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Review

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Abstract Noise-induced hearing loss and related tinnitus are often unrecognized problems, especially in non-occupational settings. Research indicates that increasing numbers of children and adolescents have or are acquiring noise induced hearing losses. Noise induced hearing loss can almost completely be prevented with simple precautionary measures. Educational programs rarely exist outside of those mandated in occupational settings. Health Communication theory can be applied to hearing health for developing effective loss prevention programs. Dangerous Decibels is one example of an effective multi-disciplinary effort to develop and disseminated prevention strategies.

Key Words noise induced hearing loss; tinnitus; prevention; health communication; museum; classroom; education; children; dangerous decibels

Introduction

In an article titled Noise-Induced Hearing Loss in Children, by Brookhouser et al (1992), the authors note a dramatic loss of hearing in children 19 years of age and under. According to Brookhouser et al (1992):
"Such irreversible, but potentially preventable losses, should be given high priority on the public health agenda. Comprehensive, age-appropriate educational programs must be developed for elementary and secondary students and their parents to acquaint them with potentially hazardous noise sources in their environment."

The problem: Noise-induced hearing loss (NIHL) and related tinnitus pose significant health risks to millions of individuals. Educational interventions, based upon health communication theory, have yet to be systematically applied to NIHL and tinnitus prevention.

Approximately 10 million persons in the United States have permanent hearing loss from noise or trauma (Jackson and Duffy, 1998). Additionally, an estimated 30 million people a day are exposed to injurious noise levels. Tinnitus, a ringing, buzzing, or roaring in the ears, is a symptom that accompanies many forms of hearing loss and can be debilitating. Approximately 40 to 50 million Americans have tinnitus, one-quarter of them to a severity that they seek medical help (Seidman and Jacobson, 1996). The most commonly identified precipitating factor in the onset of severe, problematic tinnitus is noise exposure (Meikle and Griest, 1989) and tinnitus has been demonstrated to be an early indicator of NIHL (Griest and Bishop, 1998). Simple precautions can prevent nearly all cases of noise-induced hearing disorders.

Hearing loss in the United States

An estimated 28 million people in the United States are deaf or hard of hearing(1996). Some 1,465, 000 individuals aged 3 years or older are deaf in both ears(Collins, 1997). Deafness or hearing impair-ment may be caused by genetic factors, noise or trauma, sensitivity to certain drugs or medications, and viral or bacterial infections.

Hearing loss is one of the most prevalent chronic conditions affecting older adults in the U.S., and remains an under-diagnosed and under-treated health problem. Data from the Health Interview Survey indi-

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cates that more than 2.2 million adults older than 70 years have hearing impairment (Campbell et al, 1999). Self-reported hearing loss between the 1971 and 1990-91 surveys indicate a 14% increase in age-adjusted prevalence (Reis, 1994), with only 10 percent of respondents over age 65 reporting normal hearing, and nearly half reporting that they could not hear and understand normal speech, limiting activities of everyday life.

The few available population-based surveillance studies support this high and growing prevalence of hearing loss in older segments of the population (Gates and Cooper, 1991; Brandt, 1996). The largest cogent study specifically designed to examine hearing loss, "The Epidemiology of Hearing Loss Study" conducted in Beaver Dam, WI, found substantial hearing loss in 21% of adults aged 48-59 years and 90% of adults 80 years or older at the time of their baseline survey in 1993-95 (Cruickshanks et al, 1998).

Using the data from the Beaver Dam cogent to forecast national trends in hearing loss, Cruickshanks and colleagues (2003) have estimated that there will be 9 million new cases of hearing loss in older adults in the next 5 years, and hearing will worsen in 17 million people with hearing loss. These losses appear to have important consequences for quality of life and social functioning. As life expectancy increases, these trends in hearing loss will present serious challenges to the U. S. health care infrastructure to provide audiologic services to a growing number of older persons.

Hearing loss is not limited to adults. NHANES III data from a national population-based sample provide information on the prevalence of hearing loss among U. S. children (Niskar, 1998). Audiometry conducted during the 1988-94 survey of over 6,100 children and adolescents aged 6 to 19 years indicates that approximately 15% have low-frequency hearing loss of at least 16 dB in one or both ears. Male adolescents were found to have a greater prevalence of high-frequency hearing loss than females. No significant differences were observed by race and ethnic groups; however, children from families with low poverty-to-income ratios have more high-frequency hearing loss than children from the middle and high poverty-to-income ratios, suggesting that class disparities may exist.

Noise exposure in children

Noise exposure, leading to hearing loss, is an increasing problem among children. At some time during their young lives, 97% of 273 third graders surveyed had been exposed to hazardous sound levels (Blair et al., 1996). Another study reported that 43% of the elementary school students in their study routinely listened to a personal stereo system or television at a loud volume(Chermak and Peters-McCarthy, 1991). Thirty percent of the students said they sometimes participated in other noisy activities(such as shooting firearms or attending auto races); however, only 5.5% of the students ever used hearing protection while engaged in these activities. Sources of excessive sound exposure for children include loud music (Lipscomb, 1972; Meyer-Bisch, 1996), real or toy firearms (Woodford, 1973; Lipscomb, 1974), power tools(Roeser, 1980; Plakke, 1985), fireworks (Gupta and Vishwakarma, 1989), loud toys (Axelsson and Jerson, 1985; Hellstrom et al., 1992), snowmobiles or other loud engines such as jet skis or motorcycles (Bess and Poynor, 1972). The World Health Organization reported that North American children "may receive more noise at school than workers from an 8-hour work day at a factory." (WHO, 1997)

Surveys of junior high and high school students identified large deficiencies in their knowledge about normal hearing as well as about hearing loss, and they knew little about the damaging effects of noise exposure (Lass et al., 1987a; Lass et al., 1987b). In St. Louis, Missouri, a group of high school students measured their daily noise exposure levels and monitored their perceptions regarding the extent of risk from such noise (Goebel, 1999). The study indicated that students significantly underestimated the extent of their sound exposure.

Several studies have demonstrated that the prevalence of NIHL among children is increasing (Woodford and O'Farrell, 1983; Chermak and Peters-McCarthy, 1991; Montgomery and Fujikawa, 1992). Anderson (1967) reported a surprisingly high prevalence of NIHL in school-aged children more than 30 years ago. A study of California youths from 1979 to 1989 reported, "In the district data over the last 10 years, the percentage of 2nd graders with hearing loss has increased 2.8 times; hearing loss in 8th graders has increased over 4 times; hearing loss in 8th graders has increased over 4 times."(Montgomery and Fujikawa, 1992). Another report estimated that 12.5% of students 6-19 year olds in the U.S. (5.2 million) have documented evidence of elevated hearing thresholds directly attributed to noise exposure (Niskar et al., 2001).

Consequences of NIHL

In addition to social and cultural isolation, loss of educational opportunities and revenue generation, there are staggering economic costs associated with hearing loss. A recent analysis commissioned by the Center for Disease Control and Health and Human Services documents the opportunity for reducing the prevalence and associated costs of hearing loss to society and individual citizens. The direct medical cost of hearing loss is estimated to exceed $132 million, with an additional $640 million in special education expenses. Indirect costs, or the loss of productivity in workplaces and households was estimated to exceed $1.3 billion. The average lifetime costs for hearing loss were estimated at $417,000 per person (Honeycutt, 2003).

NIHL in children has serious, long-term consequences. Data show that students with disabilities, including hearing impairment and deafness, are disproportionately disadvantaged (Atkin and Wallack, 1990). Even though the degree of high-frequency hearing loss detected in noise exposure studies has been generally mild and usually not even noticed by the children involved, Lass et al. (1986) warned: "The significance of the problem lies in the insidious nature of noise-induced hearing loss(NIHL) as well as the cumulative interaction between this type of loss and sociocusis. It follows then that a mild high-frequency hearing loss in a 16-year-old high school student may well deteriorate to a debilitating degree in later life. Additionally, there is another factor that could indicate that damage to the auditory system in this population is more prevalent and/or significant than might be believed from results of hearing tests."

Children with high-frequency hearing loss in Anderson's study had more learning difficulties and behavioral problems than their classmates who had normal hearing. Bess et al. (1998) reported that, compared to their classmates with normal hearing, children with minimal sensorineural hearing loss (MSHL) scored significantly lower on the Comprehensive Test of Basic Skills; they also exhibited more behavioral problems and lower self-esteem. Thirty-seven percent of children in the study with MSHL failed at least one grade compared to the school district average of eight percent or less.

Interventions work, but few are in place

Hearing conservation programs, mandated by the Occupational Safety and Health Administration (OSHA), are helpful in reducing the rate of noise related health problems in occupational settings. Non-occupational hearing loss prevention programs for adults are virtually non-existent in the United States. The risk factors for hearing loss demonstrated in cross-sectional and longitudinal studies include age(Cruickshanks et al., 1998; Cruickshanks et al., 2003), male gender (Pearson, 1995; Cruickshanks et al., 2003), and history of occupation in high noise jobs such as manufacturing and construction (Monocodecicki, 1985; Wallhagen, 1997; Cruickshanks et al., 1998; Cruickshanks et al., 2003). Exposure to noise during the course of work, but also during the other activities of daily living, are theorized to cause damage that appears as chronic hearing loss at older age. If exposure to noise causes cumulative damage that accelerates age-related changes, prevention of noise exposure may conserve hearing function in later life.

Educational interventions can increase knowledge about NIHL issues. One study, which evaluated the effectiveness of hearing conservation education in high school students, showed an average increase of 16% correct responses following the educational program (Lass et al., 1986). A second study presented an educational program on hearing conservation to elementary school children and found that their knowledge regarding NIHL improved by an average of 23% (1991). We recently published a detailed review of existing hearing conservation programs and materials that are currently available (Folmer et al., 2002) and found that, unfortunately, few programs had undergone summative evaluations for their effectiveness at communicating hearing health information. In addition, we could identify no ongoing, systematic delivery of hearing loss prevention programs on a widespread basis in public schools.

Knowledge of potentially dangerous sounds, their consequences and simple ways to protect oneself are all significant factors in prevention of NIHL and tinnitus. Public education can promote hearing health and behavior to reduce noise-induced hearing loss, a fully preventable condition.

Health communication : The road to hearing health

Healthy People 2010 (2000) states: "Health communication encompasses the study and use of communication strategies to inform and influence individual and community decisions that enhance health. It links the domains of communication and health and is increasingly recognized as a necessary element of efforts to improve personal and public health. Well-designed health communication activities help individuals better understand their own and their communities' needs so that they can take appropriate actions to maximize health" (2000).

The effectiveness of health communication programs is dependent upon optimal contexts, channels, content, and reasons that will motivate people to pay attention to, and use health information.

The proposed project represents the first effort to systematically apply health communication research to the prevention of noise-induced hearing loss and related tinnitus. Health communication theory will be applied to the design, presentation and evaluation of educational interventions with the purpose of identifying effective prevention methods that will be made available to other educators and public health professionals.

Behavior theory is a critical component in health education program planning. A great deal is known about behavior change in adolescent populations as a result of extensive literature in the behavioral science fields. The planning and implementation of a hearing loss and prevention program like the one being proposed is a complex task requiring the preliminary evaluation of the needs and behaviors of the target group. It is essential to identify the barriers to change as well as the factors that motivate the audience to make changes. The needs of the target audience reflect a specific "stage of change" according to Prochaska et al. (1994). While some individuals may already be contemplating making changes in risky behaviors, based on knowledge and attitudes, others are lacking the information and/or motivation to contemplate taking action. Our preliminary data suggest that most fourth graders in school districts in Oregon know little about hearing loss and tinnitus prevention. They are by definition "precontemplators" (Prochaska et al., 1994). Therefore, knowledge about the problem of hearing loss is a necessary, but not sufficient, component of the process. Attitudes about social norms, important skills and self-efficacy are all essential to the task at hand.

An action plan must tailor the intervention to the knowledge levels, attitudes, skills and learning styles of the early adolescent population. Fortunately, there is a body of work in the fields of health behavior and health communication that provides very useful assistance in the task of designing, implementing and evaluating health education interventions. One such theory, the Theory of Reasoned Action and Social Influence, originally developed by Fishbein and Ajzen(1975), is particularly well suited to behavior change interventions, and has been successfully tested in adolescent populations. While this theoretical model has not been applied to hearing loss prevention to date, many school-based risk reduction programs grounded in the theory of reasoned action have been shown to be effective.

Theory of reasoned action and social influences

Fishbein and Ajzen(1975) determined that there are three constructs that affect an individual's intention to adopt a new behavior, and in order to motivate an individual to make a behavior change, health educators must address each of the three constructs (Albarracin et al., 2001). These include the attitude that the individual has about the given behavior, whether or not significant others think the behavior is important(subjective norms), and the individual's perceived control over their behavior. These three variables affect the intention of the individual to perform the behavior. Behavioral intentions have been shown to be highly predictive of future behavior (Albarracin et al., 2001).

Fishbein and Ajzen (1975) suggest that any strategy for health behavior change must consider the context of relevant social influences. Students learning hearing loss prevention skills will be more likely to attend to and apply the learning if they find that their parents, teachers and/or other important adults identify this issue as important. In addition to important adult influences, the influence of the student's peer group is very strong. The attitude of peers about the use of hearing protection and avoidance behavior will have a dramatic effect on its use (Chermak et al., 1996). To a great extent, social norms determine attitudes.

The theory of reasoned action also addresses the importance of self-efficacy. It has been clearly demonstrated that students who believe that they have the knowledge and ability to apply the skills necessary for risk reduction and believe that they are in control of this skill may be more likely to practice healthy behaviors. Communication skills are also an important aspect of self-efficacy. Learning to explain to peers the reason for practicing new behaviors is important both because it increases the likelihood that the behavior will be tried in the first place and because it increases the likelihood that the social norm will be changed.

According to Cialdini, Kallgren and Reno (1991), social norms are very important to an understanding of behavior change in young people. Social norms are best understood as the perception of how most people behave(descriptive norms) and how most people should behave (injunctive norms). They argue, "norms can be demonstrated to affect human action systematically and powerfully" (Cialdini et al., 1991). Social norms are especially relevant when designing youth-oriented programs, because so much of what they do is determined by what their peers deem acceptable. Sun-safety research conducted by Donavan and Singh (1999) found elementary school students were highly affected by social norms. A significant relationship was found between children being opposed to wearing long-sleeved shirts in the sun and the belief that their peers would tease them for this behavior.

In a study by Main et al. (1994), the theory of reasoned action was used as the basis for developing a skills-based HIV risk-reduction program for school-aged children. The researchers found that careful training of instructors was critical to program effectiveness. Students exhibited a greater amount of knowledge regarding HIV transmission and greater intent to engage in safer sex when trained teachers taught them about the risks of sexual intercourse and the skills they needed to negotiate safer sex with their partners, as compared to untrained teachers. Prevention programs that target adolescents must include skills necessary to be able to communicate to peers about new behaviors. This skill acts to enhance self-efficacy in adolescents (Devries et al., 1992; Main et al., 1994; Noland et al., 1998; Price et al., 1998).

Additionally, in a meta-analysis by Albarracin et al. (2001), support was found for the theory of reasoned action. Researchers determined that health behaviors were related to behavioral intentions, and that reports of behavioral intentions were closely associated with attitudes and the subjective norm.

The proposed intervention will apply the constructs of the theory of reasoned action to the task of educating early adolescents about hearing loss and tinnitus prevention. The evidence presented above shows definitively that changing adolescent attitudes must be an essential goal of the program. The curriculum needs to focus on those attitudes associated with normative beliefs about avoiding loud noises, while addressing essential information about hearing loss and effectively teaching the skills needed to practice healthy behaviors.

Critical characteristics of effective health communication programs

1. Gear the program to the target audience

Because schools are composed of many different types of children, with many different interests and abilities to learn, it may be overwhelming to create a health education program that reaches everyone. Knowing the characteristics of the population is very important for a successful campaign. Researchers studying Cardiovascular Health Education Programs found that their program had a higher impact on rural adolescents than on urban adolescents, even though prior knowledge was the same (MacDonald, 1999). Researchers studying HIV prevention found the importance of not assigning particular classes but rather whole schools to skills-based risk reduction. They found that this approach created a school environment that was supportive of HIV education, and encouraged other classes to incorporate discussions into the matter (Main et al., 1994). Another group of researchers found that Adolescent Dating Violence was a problem for both genders, not just females, so their program needed to include information and resources accordingly (Foshee et al., 1998). Researchers focusing on tobacco prevention in adolescents living in a tobacco-producing region recognized the need to provide a culturally relevant program, and were rewarded by lower smoking rates for those involved in raising tobacco than those who were not (Noland et al., 1998).

2. Use interactive, not passive instruction

Black et al.(1998) state that interactive peer-led interventions are statistically superior to non-interactive lecture programs led by teachers or researchers when working with middle school children. They go on to further define interactive programs as those utilizing face-to-face peer interactions, role-plays, age-appropriate information, and feedback from peers to stimulate active participation. This is in contrast to non-interactive, teacher-led programs that involve passive exchanges between teachers and students.

3. Incorporate skills-based learning

If the health behavior requires a student to refuse or avoid something, it is important to teach skills needed to accomplish this task, and allow time to practice the new skills in class (Devries et al., 1992; Main et al., 1994; Reding et al., 1996; Black et al., 1998; Lukes and Johnson, 1998; Noland et al., 1998; Price et al., 1998). Once a student has learned about the normal workings of the body and the negative impact of a health behavior, they need to learn about how to prevent damage to themselves (Chermak and Peters-McCarthy, 1991; Devries et al., 1992; Reding et al., 1996; Knobloch and Broste, 1998; Lukes and Johnson, 1998; MacDonald, 1999).

4. Use multi-component programs and program repetitions.

Main et al. (1994) state in their study that successful programs include acquisition of skills and development of self-efficacy, but that requires adequate class time, activities beyond the classroom, and adequate teacher training (Main et al., 1994). The frequency and duration of the educational program are important to the success of the outreach, but many programs have demonstrated significant knowledge gains in just a few sessions. Some programs have devoted large amounts of time to health topics (Main et al., 1994), and others have had relatively brief exposures (Reding et al., 1996), depending on need or availability of resources. In research done by Black, Tobler and Sciacca, recommendations were made by Tobler, which reinforced the need to examine the potential long-term effects that can be obtained through low-intensity programs in the schools (Black et al., 1998).

Some investigators have made specific recommendations for hearing loss prevention education. Lass et al. (1987a) recommended instruction about 1) normal auditory mechanisms; 2) types of hearing loss and their causes; 3) noise and its effect on hearing; 4) warning signs of noise-induced hearing loss; and 5) specific recommendations for preventing noise-induced hearing loss. Anderson (1991) added the following topics to the list: Instruction about consequences of hearing loss and how it can affect life quality, and what kinds of noises or noisy activities are most dangerous to hearing.

Chermak et al.(1996) reported that students who received the hearing conservation message through an interactive style of instruction exhibited greater improvement on post-instruction tests than students who heard it in a more traditional lecture format. Results from a study by Bennett and English (1999) agree with this conclusion. Therefore, a hearing conservation program for children should be as interactive as possible and utilize a variety of media and activities.

Dangerous Decibels hearing health partnership

The Oregon Health & Science University's Oregon Hearing Research Center(OHRC), in conjunction with the Oregon Museum of Science and Industry (OMSI), Portland State University School of Community Health, the Veterans Affairs National Center for Rehabilitative Auditory Research and the American Tinnitus Association (all located in Portland, Oregon), has formed a public health partnership to address the problem of increasing noise-induced hearing loss and tinnitus. The Dangerous Decibels partnership has received private funding from several private foundations and public sources (see Acknowledgements). The support provided funds for the development of four program activities: 1) A permanent Dangerous Decibels museum exhibition at the Oregon Museum of Science and Industry; 2) A virtual Dangerous Decibels museum exhibition at the Dangerous Decibels website (www.dangerousdecibels.org); 3) An interactive, inquiry-based classroom outreach and teacher training program targeting kindergarten through 12th grade students; and 4) Noise-induced hearing loss and tinnitus research in the museum setting using data acquired from the Listen Up! hearing screening game exhibit at OMSI.

All of the Dangerous Decibels activities communicate three educational messages: What are sources of dangerous sounds? What are the consequences of being exposed to dangerous sounds? How can I protect myself from dangerous sounds?

The Dangerous Decibels program has been adopted by the Marion Downs National Center for Infant Hearing and is supported by the National Hearing Conservation Association Taskforce for Noise Induced Hearing Loss Prevention in Children.

Museum exhibition

The permanent museum exhibition at OMSI, consisting of 12 interactive, educational exhibit components, opened in July, 2002 (Figure 1). It represents the only museum exhibit in the world dedicated to the prevention of noise-induced hearing loss and tinnitus. Exhibits include presentations of the physics of sound, normal anatomy and physiology of hearing, simulations of noise-induced hearing loss and tinnitus, indicators of dangerous sound levels, interactive instruction on the selection of appropriate hearing protection, a "game show" style group interactive about hearing health facts and a computer game that educates, entertains, and performs data acquisition about the visitor's noise exposure history while simultaneously performing hearing screening. The exhibit has been on display to approximately 670,000 visitors per year, including 72,000 K-12 students on school group field trips.

Web-based virtual museum exhibition

Internet access provides a web-based entertaining and educational experience at the Dangerous Decibels Virtual Exhibit(www.dangerous decibels.org). Eight of the OMSI museum exhibits have been translated into computer activities, demonstrations and games that communicate the fundamental educational messages of the project. The Virtual Exhibit was developed as an experimental intervention for the NIDCD funded project, Health Communications: NIHL and Tinnitus Prevention has proven effective at changing knowledge, at-

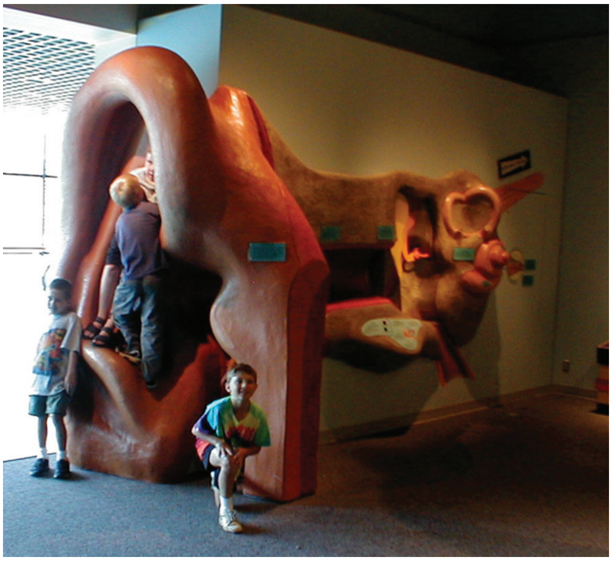

Figure 1. Future hearing scientists explore the Giant Ear at the Oregon Museum of Science and Industry Dangerous Decibels exhibition. The 12 components of the exhibit cover 2000 square feet and include family-friendly activities for all ages. It is the only exhibition in the world dedicated to the prevention of noise-induced hearing loss and tinnitus.

titudes and intended behaviors in young people. The Virtual Exhibit was made available to the public in May of 2005. It is a resource that is used in NIOSH young worker safety training and U.S. Army educational programs for new recruits.

Classroom outreach program

The Dangerous Decibels program developed an outreach educational program designed for kindergarten though 12th grade students (Figure 2). The content was developed by OHRC hearing scientists and the format and delivery was developed through three formative evaluation efforts in six counties across Oregon and Southwest Washington. The formative evaluations included student and teacher focus groups conducted by external evaluators, teacher consultants, and educational experts from OMSI. OHRC and OMSI staff have developed an educator training program that has been used to train school nurses, high school students, audiologists, speech pathologists, teachers and other interested individuals as presenters of the Dangerous Decibels curriculum. Graphical displays, 3-D models and interactive "hands-on" activities provide a multimodality learning experience. Educators are provided the extensive Dangerous Decibels Teacher's Resource Guide containing simple strategies for age-appropriate classroom activities that meet state-mandated educational goals and benchmarks. The Teacher's Resource Guide can be downloaded from the Dangerous Decibels website (www.dangerous decibels.org). The classroom program has been presented to and well received by all age groups.

Listen Up! Educational hearing screener and data acquisition system

This exhibit is a massive, cochlea-shaped chamber housing an educational, interactive computer game that entertains while automatically screening hearing thresholds at 4,000 Hz − the frequency most vulnerable to noise-induced cochlear damage (Figure 3, 4). While visitors are playing, it also acquires demographic information and a history of recent noise exposures. Visitors are given the results of their hearing screening and information about their personal risk factors for exposure to hazardous noise. Over 36,000 visitors to Listen Up! have elected to include their test results in an OHRC study of automated hearing health data acquisition. The system has been shown to provide valid and reliable results for information gathering and hearing screening in an unsupervised setting.

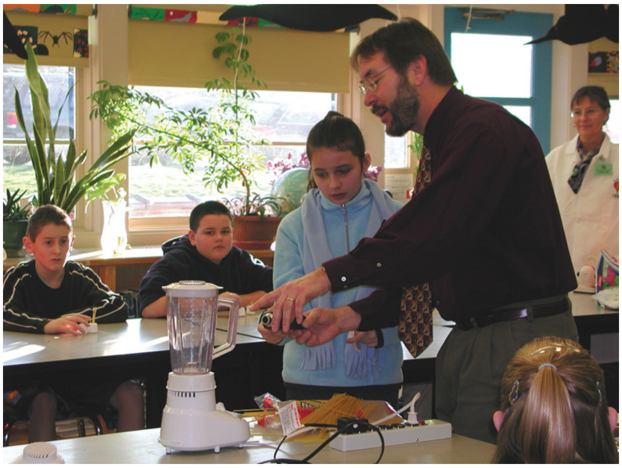

Figure 2. The Dangerous Decibels classroom outreach program uses "inquiry-based learning" methods to engage kindergarten through high-school students. Here a student is learning to measure sound levels and the principle of sound pressure diminishing with distance from the source. The science-rich, age-appropriate curriculum includes the physics of sound, normal function and pathophysiology of hearing, consequences of hearing loss and methods of hearing loss prevention. The program was developed by collaborations between hearing scientists, educators and health communications experts.

The total number of individuals reached by Dangerous Decibels activities, including the museum exhibition at OMSI, classroom presentations, OMSI Science Festivals at County Fairs and educational training sessions approaches one million annually. It is the most extensively developed, disseminated and evaluated hearing loss and tinnitus prevention program in the world.

Summative evaluations have been performed on the classroom intervention for 4th and 7th grade students (Griest, 2005b) and for adults visiting the Dangerous Decibels museum exhibition at OMSI (Griest, 2005a).

Effectiveness evaluation of the Dangerous Decibels classroom intervention included baseline post-presentation, and one-month follow-up questionnaires with control and study groups. Results of the study demonstrated significant changes in knowledge, attitudes and behavioral intent regarding hearing loss prevention practices. 4th and 7th grade students (N=507) significantly improved across all knowledge items, ranging from a 10% to 52% increase in correct responses. Items addressing attitudes also improved, showing increases ranging from 13% to 23%. Intended behavior was measured by whether they would wear hearing protection while attending a loud concert. Prior to receiving the program, 15% of the 7th grade students said they would use hearing protection at a loud concert. Following the program, the percentage increased to 44%. All increases from baseline to post intervention were statistically significant at $p < 0.01$. The control group (N=521) showed no improvement from the time of baseline to follow-up questionnaire, strongly suggesting that the increases obtained by the study groups were due to the educational intervention(Griest, 2005b).

A sample of 300 adult visitors, ages 18-84, participated in a summative evaluation of the OMSI museum exhibit. Participants were asked to fill out a baseline questionnaire that addressed their knowledge, attitude and behavior regarding hearing and hearing loss prevention. Following their experience with the Dangerous Decibels exhibit, they were asked to fill out a second questionnaire with similar questionnaire items. The majority of adults (90%) were able to correctly identify dangerous sources of sound prior to experiencing the museum exhibit. However, when asked about their use of hearing protection, only 8% indicated consistent use of hearing protection when around loud sound. Questionnaire items related to the consequences of noise exposure and strategies for prevention of hearing loss showed fewer correct responses at baseline (10% - 22% correct responses) and demonstrated significant increases in correct responses following the museum visit, ranging from 10% - 56%. To evaluate the impact of the museum exhibit on future behavior, participants were asked whether they would wear hearing protection if they went to a loud concert. Only 30% of the participants said they would wear hearing protection prior to their visit. Whereas, following the visit, 62% of the participants stated that they would wear protection,

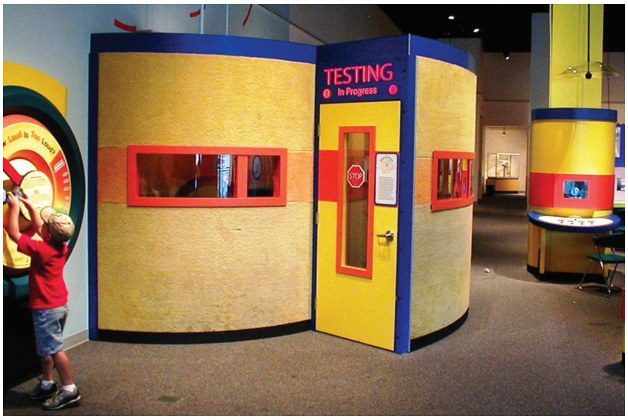

Figure 3. The Listen Up! exhibit in the Dangerous Decibels exhibit is a custom designed chamber that meets ANSI testing standards. It houses an educational, interactive computer-based game that acquires epidemiological and physiological data from visitors.

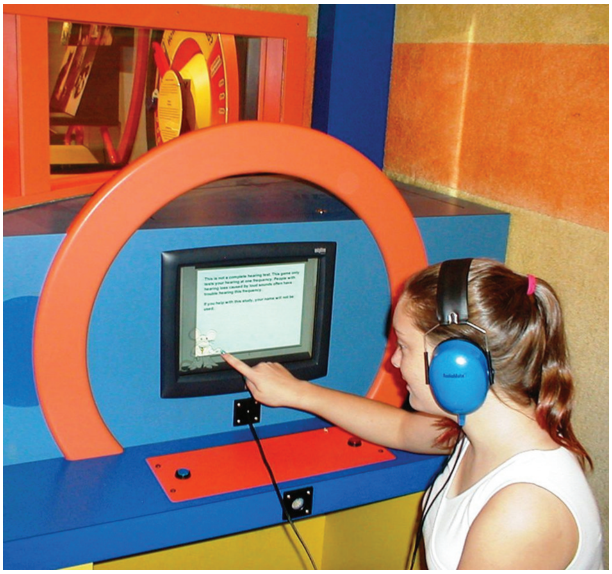

Figure 4. Visitors are given the opportunity to participate in ongoing research on the relationship between noise exposures and the presence of tinnitus and hearing loss in the population. Data are continually transferred from the museum to the Oregon Hearing Research Center for analysis. In addition, a subset of the data can be viewed online at the Dangerous Decibels website (www.dangerous decibels.org) in the Information Center, Exhibit Research section. To date, results from over 36,000 subjects, from the ages of 6 to 85 years, can be accessed for study by the public.

an increase of 32%. Overall, participants demonstrated a statistically, significant increase in their knowledge of hearing and hearing loss prevention as a result of their experience with the Dangerous Decibels exhibit. In addition, intentions to use hearing protection when around loud noise were significantly improved (Griest, 2005a).

An evaluation of the validity and reliability of the automated, educational, hearing screener and hearing health information acquisition system was recently completed(Martin, 2005). Responses obtained from 224 subjects(448 ears) participating in the Listen Up! exhibit (automated screener) at OMSI were compared to responses from the same subjects, retested immediately after visiting the exhibit. The results indicated that the test-retest reliability of answers about recent noise-exposure histories ranged from 85% to 97% (average 92%) accuracy for the 10 questions asked by the system. The hearing screening section of the system had a sensitivity of 98% and specificity of 97% using a + 5 dB error range employed in standard audiometric testing. This means that hearing thresholds were underestimated during 2% and overestimated during 3% of tests. These results were independent of whether or not the subjects were supervised during the screening process. This indicates that a stand-alone health information questioning and hearing screening system has the capability of performing remarkably accurate data acquisition from unsupervised participants.

Conclusion

Noise-induced hearing loss is a significant public health risk, even in non-occupational settings. Little has been done on the national or international level to increase public awareness of the issue or to implement appropriate, proven interventions to equip the public to protect their hearing and insure long-term hearing health and quality of life. Resources like Dangerous Decibels are now available and should be implemented in formal and informal educational settings at early ages in order to insure healthy behavior choices through development and into adulthood.

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