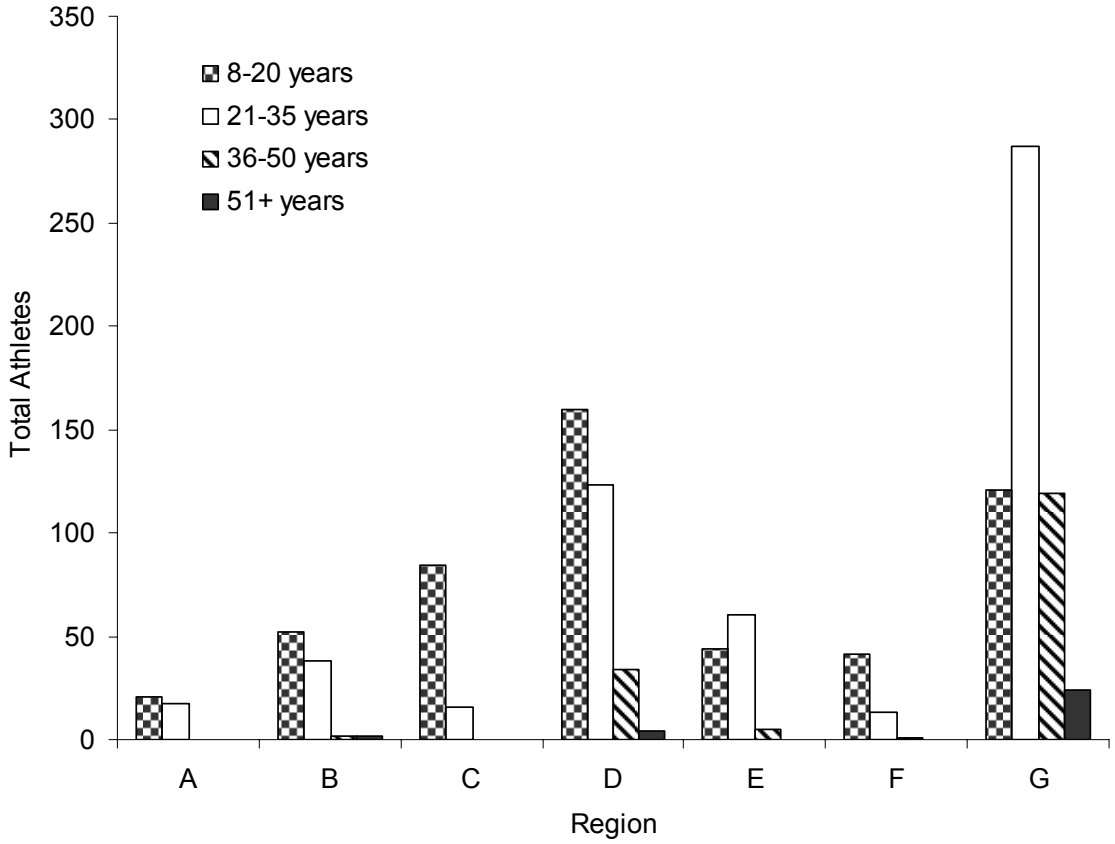

Figure 6. *Total number of athletes from each region according to athlete age in years.*

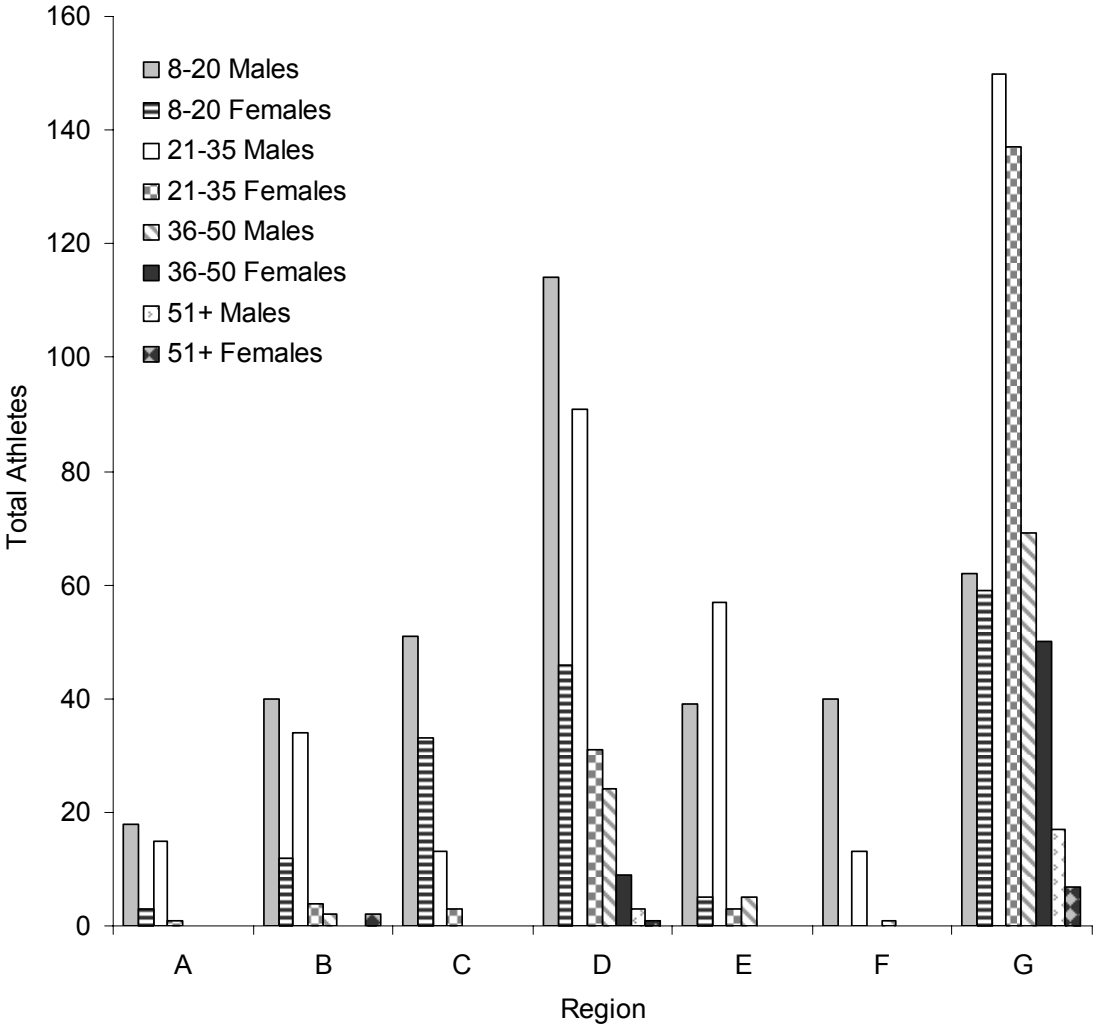

Figure 7. *Total number of athletes from each region according to athlete sex and age in years.*

Table 14

Screening Pass/Fail Results by Athlete Age

Screening Measure	8–20 years	21–35 years	36–50 years	51+ years	*M*	*SD*
Ear Canal Screen						
Pass	322 (62.9%)	319 (59.2%)	89 (56.0%)	16 (55.2%)	187	157.6
Fail	190 (37.1%)	220 (40.8%)	70 (44.0%)	13 (44.8%)	123	98.0
Total no.	512	539	159	29		
OAE						
Pass	319 (61.8%)	223 (41.2%)	36 (23.4%)	3 (10.0%)	145	151.0
Fail	197 (38.2%)	318 (58.8%)	118 (76.6%)	27 (90.0%)	165	123.4
Total no.	516	541	154	30		
Tympanometry						
Pass	93 (46.0%)	180 (54.7%)	71 (61.7%)	16 (64.0%)	90	68.2
Fail	109 (54.0%)	149 (45.3%)	44 (38.3%)	9 (36.0%)	78	63.0
Total no.	202	329	115	25		
Pure-tone Screen						
Pass	107 (60.1%)	137 (47.2%)	39 (34.2%)	5 (20.0%)	72	60.6
Fail	71 (39.9%)	153 (52.8%)	75 (65.8%)	20 (80.0%)	80	54.9
Total no.	268	290	114	25		

Table 15

Chi-square Analysis of Differences Between Age Group and Screening Results

Screening Area	Age, Age (in years)	χ^2	*df*	*p*
Ear Canal Screen				
	8–20, 21–35	1.37	1	0.243
	8–20, 36–50	2.16	1	0.141
	8–20, 51+	0.41	1	0.523
	21–35, 36–50	0.40	1	0.529
	21–35, 51+	0.06	1	0.815
	36–50, 51+	0.02	1	0.902
OAE				
	8–20, 21–35	44.05	1	< 0.001*
	8–20, 36–50	68.84	1	< 0.001*
	8–20, 51+	29.36	1	< 0.001*
	21–35, 36–50	15.57	1	< 0.001*
	21–35, 51+	10.32	1	< 0.001*
	36–50, 51+	1.95	1	0.163
Tympanometry				
	8–20, 21–35	3.43	1	0.064
	8–20, 36–50	6.62	1	0.010
	8–20, 51+	2.20	1	0.138
	21–35, 36–50	1.44	1	0.230
	21–35, 51+	0.48	1	0.489
	36–50, 51+	0.00	1	0.987
Pure-tone Screen				
	8–20, 21–35	6.82	1	0.009
	8–20, 36–50	17.63	1	< 0.001*
	8–20, 51+	12.69	1	< 0.001*
	21–35, 36–50	5.13	1	0.023
	21–35, 51+	5.84	1	0.016
	36–50, 51+	1.31	1	0.252

* = $p \leq 0.001$

Age-related ear canal screen results. Results from the ear canal screen show that the greatest percentage of athletes per age group who passed were in the 8–20 years group (62.9%). Results for the 36–50 years and 51+ years groups were within .8% of each other. Although the percentage of passing results per age group is declining, it is only a small amount. A chi-square test performed on this group demonstrated no significant differences between groups [$\chi^2(3, N = 1239) = 3.27, p = 0.476$].

Age-related OAE results. Results from the OAE screen show a significant declining in pass results as the athletes grow older (61.8% in 8–20 year group to 10% in 51+ year group). This declining is supported by a significant chi-square difference between groups [$\chi^2(3, N = 1239) = 89.42, p < 0.001$]. This difference is significant between all groups except the 36–50 year group and the 51+ year group.

Age-related tympanometry results. Results from the tympanometry screen demonstrate a small but steady increase in pass rate as athletes become older (46.0% in 8–20 year group to 64.0% in 51+ year group). This increase was not considered significant using a chi-square test between groups [$\chi^2(3, N = 1239) = 8.96, p = 0.038$].

Age-related pure-tone screen results. Pure-tone screen results demonstrate a similar trend to that of the OAE results. As the athletes become older, less athletes pass the screen (60.1% in 8–20 year group to 20.0% in 51+ year group). This difference between groups was considered statistically significant [$\chi^2(3, N = 1239) = 27.02, p < 0.001$]. The 8–20 year group compared to the 36–50 year and 51+ year groups was also statistically significant [$\chi^2(1, N = 399) = 17.63, p < 0.001$; $\chi^2(1, N = 203) = 12.69, p < 0.001$].

Discussion

Differences between Games

Utah Games

Results from the hearing screenings performed in Utah reveal some interesting facts. Noise and mechanical problems were the most apparent reasons for differences between the Utah games. Ambient noise affecting the OAE and pure-tone screens, caused significant problems. Another less apparent reason for differences is screener experience (i.e. student versus professional).

Summer 2004. Screening conditions for the Summer 2004 games were less than optimal for a few reasons: (a) the positioning of the screening station was in an outdoor tent near the intersection of two busy roads and (b) the screening station was placed near the entertainment stage for the Olympic Village. Although this setting may meet the needs for a public health screening, it does not meet typical audiometric standards for hearing screenings (Neumann et al., 2006). Other problems noted at the Summer 2004 games include using students, who, although briefly trained to use the equipment, did not have as much clinical experience as many of the screeners at the Fall 2004 Train-the-Trainer, or at the 2005 Nagano games. (The Train-the-Trainer was a Healthy Athletes training symposium where professionals from different health care disciplines learned to run their own Healthy Athletes screenings in their own countries or states.) This screening period also had the greatest number of athletes who were tested during two screening sessions during the same screening period. This stems from the use of a reward for the athletes coming to get their hearing tested (a massage from the local massage school). Although these results were counted twice, in some cases, these results also give

valuable information regarding testing difficulties (i.e. from noise) that may have occurred during one morning, but not have caused problems during another afternoon.

Fall 2004. Testing from the Fall 2004 games is the most consistent with the Fall 2005 and Nagano 2005 games, each for different reasons. The location of the Fall 2004 and Fall 2005 games was the same building, but not the same room. Many of the logistical placements (ear canal screen in the hall, OAE and tympanometry in the same room, and pure-tone screen in another neighboring room) for the Fall 2005 games were made because of placement decisions made during the Fall 2004 games. This same station placement made many results that are often affected by noise (i.e. OAE and pure-tone screen) or unaffected by noise (i.e. ear canal screen), consistent between the games. One advantage seen from a Healthy Athletes standpoint regarding this particular event was all of the Healthy Athlete areas (Healthy Hearing, Special Smiles, Opening Eyes, Fit Feet, FUNfitness, and Health Promotion) were represented at the Train-the-Trainer and testing was completed in multiple areas for multiple athletes. Having the presence of more experienced screeners to guide and be available for the student screeners' questions, and therefore gain more reliable results especially in the areas of ear canal screen and tympanometry, was also a helpful facet of this screening session. Another positive aspect of this screening period was that 98 athletes participated in a second screening. This allowed the researchers to do a number of things with the data: (a) determine which athletes were given a false "fail" due to noise and mechanical problems from the Summer 2004 Games, (b) track the presence of conductive hearing loss, and (c) follow the progression of athletes' SNHL for further follow-up after the testing period. For these reasons, this screening period was successful.

Fall 2005. As before mentioned, the Fall 2005 games were held in the same building as the Fall 2004 games with a very similar set-up for testing. Results from the Fall 2005 testing period are easily related to other testing periods (i.e. ear canal screen: Summer 2004 and Fall 2004, OAE: Fall 2004, tympanometry: Summer 2004, and pure-tone screen: Fall 2004). This screening period had the fewest number of athletes participating in screening because of two specific reasons: (a) many of the event venues were located far from Olympic Village and the Healthy Athlete screenings and (b) the presence of the screenings was not well communicated to the coaches before the games began.

Nagano 2005

The 2005 Nagano games reveal information for all seven regions and give specific differences between the health of Utah (USA) athletes in relation to athletes in the rest of the world. The most significant differences seen between these two groups are in relation to the tympanometry and pure-tone screening. The screening conditions in Nagano were more favorable than those at some of the Utah games. This may account for the great difference in pure-tone screen results between all Utah games and the Nagano 2005 games. Tympanometry results may be accounted for by screener experience, as only the Fall 2004 results were not statistically different from the Nagano 2005 results.

Comparison to Previous Healthy Hearing Results

Previous published conglomerate Healthy Hearing results estimate a 30% failure rate (Special Olympics, 2005). The current study found a comparable total fail rate of 31.1% (450/1450 athletes) when only complete data were used. This is the total screening failure rate. When the total fail rate with incomplete data included was calculated, 34.7%

(528/1521 athletes) failed the screening. This statistic indicates how many athletes truly need further follow-up. Interestingly, the fail rate found in the Summer 2004 games was more than twice the estimated fail rate (63.8%), the Fall 2004 games had a fail rate that was comparable to the published fail rate (32.4%), and the Nagano 2005 games had a fail rate that was quite smaller (18.7%). Few hearing screen results from previous Special Olympic games have been published, however, results from the May 2000 European games and summer 2004 German games are available (Montgomery, Herrer, & Willems, 2001; Neumann et al., 2006).

Europe 2000 games compared to total screening results. During the Europe 2000 games, 529 athletes from 61 countries were screened and a failure rate of 26.1% (pure-tone failure) was determined. When all complete results from the Utah games and Nagano 2005 games are compiled, the total failure rate is 31.1%. It was determined that differences between the two groups are not statistically significant by using a chi square test [$\chi^2(1, N = 1979) = 2.34, p = 0.126$]. A conductive hearing loss is suggested regarding those athletes who failed the screening and did not pass tympanometry (Europe 2000: 52.2%, compiled 2004 and 2005 games: 46.9%). Likewise, a sensorineural loss is suggested for those athletes who failed the screening and did not fail tympanometry (Europe 2000: 47.8%, compiled 2004 and 2005 games: 53.1%). The percentage of athletes passing the screen with a blocked or partially blocked ear canal was 34% at the combined 2004 and 2005 games versus 19% at the 2000 European Games. Both of these rates are alarmingly high for any group of people age 8 years and older (Montgomery et al., 2001).

Europe 2000 games compared to the Nagano 2005 games. The Nagano 2005 games, as an international event, allows for a more even comparison between regions than when all results from the 2004 and 2005 games are combined. When compared to the 2000 European Games, results from the Nagano games revealed a pass rate of 77.8% which was similar to the 2000 European games pass rate of 73.9% [$\chi^2(1, N = 1979) = 2.51, p = 0.113$]. The Nagano 2005 failure results reveal slightly more conductive losses (55.7% versus 52.2%) and slightly less sensorineural losses (44.3% versus 47.8%) when compared to the 2000 European results. Results from Nagano 2005 show a greater percentage of athletes passing the screen with a blocked or partially blocked ear canal (32.1%) versus the 2000 European Games (19%). These differences are consistent with the compiled 2004 and 2005 results (Montgomery et al., 2001).

German 2004 games compared to total screening results. The German 2004 games had a pure-tone failure rate of 38.0%. Although this failure rate is slightly greater than that of the estimated failure rate among Special Olympic athletes world wide, it is much greater than the fail rate of the Nagano 2005 games (18.7%) and fairly similar to the Fall 2004 and 2005 failure rates (32.4% and 42.0% respectively). Athletes at the German 2004 games were given the option of having cerumen removed and then continuing with the testing; 53.0% of the 755 athletes needed cerumen removed. Athletes at the Utah Games were not given that opportunity; 41.7% of these athletes needed failed the ear canal screen because of partially blocked or blocked ear canals. Overall, the percentage of athletes needing cerumen removal during the Summer 2004, Fall 2004 and 2005, and Nagano 2005 games was 38.8% (Neumann et al., 2006).

Differences between Regions

Testing Differences

Ear canal screen. Athletes tested during these games presented with an overall ear canal screen failure rate of 36.4%. Although this judgment of clear, partially blocked, or blocked is relatively subjective, screeners were trained to observe portions of the ear canal and tympanic membrane. A rating of partially blocked or blocked demonstrates increased cerumen production, impacted wax or foreign bodies, tympanic membrane problems, or possible hygiene issues that can be resolved with additional training for the athletes participating in Special Olympics and their families.

Otoacoustic emissions. The OAE mean failure rate is 42.1%. The use of OAEs to help determine both sensorineural and conductive hearing losses is very important. Although found to be very sensitive to noise problems in testing areas (as discussed regarding the Summer 2004 testing period), OAEs are a great tool for determining which athletes should and should not be tested further.

Tympanometry. For those athletes failing OAEs, tympanometry results reveal a mean failure rate of 53.4%. This has important implications regarding the presence of ear canal problems, otitis media (e.g. chronic, suppurative), and other related conductive hearing loss problems.

Pure-tone screen. Also comparable to the tympanometry results are the pure-tone screen results with a mean failure rate of 51.3%. These results, like the OAE screen, are sound intensity sensitive. The pure-tone screen results are the standard to which the athletes either pass or fail the entire screen.

Regional Hearing Loss Factors

Throughout the world, several causes of hearing loss affect specific regions differently. For example, in Africa (Smith A. & Hatcher, 1992) the top twelve factors that cause hearing impairment are (a) foreign bodies and impacted cerumen, (b) chronic otitis media (COM), (c) unknown congenital causes, (d) measles, meningitis (especially along the meningitis belt of equatorial Africa as seen in Gambia), (e) convulsions, (f) perinatal causes, (g) mumps, (h) ototoxic drugs, (i) noise induced hearing loss, and (j) cassava diet. In areas where these factors are of concern, certain measures can be taken to prevent additional hearing loss from occurring. Some countries are making immunizations more widely available for mumps, measles, and meningitis. In Gambia, this specific measure is expected to reduce burden of hearing loss in the country. Areas specifically noted as being a concern to Special Olympic athletes' hearing health were cerumen management problems, chronic otitis media, and noise induced hearing loss.

Cerumen blockages. Blocked or partially blocked ear canals are seen as a very prevalent and easily treated problem throughout the world. An example of this is the number of blocked or partially blocked ear canals seen in the Special Olympics athletes from the Latin America region compared to other children from the region. In a study conducted in Brazil regarding children ages 6 to 18 years, impacted cerumen was present in 12.3% of children and other ear canal abnormalities were present in 10.5% of children (Godinho et al., 2001). In comparison, the Latin America region athletes had ear canal screen failure rates of 31.5%. This region was statistically similar to all other regions except East Asia, which had an ear canal screen failure rate of 49.1%. When compared to the percentage of Nagano 2005 athletes who passed or failed the entire screening with a

blocked or partially blocked ear canal(s), the difference (36.7% versus 12.3%) is nearly three times as much. This difference may indicate a lack of healthcare for individuals with intellectual disabilities and specifically Special Olympics athletes worldwide.

Chronic otitis media. Chronic otitis media is a concern throughout the world. According to WHO (2000), COM affects many diverse regions of the world. Those with the highest prevalence of COM include Inuits (12–46%), Australian Aboriginals (12–25%), and Native Americans (4–8%; Caban, Lee, Gomez-Marin, Lam, & Zheng, 2005). The lowest prevalence of COM is the US and UK with <1%. In Brazil, the prevalence of COM was 0.94%, however, 8.3% of the children had a history of COM. This prevalence rate is comparable to those also found in Korea, India, and Saudi Arabia (Godinho et al., 2001; WHO, 2000). Although the prevalence of COM may be lower in some regions compared to other regions, its effects are often long lasting in the form of speech and language problems and significant, more permanent hearing loss (Laws, 2004). Risk factors named by WHO include overcrowding, poor hygiene, poor nutrition, passive smoking, and unavailable/inadequate healthcare. These are factors seen throughout the world and affect many people with intellectual disabilities, often because those with intellectual disabilities have a poor quality of life (WHO, 2000).

When compared to tympanometry results from the seven regions, the total failure rate was 44.7%. This rate can reflect middle ear pathology involvement in almost half of the athletes participating in Special Olympics. These figures are comparable to those populations in the world with a very high risk for developing COM (Inuits and Australian Aboriginals). All regions except North America (38.2%) had failure rates near or greater

than that of the highest single population failure rate (46%; Caban et al., 2005; WHO, 2000).

Noise induced hearing loss. Noise induced hearing loss is becoming a greater concern in regions throughout the world as more countries are becoming more industrialized. In a report from WHO (1997), awareness of the dangers of noise induced hearing loss is low. Occupational noise limitations have been set in many nations, but are not always thoroughly regulated. Some developed countries surveyed have a policy of 90 dB A or less for their maximum noise exposure levels and encourage the use of ear protection or other conservation strategies (e.g. US, Canada, Thailand, and Japan). Areas of Europe have created hearing conservation programs to reduce occupational and environmental noise levels. Other areas have recorded problems with noise induced hearing loss and high noise levels in factory-like occupations (Pakistan, Egypt, Ghana, Kenya, Nigeria, South Africa, Swaziland, Tanzania, Cote d'Ivoire, Zimbabwe, and India). Although more groups of people are becoming aware of noise-induced hearing loss, it is a concern that individuals with intellectual disabilities, who are often placed in work or recreation conditions with high noise levels, are not receiving the education they need to protect their hearing.

Differences between Age Groups

Results from the different screening measures demonstrate a few ideas regarding the intellectually disabled population: (a) ear canal health worsens only a small amount with age; (b) middle ear health and conductive losses due to middle ear involvement decrease slightly with age; and (c) hearing sensitivity, as determined through pure-tone

screening measures, decreases with age in a comparable manner to that of the normal population, but at an increased rate.

Conductive and Mixed Hearing Loss

Cerumen management. Impacted cerumen is a problem in approximately 2–6% of the general population (Brownson, 2000). Some researchers have found an incidence of 28% in the intellectually disabled adult population (Crandell & Roeser, 1993). Across all ages, 39.8% of Special Olympic athletes, whose age was known, had partially blocked or blocked ear canals. This result is approximately 6 to 20 times more than the general population and still greater than published estimates for individuals with intellectual disabilities. When comparing Down syndrome children to other intellectually disabled children ages 5–14 years, Dahle & McCollister (1986) found a prevalence of 83% versus 59% of ear canal abnormalities or cerumen problems. Current results for athletes aged 8–20 years having cerumen management problems were 37.1%, which is slightly lower than published results, but may also be explained by the slightly older population. Additionally, other prevalence statistics of ear canal abnormalities or cerumen problems for individuals with Down syndrome found a prevalence rate of 38.6% for middle-aged individuals (Evenhuis, van Zanten, Brocaar, & Roerdinkholder, 1992). For athletes ages 21–50, cerumen management problems or ear canal abnormalities were present in 41.5% of athletes. Although this result includes athletes having intellectual disabilities other than Down syndrome, this result is comparable to Evenhuis et al. (1992) which includes only Down syndrome individuals. The trend in slight increase of cerumen management problems with age seen in these results differs from the trend presented in the literature, which demonstrates a decrease in cerumen management difficulties as individuals age.

However, these rates for the intellectually disabled population are very high compared to the general population. For this reason, many researchers recommend that otoscopy should be performed once a year on individuals with an intellectual disability and twice a year specifically on individuals with Down syndrome to determine if cerumen removal is needed for adequate ear canal hygiene (Crandell & Roeser, 1993; Evenhuis, 1995; Evenhuis, Mul, Lemaire, & de Wijs, 1997; Neumann et al., 2006).

Middle-ear pathology. Tympanometry has become a helpful tool in determining the presence of conductive pathologies in people. Specifically, in testing individuals with intellectual disabilities, it uses an objective measure (pressure and compliance) to determine presence of conductive pathologies. Results from the current study demonstrated a mild decrease in middle ear pathology, as determined by abnormal tympanogram, as athletes aged. This trend is demonstrated in the literature for both individuals with Down syndrome and other intellectual disabilities.

Dahle and McCollister (1986) found 24 of the 27 children with Down syndrome (89%), ages 5 to 14 years, had abnormal tympanograms and only 13 of the 29 (45%) children with other intellectual disabilities of the same age range had abnormal tympanograms. The Down syndrome children demonstrated conductive or mixed losses in 46.2% of ears versus the children with other intellectual disabilities who exhibited conductive and mixed losses in 7.4% of ears. Hildmann, Hildmann, and Kessler (2002) found a prevalence rate of 88% for conductive hearing loss and a 7% rate of mixed hearing loss among Down syndrome children, 32 of which were under two years old. Hassmann, Skotnicka, Midro, and Musiatowicz (1998) found similar rates of abnormal tympanograms in Down syndrome children ages 3–10 years (89%). 54% of athletes in the

current study ages 8–20 were found to have abnormal tympanograms. This difference in rates could be attributed to the age difference between the groups and the mixture of athletes with and without Down syndrome. In the same study by Hassmann et al. (1998), an adult group of Down syndrome individuals ages 17–37 years abnormal tympanograms were found for 32.1% of ears tested. Athletes ages 20–35 years had a tympanometry failure rate of 45.3%, which is greater than that published by Hassmann et al. Evenhuis et al. (1992) found an increased abnormal tympanogram prevalence of 47.1% among ears of individuals with Down syndrome ages 35 to 62 years. This specific group with abnormal tympanograms was also found to have cochlear or mixed losses in 32.9% of the ears tested using brainstem evoked response audiometry. Athletes ages 36–50 years (both those with and without Down syndrome) had a slightly lower prevalence of abnormal tympanogram results (38.3%) than that of the group of individuals with Down syndrome mentioned in Evenhuis et al (47.1%). In non-Down syndrome individuals over age 60, a prevalence of abnormal tympanogram type was found in 24.6% of individuals including a conductive component to a mixed hearing loss (presbycusis) also being present (Evenhuis, 1995). The current study found a slightly greater prevalence of 36.0% among athletes over 50 years of age.

Sensorineural Hearing Loss

Athletes demonstrated between a 38.2% (8–20 years) and 90.0% (51+ years) fail rate for OAEs and a 39.9% (8–20 years) and 80.0% (51+ years) fail rate for pure-tone screen. According to current Healthy Hearing estimates, failure rates of 25% were found for athletes ages 8–17 years, 50% for athletes ages 35–50 years, and 70% for athletes

ages 51–70 years (Special Olympics, 2005). These estimates are approximately 13.6% lower, on average, for each age group compared to that found in the current study.

This problem of decreased hearing sensitivity in the Special Olympic athletes is more than double that of current hearing loss prevalence estimates in the US. In the US, hearing impairment prevalence is estimated to range from 1.1% to 3.5% for children ages 0–17 (Boyle et al., 1994; Boyle et al., 1996), 4.6% to 7.1% for individuals 18–44 years, 14% to 19.3% for individuals 45–64 years, and 54% to 88% for individuals 65 years and older (ASHA, n.d.; Caban et al., 2005). When percentages for athletes ages 18–50 years are combined, a total of 42.1% for pure-tone screen failures is found. This increase in prevalence is six to ten times as much as that of the normal population.

In the intellectually disabled population, Brannan, Sigelman, and Bensberg (1975) found approximately 69.3% of residents 18 and older were "hard of hearing" and 60.4% of residents also 18 and older were "deaf." Cooke (1988) found hearing impairment rates between 22.4% and 31.5%. Buchanan (1990) demonstrated an early onset of presbycusis in the Down syndrome population starting between ages 21–30 years and in the non-syndrome population in the 41–50 years group. This early onset of presbycusis may be partially responsible for the average increase of 13.4% per age group in pure-tone fail rate demonstrated in athletes over age 21 years.

Conclusion

Special Olympics, Inc. stated in the document, "Promoting Health for Persons with Mental Retardation – A Critical Journey Barely Begun" that individuals with an intellectual disability are more likely to suffer from a wide range of acute and chronic diseases. These ailments are often more severe than those of the normal population

(2001). The comprehension for the need to get medical care is not always present in individuals with intellectual disabilities and the responsibility lies on their caregivers. Often the opinion of the caregiver regarding the actual health status of the intellectually disabled is far from the mark This was demonstrated by UK researchers Kerr et al. (2003) who found that caregivers who believed, through observation, that 74% of the individuals tested had perfect hearing. Only 11% of individuals actually had perfect hearing in a group of 589 intellectually disabled individuals ranging from 14 to 93 years of age. Those with intellectual disabilities are more likely to receive poor health care was also demonstrated in a group of 70 intellectually disabled individuals in the UK. Half of the individuals had seen their general practitioner once or not at all during the past year. Only five individuals had had their hearing tested in the last five years. Three individuals, none of which had Down syndrome, wore hearing aids, and two of these individuals needed new hearing aids fitted. Additionally, 33 of the 70 individuals had impacted cerumen which totally obstructed the view of the tympanic membrane in one or both ears (Wilson & Haire, 1990). The need for special medical care for individuals with intellectual disabilities is dire.

Currently, little is known regarding the true prevalence of hearing loss among the intellectually disabled population of the world. This study gives a portion of information regarding the prevalence of hearing loss among Utah Special Olympic athletes and only a glimpse of information about Special Olympic athletes' hearing health worldwide. The athletes participating in the Utah games had a higher overall failure rate than those of the Nagano games. This may be a difference of athlete origin, testing conditions, or other factors regarding demographics such as age, gender, or cognitive abilities. It is unknown

if this same difference would also be found when comparing the Utah games results with those of other US delegations. More information is needed to determine (a) the causes of identified hearing loss (i.e. cerumen blockages, middle ear pathology, noise-induced, or congenital hearing loss) among Special Olympic athletes and individuals with intellectual disabilities; (b) solutions for better communication of referrals to coaches and care givers to ensure more follow-up is sought; (c) the follow-up being performed once the athletes have their hearing examined; (d) the steps being taken to educate athletes regarding hearing acuity preservation; (e) improvements for testing conditions in order to gain more reliable results during screenings; and (f) the differences in prevalence according to region or delegation.

Although it has been found between this and other Healthy Hearing studies (Montgomery et al., 2001; Neumann et al., 2006) that an estimated 30% of the intellectually disabled population tested have some hearing impairment, this rate is alarmingly high compared to the general population. Considering cerumen management problems (partially blocked or blocked ear canals) were prevalent among athletes participating in all four games and from all seven regions, it is advised that future screenings include an optional re-screen after cerumen removal to investigate the effects of this factor on screening results (Neumann et al., 2006). Recommendations for further study or program implementation include: (a) measuring and controlling for noise interference during testing to reduce the number of false positive failures, (b) additional information regarding athlete hearing aid status at the time of screening and the number of athletes referred for hearing aid usage, (c) development of a brochure/information sheet which would further educate coaches, care givers, and athletes regarding hearing

loss prevention and treatment, (d) a more established follow-up system to ensure that athletes are seeking and receiving the follow-up care recommended during screening, and (e) determine the actual prevalence of hearing loss in the athletes through a follow-up study which allows for more controlled testing conditions such as a sound treated room.

Findings from this and other studies demonstrate the crucial need for the intellectually disabled population to have additional health care attention in the areas of cerumen management and hearing acuity preservation. It is the responsibility of health care providers to use their knowledge to raise the quality of life for those who cannot afford to or gain access to health care because of their intellectual disability.

References

American Speech-Language-Hearing Association. (n.d.). The prevalence and incidence of hearing loss in adults. Retrieved March 14, 2005, from http://www.asha.org/public/hearing/disorders/prevalence_adults.htm

American Speech-Language-Hearing Association Audiologic Assessment Panel 1996. (1997). Guidelines for audiologic screening (pp. 333–382). Rockville, MD: Author.

American Speech-Language-Hearing Association. (1978). Guidelines for manual pure-tone threshold audiometry. *Asha, 20*, 291–301.

Boyle, C. A., Decoufle, P., & Yeargin-Allsopp, M. (1994). Prevalence and health impact of developmental disabilities in US children. *Pediatrics, 93*, 399–403.

Boyle, C. A., Yeargin-Allsopp, M., Doernberg, N. S., Holmgreen, P., Murphy, C. C., & Schendel, D. E. (1996). Prevalence of selected developmental disabilities in children 3-10 years of age: the Metropolitan Atlanta Developmental Disabilities Surveillance Program, 1991. *Morbidity and Mortality Weekly Report CDC Surveillance Summaries, 45*(2), 1–14.

Brannan, A. C., Sigelman, C., & Bensberg, G. J. (1975). The hearing impaired in state institutions for the retarded: II. Services and programs. *American Annals of the Deaf, 120*, 502–508.

Brownson, P. J. (2000, 4 Feb 2000). Cerumen Management. Retrieved 17 Oct 2005, from http://www.caohc.org/updatearticles/winter2000/cerumen.html

Buchanan, L. H. (1990). Early onset of presbycusis in Down syndrome. *Scandinavian Audiology, 19*, 103–110.

Caban, A. J., Lee, D. J., Gomez-Marin, O., Lam, B. L., & Zheng, D. D. (2005). Prevalence of concurrent hearing and visual impairment in US adults: The National Health Interview Survey, 1997-2002. *American Journal of Public Health, 95*, 1940–1942.

Church, M. W., & Abel, E. L. (1998). Fetal alcohol syndrome. Hearing, speech, language, and vestibular disorders. *Obstetrics and Gynecology Clinics of North America, 25*(1), 85–97.

Church, M. W., Eldis, F., Blakley, B. W., & Bawle, E. V. (1997). Hearing, language, speech, vestibular, and dentofacial disorders in fetal alcohol syndrome. *Alcoholism: Clinical and Experimental Research, 21*, 227–237.

Church, M. W., & Gerkin, K. P. (1988). Hearing disorders in children with fetal alcohol syndrome: findings from case reports. *Pediatrics, 82*, 147–154.

Cooke, L. B. (1988). Hearing loss in the mentally handicapped. A study of its prevalence and association with ageing. *The British Journal of Mental Subnormality, 34*, 112–116.

Crandell, C. C., & Roeser, R. J. (1993). Incidence of excessive/impacted cerumen in individuals with mental retardation: a longitudinal investigation. *American Journal of Mental Retardation, 97*, 568–574.

Dahle, A. J., & McCollister, F. P. (1986). Hearing and otologic disorders in children with Down syndrome. *American Journal of Mental Deficiency, 90*, 636–642.

Evenhuis, H. M. (1995). Medical aspects of ageing in a population with intellectual disability: II. Hearing impairment. *Journal of Intellectual Disability Research, 39*, 27–33.

Evenhuis, H. M. (1996). Dutch consensus on diagnosis and treatment of hearing impairment in children and adults with intellectual disability. The Consensus Committee. *Journal of Intellectual Disability Research, 40*, 451–456.

Evenhuis, H. M., Mul, M., Lemaire, E. K., & de Wijs, J. P. (1997). Diagnosis of sensory impairment in people with intellectual disability in general practice. *Journal of Intellectual Disability Research, 41*, 422–429.

Evenhuis, H. M., Theunissen, M., Denkers, I., Verschuure, H., & Kemme, H. (2001). Prevalence of visual and hearing impairment in a Dutch institutionalized population with intellectual disability. *Journal of Intellectual Disability Research, 45*, 457–464.

Evenhuis, H. M., van Zanten, G. A., Brocaar, M. P., & Roerdinkholder, W. H. (1992). Hearing loss in middle-age persons with Down syndrome. *American Journal of Mental Retardation, 97*, 47–56.

Ginsberg, I. A., & White, T. P. (1994). Otologic disorders and examination. In J. Katz (Ed.), *Handbook of clinical audiology* (pp. 6-24). Baltimore: Williams & Wilkins.

Godinho, R. N., Goncalves, T. M., Nunes, F. B., Becker, C. G., Becker, H. M., Guimaraes, R. E., et al. (2001). Prevalence and impact of chronic otitis media in school age children in Brazil. First epidemiologic study concerning chronic otitis media in Latin America. *International Journal of Pediatric Otorhinolaryngology, 61*, 223–232.

Grason-Stadler, Incorporated. (1996). GSI-37 Auto-Tymp Instruction manual 1737-0100, Rev. 4.

Griffiths, P. D., & Walter, S. (2005). Cytomegalovirus. *Current Opinion in Infectious Diseases, 18*, 241–245.

Hassmann, E., Skotnicka, B., Midro, A. T., & Musiatowicz, M. (1998). Distortion products otoacoustic emissions in diagnosis of hearing loss in Down syndrome. *International Journal of Pediatric Otorhinolaryngology, 45*, 199–206.

Herer, G. R., & Montgomery, J. (2001). *Special Olympics, Incorporated Healthy Hearing program guidelines for standardized screening procedures* (1st ed.). Washington, D.C.: Special Olympics, Inc.

Hildmann, A., Hildmann, H., & Kessler, A. (2002). Hearing disorders in children with Down syndrome. *Laryngo-Rhino-Otologie, 81*, 3–7.

Iino, Y., Imamura, Y., Harigai, S., & Tanaka, Y. (1999). Efficacy of tympanostomy tube insertion for otitis media with effusion in children with Down syndrome. *International Journal of Pediatric Otorhinolaryngology, 49*, 143–149.

Jordan, J. A., & Roland, P. S. (2000). Disorders of the auditory system. In R. J. Roeser, M. Valente & H. Hosford-Dunn (Ed.), *Audiology diagnosis* (pp. 85-108). New York: Thieme.

Kanamori, G., Witter, M., Brown, J., & Williams-Smith, L. (2000). Otolaryngologic manifestations of Down syndrome. *Otolaryngology Clinics of North America, 33*, 1285–1292.

Kerr, A. M., McCulloch, D., Oliver, K., McLean, B., Coleman, E., Law, T., et al. (2003). Medical needs of people with intellectual disability require regular reassessment, and the provision of client- and carer-held reports. *Journal of Intellectual Disability Research, 47*, 134–145.

Laws, G. (2004). Contributions of phonological memory, language comprehension and hearing to the expressive language of adolescents and young adults with Down syndrome. *Journal of Child Psychology and Psychiatry, 45*, 1085–1095.

Lewis, D. D., & Woods, S. E. (1994). Fetal alcohol syndrome. *American Family Physician, 50*, 1025–1032.

Martin, F. N., & Clark, J. G. (2003). *Introduction to audiology* (8th ed.). Boston: Allyn & Bacon.

Mazzoni, D. S., Ackley, R. S., & Nash, D. J. (1994). Abnormal pinna type and hearing loss correlations in Down's syndrome. *Journal of Intellectual Disability Research, 38*, 549–560.

Montgomery, J., Herrer, G., & Willems, M. (2001). The hearings status of athletes in Special Olympics program. *Audiology Today, 13*, 46–47.

Neumann, K., Dettmer, G., Euler, H. A., Giebel, A., Gross, M., Herrer, G., et al. (2006). Auditory status of persons with intellectual disability at the German Special Olympic Games. *International Journal of Audiology, 45*, 83–90.

Northern, J., & Downs, M. P. (2002). *Hearing in children* (5th ed.). Baltimore: Lippincott Williams & Wilkins.

Norton, S. J., & Stover, L. J. (1994). Otoacoustic emissions: An emerging clinical tool. In J. Katz (Ed.), *Handbook of clinical audiology* (pp. 448-462). Baltimore: Williams & Wilkins.

Pass, R. F. (2005). Congenital cytomegalovirus infection and hearing loss. *Herpes, 12*(2), 50–55.

Pulsifer, M. B. (1996). The neuropsychology of mental retardation. *Journal of the International Neuropsychological Society, 2*, 159–176.

Robinette, M. S., & Glattke, T. J. (2000). Otoacoustic emissions. In R. J. Roeser, M. Valente & H. Hosford-Dunn (Eds.), *Audiology diagnosis* (pp. 503–526). New York: Thieme.

Roeser, R. J., Buckley, K. A., & Stickney, G.S. (2000). Pure-tone tests. In R. J. Roeser, M. Valente & H. Hosford-Dunn (Eds.), *Audiology diagnosis* (pp. 227–251). New York: Thieme.

Roizen, N. J. (1996). Down syndrome and associated medical disorders. *Mental Retardation and Developmental Disabilities Research Reviews, 2*, 85–89.

Rossig, C., Wasser, S., & Oppermann, P. (1994). Audiologic manifestations in fetal alcohol syndrome assessed by brainstem auditory-evoked potentials. *Neuropediatrics, 25*, 245–249.

Shott, S. R. (2000). Down syndrome: Common pediatric ear, nose, and throat problems. *Down Syndrome Quarterly, 5*(2), 1-6.

Shott, S. R., Joseph, A., & Heithaus, D. (2001). Hearing loss in children with Down syndrome. *International Journal of Pediatric Otorhinolaryngology, 61*, 199–205.

Smith, A., & Hatcher, J. (1992). Preventing deafness in Africa's children. *Africa Health, 15*(1), 33–35.

Smith, D. S. (2001). Health care management of adults with Down syndrome. *American Family Physician, 64*, 1031–1038.

Special Olympics, Inc. (2001). *Promoting health for persons with mental retardation – A critical journey barely begun*. Washington, D. C.: Special Olympics, Inc.

Special Olympics, Inc. (2005). *Changing attitudes changing the world: The health and healthcare of people with intellectual disabilities*. Washington, D. C.: Author.

Special Olympics, Inc. (n.d.). Eligibility. Retrieved March 19, 2005, from http://www.specialolympics.org/Special+Olympics+Public+Website/English/Compete/Eligibility/default.htm

Special Olympics, Inc. (n.d.). Healthy Athletes. Retrieved April 9, 2005, from http://www.specialolympics.org/Special+Olympics+Public+Website/English/Initiatives/Healthy_Athletes/default.htm

Special Olympics, Inc. (n.d.). Healthy Hearing. Retrieved March 23, 2005, from http://www.specialolympics.org/Special+Olympics+Public+Website/English/Initiatives/Healthy_Athletes/Healthy+Hearing.htm

Special Olympics, Inc. (n.d.). History. Retrieved April 20, 2005, from http://www.specialolympics.org/Special+Olympics+Public+Website/English/About_Us/History/default.htm

Special Olympics, Inc. (n.d.). Program Locator. Retrieved 11 March 2006, from http://www.specialolympics.org/Special+Olympics+Public+Website/English/Program_Locator/default.htm

Stedman's medical dictionary for the health professions and nursing. (5th ed.). (2005). Baltimore: Lippincott Williams & Wilkins.

Van Allen, M. I., Fung, J., & Jurenka, S. B. (1999). Health care concerns and guidelines for adults with Down syndrome. *American Journal of Medical Genetics, 89*, 100–110.

Van Buggenhout, G. J., Trommelen, J. C., Schoenmaker, A., De Bal, C., Verbeek, J. J., Smeets, D. F., et al. (1999). Down syndrome in a population of elderly mentally retarded patients: Genetic-diagnostic survey and implications for medical care. *American Journal of Medical Genetics, 85*, 376–384.

Van Naarden, K., Decoufle, P., & Caldwell, K. (1999). Prevalence and characteristics of children with serious hearing impairment in metropolitan Atlanta, 1991-1993. *Pediatrics, 103*, 570–575.

Wilson, D. N., & Haire, A. (1990). Health care screening for people with mental handicap living in the community. *British Medical Journal, 301*, 1379–1381.

World Health Organization. (1997). *Prevention of noise-induced hearing loss: Report of a WHO-PDH informal consultation*. Geneva: Author.

World Health Organization. (2000). *Prevention of hearing impairment from chronic otitis media: Report of a WHO/CIBA Foundation workshop*. London: Author.

World Health Organization. (2001). Mental and neurological disorders (Fact sheet no. 265). Retrieved March 25, 2005, from http://www.who.int/mediacentre/factsheets/fs265/en/

Appendix A

Index of Hearing Disorders Associated with Intellectual Impairment (Adapted from Northern & Downs, 2002 p. 377–394).

Disorder Name	Characteristics
Achondroplasia	Skeletal anomaly associated with short stature. Mentality can be normal but is often impaired due to hydrocephalus. Hearing impairment including conductive or sensorineural losses may be included. Physiologic aspects which cause hearing impairments include fused ossicles and a high incidence of otitis media in the middle ear and malformations of the cochlea in the inner ear.
Albers-Schönberg Disease of Osteoporosis	Craniofacial and skeletal disorder whose recessive form is associated with deafness. Intellectual impairment occurs in 20% of individuals. About 20-50% of individuals have a mild to moderate, progressive sensorineural or conductive hearing loss.
Apert Syndrome	Congenital disorder with exhibition of craniofacial malformations with fusion of toes and fingers (syndactyly), spina bifida, and intellectual impairment. Physiologic anomalies of the auditory system include conductive hearing loss due to stapedial footplate fixation, abnormal patency of the cochlear aqueduct and a large internal auditory meatus.
Cerebral Palsy	Recessive trait with occurrence of 1 in 330 babies born. Paralysis occurs due to lesion or defect in brain during development. Other motoric functions are often impaired due to spasticity, athetosis, or ataxia. Intellectual impairment is common and a mild to moderate hearing loss with increasing severity in the high frequencies often accompanies the disorder.
Cockayne's Syndrome	A rare recessive disorder often characterized by dwarfism, intellectual disability, retinal atrophy, and motor difficulties. Progressive moderate to severe sensorineural hearing loss and blindness later in life are also attributed to the disorder.
Cornelia de Lange	A multifactor disorder that is characterized by presence of

Syndrome	severe to profound growth slowing and intellectual disability. Other complications include microcephaly, external ear anomalies with low set auricles, small external auditory canals and possible heart defects and cleft palate. Conductive, sensorineural, and mixed hearing losses are common in this disorder.
Crouzon's Syndrome	Individuals with this disorder have an abnormally prominent central portion of the forehead with premature closure of the cranial sutures also causing some malformation of the skull. Intellectual disability may be present if increased intracranial pressure causes damage. Auricles may be low-set with the following effects on the auditory system: conductive or mixed hearing loss, absent tympanic membrane, deformed stapes, deformation and stenosis of the middle ear cavity, bilateral atresia, and narrow or atretic external auditory canal.
Cytomegalovirus (CMV) Disease	This disease is virus driven and causes more than 6000 cases of sensorineural hearing loss per year. About 10–15% of infants infected with the virus will exhibit signs such as intellectual disability, coordination problems, and hearing loss.
Down Syndrome	Genetic disorder causing trisomy, translocation trisomy, or mosaicism on the 21st chromosome occurring in 1 of 700 births. Intellectual disability occurs is almost all individuals with the disorder. Other physiologic manifestations include flattened nose bridge, and short limbs and fingers. The auditory system is affected with congenital hearing loss (sensorineural, conductive, and mixed losses), small auricles, stenotic external ear canals, recurrent otitis media, and ossicular malformations.
Fetal Alcohol Syndrome (FAS)	This disorder is caused by alcohol abuse during pregnancy and has an occurrence of 1 in 500 births. Complications associated with this disease are cardiac and eye problems with the presence of craniofacial malformations in the form of cleft palate, abnormal auricles, and hearing loss.
Hallgren Syndrome	This eye disorder is similar to Usher's syndrome and is characterized by a congenital sensorineural hearing loss, which develops into profound deafness in 90% of individuals. Other symptoms found in about 25% of individuals are retinitis pigmentosa, progressive ataxia, and intellectual disability.

Hurler's Syndrome-Hunter's Syndrome	Genetic diseases (autosomal recessive and X-linked recessive, respectively) causing marked growth slowing, intellectual disability, joint stiffness, and chronic nasal excretions. Progressive deafness often occurs in Hurler's syndrome, while in Hunter's syndrome nearly half of affected individuals have a mixed loss. Both diseases are prone to eustachian tube dysfunction and serous otitis media.
Laurence-Moon-Biedl-Bardet Syndrome	Recessively inherited eye disease with progressive sensorineural hearing loss and intellectual disability. Other slight differences occur between Laurence-Moon syndrome and Biedl-Bardet syndrome.
Long Arm 18 Deletion Syndrome	A birth defect caused by a partial deletion of the long arm on chromosome 18 characterized by intellectual disability; microcephaly; congenital heart, spine, and kidney problems; foot anomalies; abnormal facial structure; and alterations to the retina. The auricle and external auditory canals can be malformed which often causes a conductive hearing loss. In addition to these difficulties, exhibition of a collapsed Reissner's membrane in all cochlear turns and a retracted tectorial membrane may occur.
Möbius Syndrome	The disorder is passed through dominant inheritance and creates bilateral facial paralysis of cranial nerve VI and VII. Common attributes include micrognathia; missing hands, feet, or digits; paralysis of the tongue; intellectual disability; and malformation of the auricle with other anomalies of the middle ear present. This disorder may cause congenital sensorineural or conductive hearing loss due to the problems associated with the paralysis of cranial nerve VII.
Norrie's Syndrome	X-linked recessive disorder that leads to eventual blindness through eye degeneration. Two thirds of individuals with this disorder have some type of intellectual impairment (mild to severe). A late-onset progressive bilateral sensorineural hearing loss is often present.
Oral-Facial Digital (OFD) Syndrome	A recessive disorder causing anomalies of the face, hands, and mouth. Some oral malformations may cause a conductive hearing loss in addition to malformed ossicles.

	Approximately 40% of individuals with this disorder have some type of intellectual disability.
Otopalatodigital Syndrome (OPD I and II)	An X-linked recessive disorder which causes facial and bone malformations. Anomalies include cleft palate; wide nasal bridge; small and low-set auricles; and downward slanting eyes and smile. Presence of mild intellectual impairment in addition to a conductive hearing loss associated with ossicular malformations is possible.
Pierre Robin Sequence	Dominant genetic disorder causing craniofacial skeletal malformations. Characterized by cleft palate, micrognathia, and tongue displacement. Auricles may be low-set with additional congenital conductive or sensorineural loss. Approximately 20% of individuals have an intellectual disability.
Richards-Rundle Syndrome	A recessive trait causing a nervous system disorder. This creates ataxia with muscle atrophy. Progressive, severe intellectual disability and progressive, severe, early-onset sensorineural hearing loss also are exhibited.
Rubella, Congenital	Sensorineural hearing loss, congenital heart problems, and vision problems are associated with this disease. Hearing loss in this disease is caused by inner, middle, and outer ear abnormalities. This disorder can also include such problems as low birth weight, jaundice, anemia, pneumonia, meningitis, encephalitis, dental anomalies, and microcephaly. Intellectual disability is seen in nearly 40% of individuals with the disease.
Telfer Syndrome	Form of dominant piebaldism characterized by ataxia; sensorineural hearing loss, 60% of which is progressive; and intellectual impairment.
Treacher Collins Syndrome	An autosomal dominant disorder which does not always exhibit traits but causes major malformations of structures in the first branchial arch. The facial structure and auricles show significant anomalies. Other affected areas of the auditory system include an atretic external ear and an underdeveloped middle ear encasing deformed ossicles. Hearing loss in this disorder is usually conductive, but sensorineural losses may be included. Intellectual disability is included in only 5% of individuals with the disorder.

Trisomy 13–15 Syndrome	This disorder is characterized by a cleft lip and palate, microphthalmia, and polydactyly. Intellectual impairment and hearing impairment are common with many other characteristics affecting numerous other areas of the body. Possible auditory system anomalies include low-set auricles, deformed auricles, malformation of the stapedial footplate, absence of the stapedius muscle, and anomalies in the inner ear affecting areas of the cochlea and semicircular canals.
Trisomy 18 Syndrome	Chromosomal defect which causes appearance of infants with signs of "failure to thrive." Numerous bone anomalies affecting the skeleton, cleft-lip and palate, deformed auricles and atretic external ear canal, and profound intellectual disability are common in this disorder. Middle ear anomalies include numerous ossicle malformations and muscle deformations. The inner ear and nerves associated with the auditory system can also show malformations.
Usher Syndrome	A recessive disorder in which progressive blindness and sensorineural hearing loss are hallmarks. Possible concomitant problems include intellectual disability, vertigo, and epilepsy. Approximately 3–10% of profoundly deaf children have this disorder. Severity of sensorineural hearing loss ranges from moderate to profound.

Appendix B

List of participating countries in the seven Special Olympics regions with number of athletes participating per country.

Table 1

Africa and its comprising delegations with total number of athletes participating in Nagano 2005 hearing screenings.

Region	Country/Delegation	Total Athletes	
Africa			
	Benin	—	
	Botswana	—	
	Burkina Faso	—	
	Cameroon	—	
	Chad	—	
	Cote D'Ivoire	—	
	Democratic Republic of Congo	—	
	Gabon	—	
	Gambia	—	
	Ghana	—	
	Guinea	—	
	Kenya	—	
	Lesotho	—	
	Malawi	—	
	Mali	—	
	Mauritius	—	
	Namibia	—	
	Nigeria	—	
	Reunion	—	
	Rwanda	—	
	Senegal	—	
	Seychelles	—	
	Sierra Leone	—	
	South Africa	33	(73.2%)
	Swaziland	—	
	Tanzania	—	
	Togo	—	
	Uganda	11	(26.8%)
	Zimbabwe	—	
	No. athletes assigned by country	41	(100.0%)
	Unaccounted for athletes/country	0	(0.0%)
	Total athletes from region	41	(100.0%)

Table 2

Asia Pacific and its comprising delegations with total number of athletes participating in Nagano 2005 hearing screenings.

Region	Country/Delegation	Total Athletes	
Asia Pacific			
	Australia	—	
	Bangladesh	—	
	Bharat (India)	12	(11.8%)
	Brunei-Darusalaam	—	
	Cambodia	—	
	Indonesia	—	
	Japan	62	(60.8%)
	Laos	—	
	Malaysia	—	
	Myanmar	—	
	Nepal	—	
	New Zealand	1	(0.9%)
	Pakistan	—	
	Philippines	—	
	Singapore	13	(12.7%)
	Sri Lanka	—	
	Thailand	—	
	No. athletes assigned by country	88	(86.3%)
	Unaccounted for athletes/country	14	(13.7%)
	Total athletes from region	102	(100.0%)

Table 3

East Asia and its comprising delegations with total number of athletes participating in Nagano 2005 hearing screenings.

Region	Country/Delegation	Total Athletes	
East Asia			
	China	32	(31.4%)
	Chinese-Taipei	46	(45.1%)
	Hong Kong	13	(12.7%)
	Korea	3	(2.9%)
	Macau	5	(4.9%)
	No. athletes assigned by country	99	(97.1%)
	Unaccounted for athletes/country	3	(2.9%)
	Total Athletes from region	102	(100.0%)

Table 4

Europe/Eurasia and its comprising delegations with total number of athletes participating in Nagano 2005 hearing screenings.

Region	Country/Delegation	Total Athletes	
Europe/Eurasia			
	Albania	—	
	Andorra	—	
	Armenia	—	
	Austria	—	
	Azerbaijan	—	
	Belarus	12	(3.4%)
	Belgium	14	(4.0%)
	Bosnia-Herzegovina	—	
	Bulgaria	2	(0.5%)
	Croatia	—	
	Cyprus	5	(1.4%)
	Czech Republic	23	(6.6%)
	Denmark	8	(2.3%)
	Estonia	5	(1.4%)
	Faroe Islands	—	
	Finland	4	(1.1%)
	France	—	
	FYR Macedonia	—	
	Georgia	1	(0.3%)
	Germany	27	(7.7%)
	Gibraltar	—	
	Great Britain	12	(3.4%)
	Greece	13	(3.7%
	Hungary	12	(3.4%)
	Iceland	—	
	Ireland	—	
	Isle of Man	—	
	Israel	—	
	Italy	24	(6.8%)
	Kazakhstan	6	(1.7%)
	Kosovo	—	
	Kyrgyz Republic	—	
	Latvia	2	(0.5%)
	Liechtenstein	—	
	Lithuania	2	(0.5%)
	Luxembourg	3	(0.9%)
	Malta	—	
	Moldova	—	

Monaco	—	
Netherlands	1	(0.3%)
Norway	4	(1.1%)
Poland	10	(2.8%)
Portugal	1	(0.3%)
Romania	3	(0.9%)
Russia	36	(10.3%)
San Marino	—	
Serbia & Montenegro	—	
Slovakia	8	(2.3%)
Slovenia	8	(2.3%)
Spain	13	(3.7%)
Sweden	—	
Switzerland	—	
Tajikistan	—	
Turkey	—	
Turkmenistan	16	(4.6%)
Ukraine	15	(4.3%)
Uzbekistan	4	(3.2%)
No. athletes assigned by country	294	(83.8%)
Unaccounted for athletes/country	57	(16.2%)
Total Athletes from region	351	(100.0%)

Table 5

Latin America and its comprising delegations with total number of athletes participating in Nagano 2005 hearing screenings.

Region	Country/Delegation	Total Athletes	
Latin America			
	Argentina	19	(15.2%)
	Bolivia	—	
	Brazil	4	(3.2%)
	Chile	—	
	Costa Rica	11	(8.8%)
	Cuba	12	(9.6%)
	Dominican Republic	11	(8.8%)
	Ecuador	8	(6.4%)
	El Salvador	12	(9.6%)
	Guatemala	—	
	Honduras	—	
	Panama	—	
	Paraguay	—	
	Peru	12	(9.6%)
	Puerto Rico	—	
	Uruguay	—	
	Venezuela	18	(14.4%)
	No. athletes assigned by country	107	(85.6%)
	Unaccounted for athletes/country	18	(14.4%)
	Total athletes from region	125	(100.0%)

Table 6

Middle East/North Africa and its comprising delegations with total number of athletes participating in Nagano 2005 hearing screenings.

Region	Country/Delegation	Total Athletes	
Middle East/North Africa			
	Algeria	11	(17.7%)
	Bahrain	—	
	Egypt	3	(4.8%)
	Iran	4	(6.5%)
	Iraq	9	(14.5%)
	Jordan	3	(4.8%)
	Kuwait	2	(3.2%)
	Lebanon	7	(11.3%)
	Libya	—	
	Mauritania	—	
	Morocco	—	
	Oman	—	
	Palestine	—	
	Qatar	1	(1.6%)
	Saudi Arabia	—	
	Sudan	—	
	Syria	11	(17.7%)
	Tunisia	10	(16.1%)
	Yemen	—	
	No. athletes assigned by country	61	(98.4%)
	Unaccounted for athletes/country	1	(1.6%)
	Total athletes from region	62	(100.0%)

Table 7

North America and its comprising delegations with total number of athletes participating in Nagano 2005 hearing screenings.

Region	Country/Delegation	Total Athletes	
North America			
	America Samoa	—	
	Antigua & Barbuda	—	
	Aruba	—	
	Bahamas	—	
	Barbados	—	
	Belize	—	
	Bermuda	—	
	Bonaire	—	
	Canada	27	(5.4%)
	Caribbean	12	(1.5%)
	Cayman Islands	—	
	Curacao	—	
	Dominica	—	
	Grenada	—	
	Guadelope	—	
	Guam	—	
	Guyana	—	
	Jamaica	—	
	Martinique	—	
	Mexico	8	(1.0%)
	Monteserrat	—	
	St. Kitts & Nevis	—	
	St. Lucia	—	
	St. Vincent & The Grenadines	—	
	Suriname	—	
	Trinidad & Tobago	—	
	Turks & Caicos	—	
	USA	740	(93.4%)
	Nagano Games	54	(6.8%)
	Utah	686	(86.6%)
	US Virgin Islands	—	
	No. athletes assigned by country	787	(99.4%)
	Unaccounted for athletes/country	5	(0.6%)
	Total athletes from region	792	(100.0%)

Note: The number of athletes included in the USA (Utah) calculation includes athletes who were screened at multiple sessions and multiple screening periods.