International Journal of Audiology 2013; 52: S41–S49

informa
healthcare

Original Article

Randomized trial of four noise-induced hearing loss and tinnitus prevention interventions for children

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Abstract

Objective: To evaluate the effectiveness of four NIHL prevention interventions at improving knowledge, attitudes, and intended behaviors regarding sound exposure and appropriate use of hearing protective strategies in children. *Design:* A randomized trial of the four interventions with a non-intervention comparison group. Questionnaires were completed prior to, immediately after, and three months after each intervention. *Study:* Interventions included: (1) A classroom presentation by older-peer educators, (2) A classroom presentation by health professionals, (3). Exploration of a museum exhibition, and (4). Exploration of an internet-based virtual museum. A comparison group received no intervention. *Study sample:* Fifty-three fourth grade classrooms (1120 students) participated in the study. *Results:* All interventions produced significant improvements but the number of improvements decreased over time. In terms of effectiveness, the classroom programs were more effective than the internet-based virtual exhibit, which was more effective than the visit to the museum exhibition. Self-reported exposures indicated that as many as 94.5% of participants were at risk for NIHL. *Conclusions:* Interpersonal, interactive educational interventions such as the classroom program are more effective and have longer impact than self-directed learning experiences for NIHL and tinnitus prevention, however each may have an important role in promoting hearing health in elementary school students.

Key Words: Noise-induced hearing loss; dangerous decibels; prevention; tinnitus; hearing conservation; health communication

Exposure to intense or prolonged sound can cause permanent hearing loss and tinnitus in individuals of all ages. The damage caused by sound accumulates throughout life (Williams et al, 2010; Beach et al, in press). Early sound exposures may have extensive long-term consequences on cochlear and auditory neural function (Kujawa & Liberman, 2006; Lin et al, 2011). Those with early onset of hearing loss are disproportionately disadvantaged (Atkin & Wallack, 1990). Bess et al (1998) reported that, compared to their classmates with normal hearing, children with even minimal sensory neural hearing loss scored significantly lower on the Comprehensive Test of Basic Skills; they also exhibited more behavioral problems and lower self-esteem.

Several studies indicate that children are exposed to potentially hazardous sound levels on a regular basis. 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). At some time during their young lives, 97% of 273 third graders surveyed had been exposed to hazardous sound levels (Blair et al, 1996). 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 (Chermak & Peters-McCarthy, 1991). There are an estimated 1.6 million hunters in the U.S. between the ages of 6 and 15 (USFWS, 2006). A dramatically emerging source of sound exposure in youth comes from personal music players. Reports indicate that over 94% of adolescents use these devices and over 28% are estimated to do so at levels putting them at risk for hearing loss (Kim et al, 2009; Vogel et al, 2011). Output levels using standard earbuds can exceed 100 dBA (Portnuff & Fligor, 2006). Cumulative daily and weekly noise exposures can be significant. Martin et al, (2008) reported that of the 12–18 year olds they evaluated, 16% listened to music on their personal music players at levels exceeding National Institute of Occupational Safety and Health recommended exposure levels on a daily basis.

The consequences of these reported exposures appear not to be only theoretical. Based on the Third National Health and Nutrition Examination Survey conducted between 1998 and 1994 (Niskar et al, 2001), 12.5% of 6–19 year olds had noise-induced threshold shifts. A subsequent survey from 2005–2006 indicated that 16.7% of 12–18 year olds had noise-induced threshold shift (Henderson et al, 2011). Tinnitus, which is most commonly caused by sound exposure, has been reported in up to 59% of children with 19.6% indicating it as severe (Coelho et al, 2007).

Classroom educational programs have been used to successfully increase knowledge regarding dangers of sound exposure and use of

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(Received 25 September 2012; accepted 2 October 2012)

ISSN 1499-2027 print/ISSN 1708-8186 online
DOI: 10.3109/14992027.2012.743048

Abbreviations

dBA	Decibels, A-weighted
NIHL	Noise-induced hearing loss
OMSI	Oregon Museum of Science and Industry
OHSU	Oregon Health & Science University

hearing protection (Roeser et al, 1983; Lass et al, 1986; Chermak & Peters-McCarthy, 1991; Blair et al, 1996; Chermak et al, 1996; Lukes & Johnson, 1998; Bennett & English, 1999). Other work has indicated that behavioral changes can also be achieved through classroom education though gains deteriorated to some degree over time after the interventions (Knobloch & Broste, 1998; Griest et al, 2007; Neufeld et al, 2011). Highly interactive classroom programs, using problem-based learning, are more effective than traditional, lecture-based approaches for hearing-loss prevention education (Bennett & English, 1999). In the workplace, training programs with highly engaging methods (role modeling, hands on activities, and interaction between trainee and trainer) were three times more effective than less engaging programs in promoting and sustaining knowledge and skill acquisition (Burke et al, 2006).

Dangerous Decibels® is a public health partnership with the goal of reducing the incidence of noise-induced hearing loss and related tinnitus (Martin et al, 2006; Martin, 2008). The program uses educational outreach, museum exhibits, and research to promote and study hearing health. Educational activities address the sources of dangerous sounds, the consequences of being exposed to dangerous sounds, and ways to be protected from dangerous sounds. The Dangerous Decibels classroom program has been demonstrated to improve knowledge, attitudes, and intended behaviors regarding sound exposure and use of hearing protection (Griest et al, 2007) but there are still substantial barriers to acceptance of the hearing loss prevention message (Weichbold & Zorowka, 2007). There remains a need to improve the effectiveness and sustainability of methods for prevention of NIHL among children and adolescents. To reasonably attribute cause and effect relationships between various educational methods and outcomes, Robinson et al, (2010) point to the need for high quality research designs, including randomized controlled trials, to more reasonably attribute cause-and-effect relationships between various educational methods and outcomes.

Health behavior interventions have used theoretical models to test health promotion program components for many years (Ory et al, 2002) however, health communication theory has had limited application to hearing-loss prevention in non-occupational and occupational settings (Crandell et al, 2004; Sobel & Meikle, 2008; Robson et al, 2010). Sobel & Meikle proposed applying principles of the transtheoretical model (also known as stages of change), the theory of planned behavior and reasoned action, the health belief model, and the social cognitive theory towards the purposes of promoting hearing health in children. These principles were applied to four interventions developed, applied, and evaluated in this study. The interventions included: (1) A classroom presentation by older-peer educators (high school students), (2) A classroom presentation by health professionals (school nurses), (3) A self-directed visit to a museum exhibition specifically created to promote hearing loss prevention, and (4) A self-directed visit to an internet-based virtual museum experience also created to promote hearing loss prevention. A comparison group received no intervention. The target population for this randomized trial was fourth grade students.

Methods

Subject protection

This study was approved by the Institutional Review Board at the Oregon Health & Science University, IRB#7628. Approval was also obtained from district school boards when required. Formal consent for participation by each student in this study was not required by the IRB. Instead, an informal consent form with a description of the study was sent home. Parents and guardians were required to send the form back to the classroom teacher only if they did not want their student to participate. No information was collected that could be used to identify participants. Without a formal consent form, tracking of individual students was not permitted. Consequently, comparison of results across questionnaires was analysed at the classroom level rather than at the student level.

Subjects

Oregon and Southwest Washington elementary schools were invited to participate in this study. Fourth grade classes from participating schools were randomized into one of the following study groups: (1) Classroom presentation by older-peer educator: High school students presented the Dangerous Decibels classroom program; (2) Classroom presentation by health professional educators**:** School nurses presented the Dangerous Decibels classroom program; (3) On-site museum experience: Students visited and interacted with a museum exhibition on NIHL and tinnitus prevention; and (4) Internet-based virtual museum experience: Students visited and interacted with internet-based activities. A **no-intervention** comparison group matched for age, gender, and ethnicity factors did not receive any interventions until after the experiment was completed. Fifty-three classrooms, resulting in 1120 students, participated in this study.

In order to eliminate selection bias and create intervention groups that were comparable across factors, a randomized sampling process using a table of random numbers was implemented. To achieve representation of minority and under-represented groups, we specifically targeted schools with high-minority populations. A stratification process was applied separating schools into two strata: high-minority population (50% or greater) and low to moderate-minority population (less than 50%).

Interventions

The classroom program, museum exhibition, and internet-based activities were developed as part of the Dangerous Decibels partnership between the Oregon Health & Science University, Oregon Museum of Science and Industry (OMSI) and Portland State University. All of the activities were based on health communication theory principles and were intended to communicate three educational messages:

1. What are sources of dangerous sounds?
2. What are the consequences of exposure to dangerous sounds?
3. How can I protect myself from dangerous sounds?

Classroom program

The Dangerous Decibels classroom program is a 45-minute, interactive presentation with demonstrations and images. Every student participates in one or more hand-on activities. The content includes the physics of sound, normal auditory function, pathophysiology, and consequences of noise exposure, recommended exposure

limits, hearing protective strategies, and addresses peer-pressure issues related to use of hearing protection. The classroom programs were presented by either a school nurse or by a pair of high-school students. Nurses and high-school students underwent identical educator training workshops presented by a group of hearing scientists, public health specialists, museum educators, and experts in NIHL and tinnitus. Nurses and high-school students did at least four practice presentations of the classroom program under staff supervision before delivering the classroom program as part of the study to ensure the quality and consistency of the presentations.

Museum exhibition

The Dangerous Decibels museum exhibition was a 2000 square foot section of the Life Science Hall at OMSI. The 12-exhibit components included a giant ear with a functional middle-ear system, a large puzzle of ear structures, simulations of hearing loss and tinnitus, options for hearing protection, a demonstration of a traveling sound wave, an activity on selection of hearing protective strategies, and ways to address peer pressure. Classes were transported from schools to OMSI by bus. Students were given 25 minutes to visit the exhibit. They were given minimal direction. To increase the likelihood of their interacting with the entire exhibit, participants were given a score sheet and asked to rate how well they liked each of the 12 components. Students were free to interact with components individually or in self-selected groups.

Internet-based virtual exhibition

Eight on-line activities based on information content in the OMSI exhibition were combined to form the Dangerous Decibels virtual exhibition. Students were given 25 minutes in the computer labs at their schools to explore the virtual exhibit. As with the museum exhibition, they were given minimal direction but were asked to rate each activity as to how well they liked it. The virtual exhibit remains online in English and French (http://www.dangerousdecibels.org/exhibit/virtual-exhibit/).

Measurement instruments

Questionnaires evaluating baseline, post-intervention, and retained knowledge, attitudes and intended behaviors regarding sound exposure and use of appropriate hearing protective strategies (three-month follow-up) were developed for fourth-grade students in collaboration with evaluation specialists in preventive health and education as part of the Dangerous Decibels project (see Supplementary Appendix to be found online at http://informahealthcare.com/doi/abs/10.3109/14992027.2012.743048). Student focus groups and pilot studies were conducted to assess the clarity of questionnaire items and their sensitivity to measure changes resulting from a brief educational program on hearing and hearing conservation. Demographic information was collected regarding gender and ethnicity. The response format of most items required respondents to select from a list of potential answers including items that were on a five-point Likert-type scale (strongly agree to strongly disagree) or other closed-choice items (yes/no/not sure and check all that apply).

Data acquisition

All students (four intervention groups and one no-intervention group) were administered baseline questionnaires administered by research staff (not the classroom program presenters) prior to their receiving an intervention. Administration of questionnaires required no more than 15 minutes. Immediately following each intervention, project staff administered a post-presentation questionnaire. The no-intervention group did not participate in any educational program or receive the post-presentation questionnaire. Following an interval of approximately three months, a follow-up questionnaire was administered to the four intervention and non-intervention groups.

Data analysis

Responses from all questionnaires were entered into a database by an external data entry service. Data were entered using double-entry verification for quality control. The data for this study were analysed using the SPSS version 20 statistical package (SPSS Inc., Chicago, USA). Responses from all questionnaires were entered into a computer by an external data entry service and analysed by author (SG) using SPSS. Since students could not be tracked individually, percentages of correct responses within a classroom were computed for each questionnaire item using the SPSS aggregate function. To determine equivalency between intervention groups, baseline comparisons between the study and comparison classrooms were analysed using independent t-tests. Because analyses were performed using percentage correct at the classroom level, and the number of participants within a classroom varied slightly across questionnaires, non-parametric tests were also performed using the Mann-Whitney U test. To determine the immediate effectiveness of the educational program, percentages of correct responses at baseline were compared to percentages of correct responses at post intervention for the four interventions using paired t tests (parametric) and Wilcoxon matched pairs tests (non-parametric). To evaluate the long-term effectiveness of the interventions, percentages of correct responses for the intervention groups at baseline were compared to percentages of correct responses obtained from the follow-up questionnaire three months after the intervention using paired t tests (parametric) and Wilcoxon matched pairs tests (non-parametric). Level of significance was set *a priori* at 0.05.

Results

Description of study participants

Participants in this study were fourth grade students with 47% male and 53% female. Self-reported ethnicity was 47% White, 13% Hispanic, 13% Black, 7% Asian, 3% Native American, 11% other, and 6% not sure (Table 1). To achieve representation of minority and under-represented groups, we specifically targeted schools with high-minority populations. A stratification process was implemented resulting in 25 (47%) of the participating classrooms with a low to moderate minority status and 28 (53%) with a high minority status.

Role models and influence of friends

The majority of participants said that they thought it was important to their friends to protect their hearing; however, few had talked to their friends about hearing protection or seen them use it (Table 2). In contrast most had seen a parent use hearing protection, but again, they rarely discussed this with their parents (Table 2).

Self-reported sound exposures

The vast majority (94.5%) of students reported being exposed to at least one potentially hazardous sound during the previous year

Table 1. Demographics by Intervention Group.

	Health Educator Classroom Program	*Older Peer Classrooom Program*	*Web-Based*	*On-site Museum*	*No Intervention*	*Total*
Gender						
Male	98 (46.9%)	110 (40.4%)	167 (51.9%)	91 (49.5%)	67 (54.0%)	533 (48.0%)
Female	111 (53.1%)	162 (59.6%)	155 (48.1%)	93 (50.5%)	57 (46.0%)	578 (52.0%)
	209	272	322	184	124	1111
Self-reported ethnic/racial background						
Hispanic/Latino	16 (7.7%)	34 (12.5%)	57 (17.7%)	17 (9.2%)	15 (12%)	139 (12.5%)
White	93 (44.3%)	102 (37.5%)	154 (47.8%)	81 (43.8%)	69 (55.2%)	499 (44.8%)
Black/African American	34 (16.2%)	15 (5.5%)	10 (3.1%)	43 (23.2%)	7 (5.6%)	109 (9.8%)
American Indian/Eskimo	4 (1.9%)	3 (1.1%)	3 (0.9%)	7 (3.8%)	2 (1.6%)	19 (1.7%)
Asian/Pacific Island	7 (3.3%)	29 (10.7%)	23 (7.1%)	5 (2.7%)	12 (9.6%)	76 (6.8%)
Other	42 (20.0%)	62 (22.8%)	48 (14.9%)	17 (9.2%)	13 (10.4%)	182 (16.4%)
Not sure	13 (6.2%)	27 (9.9%)	27 (8.5%)	15 (8.1%)	7 (5.6%)	89 (8.0%)
Total	209	272	322	185	125	1113

and half (50%) reported exposure to at least three of the dangerous sounds presented as options. Participants reported exposure during the past year to a wide range of sounds from playing in a band (9%) to listening to music through headphones (73%) (Figure 1). Firing a gun was reported by 24%, which is notable because a single exposure may cause hearing loss or tinnitus (Figure 1). Hearing protection was rarely or never used when around loud sound by 76% of participants while only 7% reported using it often or always (Figure 2). Nearly half of participants (47%) reported being around sound that made their ears hurt or caused ringing during the past year (Figure 3), and 83% reported experiencing tinnitus at least some of the time to always (Figure 4).

Table 2. Influence of parents and friends on hearing protection.

How important do you think it is to your friends to protect their hearing (N = 1100)	
Not at all important	58 (5.3%)
A little important	278 (25.3%)
Somewhat important	153 (13.9%)
Very important	611 (55.5%)
Have you ever seen any of your friends wear earplugs or ear muffs? (N = 1111)	
No	589 (53.0%)
Yes	378 (34.0%)
Not sure	144 (13.0%)
How often do you talk to your friends about protecting your ears when you are around loud sounds? (N = 1109)	
Never	700 (63.1%)
Once in awhile	289 (26.0%)
Some of the time	96 (8.7%)
All of the time	24 (2.2%)
How often do you talk to your parents about protecting your ears when you are around loud sounds? (N = 1113)	
Never	565 (50.8%)
Once in awhile	351 (31.5%)
Some of the time	145 (13.0%)
All of the time	52 (4.7%)
Have you ever seen your parents use earplugs or ear muffs? (N = 1112)	
No	366 (32.9%)
Yes	588 (52.9%)
Not sure	158 (14.2%)

Effectiveness of interventions over time

Table 3 presents the percent of correct responses for questions related to knowledge, attitudes, and intended behaviors regarding use of hearing protection for all interventions obtained from baseline, post-intervention, and three-month follow-up questionnaires. Statistically significant changes are noted based upon the non-parametric Wilcoxon signed rank test. There were no significant differences between the numbers of correct answers on the baseline questionnaires for the intervention groups compared to the no-intervention comparison group.

Classroom program presented by health professional educator

Significant improvements between baseline and post-intervention scores were noted in 11 of 11 knowledge-based questions. Significant improvements were retained after three months for 9 of 11 knowledge-based questions. Significant improvements for both attitude and intended behavior-related questions were noted for all questions immediately after the intervention. The improvements were sustained at three months after the intervention for both attitude questions and for one of the two intended behavior questions. The average immediate improvement across all items was 28.6%. The average sustained improvement across all items was 20.7%.

Classroom program presented by older-peer educators

Significant improvements between baseline and post-intervention scores in the knowledge-based questions were present for 10 of 11 items. These improvements were also maintained at three months (8 of 11 questions). Significant improvements were found in one of the two attitude-related questions at post-intervention but these did not remain significantly improved after three months. Significant improvements related to intended behaviors were found for both questions immediately at the post-intervention and at the three month follow-up evaluation. The average post-intervention improve-

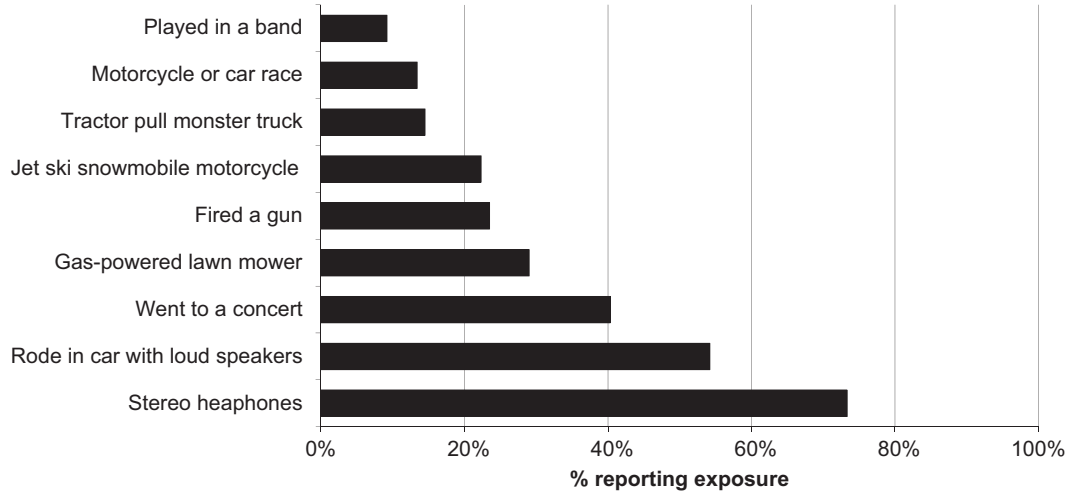

Figure 1. Self-reported sound exposures during the past year.

ment across all items was 24.8%. The average sustained improvement across all items was 18.3%.

Internet-based virtual exhibit

Significant improvements between baseline and post-intervention scores were found in 10 of 11 knowledge-based questions after exploring the internet-based virtual exhibit. Significant improvements were retained at three months following the intervention for 7 of 11 knowledge related questions. One of two attitude, and both intended behavior items, were significantly improved immediately after the intervention, but none of those improvements remained after a three month period. The average immediate improvement across all questions was 12.1%. The average sustained improvement across items was 6.8%.

Museum exhibition at OMSI

Compared to the other interventions, significant improvements in knowledge-based questions were noted in only 6 of 11 items, with sustained improvements at three months in only two of the items. There was no improvement in the two attitude questions at the post-intervention or three-month follow-up. There was significant improvement in responses to the two intended behavior questions immediately after the intervention, but the improvements were not sustained at three months following the intervention. The average immediate improvement across all items was 9.5%. The average sustained improvement across items was 5.6%.

No intervention group

For those not receiving any intervention, one of 11 knowledge-based questions showed a significant improvement at the three-month follow-up compared to those at baseline. This item related to whether music from a concert was potentially loud enough to cause hearing loss. The average improvement across all items for the control group was 2%, supporting the position that the changes recorded following the four interventions were a result of the interventions and not by chance.

Summary

In summary, all four interventions had positive effects of varying degree and duration. The improvements resulting from the classroom program presentations by the health professional and older-peer educators were equivalent and well sustained. The virtual exhibit produced improvements in areas of knowledge and intended behaviors that were similar in number but shorter in sustained duration than the classroom interventions. The visit to the museum exhibit was less effective than the other three interventions and produced long term improvements in the knowledge based items only.

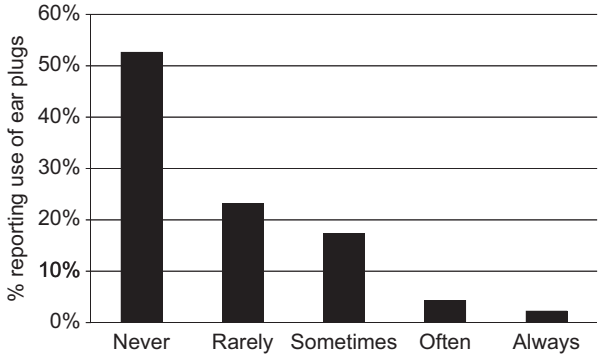

Figure 2. Baseline questionnaire answer to the question: "How often do you wear ear plugs or ear muffs when you are around loud sound?".

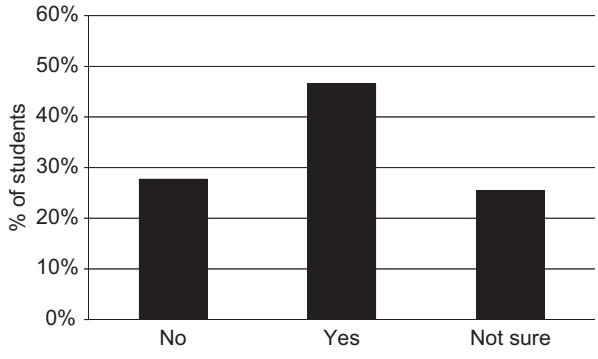

Figure 3. Baseline questionnaire response to the statement: "During the past year, I have been around loud sound that made my ears hurt or gave me "ringing" sounds in my ears".

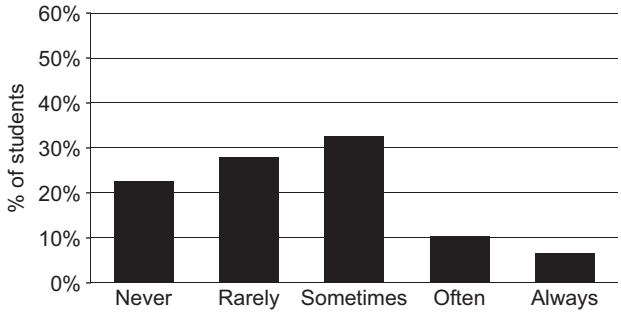

Figure 4. Baseline questionnaire answer to the question: "Do you ever experience ringing or other noises in your ear(s) or head?".

Discussion

The results of this study support previous findings that hearing-loss education can effectively improve knowledge, attitudes, and intended behaviors regarding exposure to dangerous sounds and appropriate use of hearing protective strategies when presented to elementary school children. It also demonstrates that informal, self-directed means of education such has museum exhibits and internet-based activities can be effective modalities for hearing-health promotion. The high incidence of self-reported exposures to potentially hazardous sounds in this study is consistent with those reported elsewhere. Although hearing evaluations were not part of this study, reports that nearly half of the students experienced pain or ringing in the ears from sound exposure indicates that the sound levels were likely to be dangerous. The vast majority of participants also reported experiencing tinnitus in general, which may be an indicator of cumulative sound exposure. An additional cause for concern is that 76% of students rarely or never use hearing protection, and few talk to friends or family about hearing protection. These results support the position that young students are at considerable risk of getting noise-induced hearing loss and tinnitus and that effective prevention interventions should be implemented on a national level as is being done in New Zealand (Martin et al, 2012).

Classroom program

Health communication theory indicates that role models, such as peer or older-age peer educators have the capacity to influence health behaviors (Reding et al, 1996; Starkey et al, 2009). Nurses as health educators also use their leadership positions to promote health in their school environments (Ladd, 2009). The classroom program presented by both high-school students and school nurses produced significant improvements immediately after the presentation with few exceptions. The older-age peer group did not show significant improvement for the items, "turning down the volume is a good way to protect hearing" and "hearing loss caused by loud sound is only a problem for elderly people". This most likely is due to a "ceiling effect" in that a significant number of participants gave correct answers at the baseline time point. The improvements resulting from both classroom interventions produced equivalent sustained effects. For both groups, the overall immediate (29% and 25%) and sustained improvements after three months (21% and 18%) compared favorably with previous studies ranging from 1–3% after six months for four behavior based items (Neufeld et al, 2011) to 23% after two weeks for seven knowledge based items (Chermak & Peters-McCarthy, 1991).

Internet-based virtual exhibit

The number of items showing significant improvements immediately after the internet-based intervention was equivalent to those found with both the health-educator and older-peer educator classroom programs, yet the percent of improvement in correct answers was considerably less (12%). Despite the immediate impact of the virtual exhibit on hearing-health promotion, the effects at the three-month follow-up evaluation were not as well sustained as the classroom programs (7%). Of interest is that the behavioral items did not show sustained improvement. Studies indicate that passive viewing of videos as a sole intervention has marginal if any impact on health promotion (Freimuth & Quinn, 2004; Snyder et al, 2004). It is more likely that internet-based interventions would serve well as complementary adjuncts to classroom programs. The likelihood that the effectiveness of a classroom-based health behavior program could be enhanced by an interactive internet-based component (used at school or at home) is an important direction for future research.

Museum exhibition at OMSI

The visit to the museum exhibition produced significant improvements in knowledge and intended behaviors immediately after the visit for 8 of the total 15 items, but was the least effective of the interventions evaluated. Only two knowledge-based items maintained significant improvement at the three-month follow-up. The average percent of increase in correct responses across all items was 9% from baseline to post-intervention and 6% from baseline to the three-month follow-up. At the time of the current study, this represents the first attempt at using a museum exhibition for promoting hearing health.

Summary

Of the interventions evaluated, the classroom program presented by either school nurses or high-school students proved to be more effective than either internet or museum-based interventions at producing sustained improvements in knowledge, attitudes, and intended behaviors regarding exposure to dangerous sound and use of appropriate hearing protective strategies. One possibility for this difference is that the classroom program incorporates interpersonal communication with role modeling as part of the educational approach as opposed to the self-directed method of the internet and museum-based activities. The structure of the classroom program ensures that participants are presented with all of the key educational messages that are supported through highly engaging, hands on activities and ongoing dialogue between educator and student. Self-directed activities bear no such guarantee. Instead, the depth of influence of self-directed interventions will be dependent upon the participant's attention span and interest in each activity or exhibit component. In some cases, key messages may be skipped altogether. An inherent limitation for high-content education through museum exhibits is the brevity of interactions with each exhibit component. The average length of engagement for children less than 13 years of age with a standard exhibit component is 41.8 seconds, and engagement with exhibit components designed with average prolonged engagement protocols is 167.7 seconds (Tisdal & Perry, 2004).

Although classroom programs were the most effective form of intervention in this study, the global impact of this method is limited by the number of individuals that can be reached. Typical class size is 20–30 students (although growing, due to economic factors). In contrast, OMSI boasts of approximately 600,000 visitors per year,

Table 3. Percent of correct responses at Baseline, Post-Intervention, and Follow-up by Intervention Group.

	Health Educator Classroom Program 10 Classrooms			*Older-peer Classroom Program 13 Classrooms*			*Web-Based 15 Classrooms*			*On-site Museum 9 Classrooms*			*No Intervention 6 Classrooms*	
	Baseline %	*Post %*	*Follow-up %*	*Baseline %*	*Post %*	*Follow-up %*	*Baseline %*	*Post %*	*Follow-up %*	*Baseline %*	*Post %*	*Follow-up %*	*Baseline %*	*Follow-up %*
Knowledge														
4. Which of the following types of sound can be loud enough to damage your hearing?														
Stereo Headphones	19	70**	51**	27	68***	49**	37	57***	42	26	41**	41**	30	35
Fireworks	51	86**	80**	57	82***	80**	59	82***	71**	57	67*	62	55	57
Gunfire	73	90**	85	67	94**	86**	67	86***	79**	60	72*	74*	68	64
Concert	41	80**	74**	54	84***	79***	58	74***	68*	60	74*	60	50	62*
5. Which of the following are good ways to protect your hearing when you are around loud sound?														
a. Walk away from the loud sound	50	83**	69*	60	88***	84***	63	81***	75**	56	66	63	60	63
b. Turn down the volume	74	85*	85*	83	83	86	79	76	83**	74	75	78	78	81
d. Put Cotton or Kleenex in your ears.	77	89**	78	79	94**	84	70	66*	72	82	80	72	73	76
e. Use Earplugs or Earmuffs	54	81**	81**	59	83**	87**	66	74*	75*	54	66*	63	69	68
6. Hearing an extremely loud sound even one time can cause you to lose some of your hearing.	56	87**	75*	54	76**	69	63	71*	65	55	64	63	52	51
7. Sound that is too loud can damage the hair cells of the inner ear	39	93***	88**	41	94***	83**	38	72***	67***	49	65*	59	30	33
9. Being around loud sounds a lot will help your ears get used to it and protect your hearing.	55	78**	75**	63	83**	88*	63	72**	63	69	68	70	67	73
Attitudes														
8. Hearing loss caused by loud sound is only a problem for elderly people.	58	79**	80**	68	74	76	68	75**	73	68	68	68	68	73
11. Wearing earplugs around my friends (if no one else is wearing them) would be:	56	69*	69*	61	77**	67	64	69	63	64	72	70	56	59
Intended Behaviors														
10. If you went to a loud concert with your friends would you use hearing protection?	37	74**	55**	41	82***	56**	44	55**	46	49	71*	56	40	32
15. If you were around loud machinery with an adult, would you use hearing protection?	59	84**	64	61	85**	75**	66	77**	65	58	74**	66	61	60

Wilcoxon Signed Rank Test, 2 sided *p = < .05 **p < .01 *** p< .001.

most of whom visited the Dangerous Decibels exhibition. Internet-based educational activities are readily available, but require an active marketing campaign to direct visitors to them. On their own, internet-based educational programs, regardless of their effectiveness, are destined to be underutilized.

In the overall attempt to promote hearing health to youth, each of these interventions may have an important role. The highly visible museum exhibition, while disappointing in terms of its effectiveness as a stand-alone program, has great potential to directly, albeit minimally, influence large numbers of the public in a cost-effective manner, providing them with an awareness about the hazards of loud sounds. Even moving individual viewers from a state of precontemplation, to a position of contemplating behavior change, would be a very important step (Prochaska et al, 1994).

Internet-based interventions may serve multiple roles. They may introduce the topic of hearing health to young people, serve in a limited capacity as a primary educational tool, and/or serve as an adjunct to a classroom program as part of a comprehensive approach to hearing health education. This comparison of four, stand-alone, health promotion program modalities demonstrates that the highly interactive classroom program, presented by a well-trained individual, is the most effective intervention at promoting hearing health. However, all of the individual interventions lost some of the beneficiary gains achieved over time. It is generally accepted that the effectiveness and sustainability of health promotion efforts are likely to be improved by using multiple interventions of different modalities, but this has yet to be demonstrated in hearing-loss prevention efforts. A meta-analysis of effective ingredients of substance abuse prevention programs indicated that interactive methods, social influence (including peer education), and using booster interventions increased effectiveness. Boosters included activities, community components, and use of mass media (Cuijpers, 2002). The museum exhibition and internet-based activities could be included in these types of boosters. Future studies should evaluate the effectiveness of pairing interventions of different modalities, such as a classroom program with a museum exhibition visit or with internet-based activities, to determine if multiple interventions increase the duration of healthy hearing behaviors.

Acknowledgements

Support in part by: National Institute of Deafness and Other Communication Disorders R25 – DC006431 Title: Health communication: NIHL and tinnitus prevention. Thanks to Tom Becker, John Brigande, Genna Martin, and JoAnn Percic for editorial comments.

Declaration of interest: The authors report no declarations of interest.

References

Atkin C. & Wallack L. 1990. *Mass Communication and Public Health: Complexities and Conflicts*. Newbury Park, USA: Sage Publications.

Beach E., Williams W. & Gilliver M. In press. Estimating young Australian adults' risk of hearing damage from selected leisure activities. *Ear Hear*.

Bennett J.A. & English K. 1999. Teaching hearing conservation to school children: Comparing the outcomes and efficacy of two pedagogical approaches. *Journal of Educational Audiology*, 7, 29–33.

Bess F.H., Dodd-Murphy J. & Parker R.A. 1998. Children with minimal sensorineural hearing loss: Prevalence, educational performance, and functional status. *Ear Hear*, 19, 339–354.

Blair J.C., Benson P.V.A. & Hardegree D. 1996. Necessity and effectiveness of a hearing conservaiton program for elementary students. *Educational Audiology Monograph*, 4, 12–15.

Burke M., Sarpy S.A., Smith-Crowe K., Chan-Serafin S., Salvador R.O. et al. 2006. Relative effectiveness of worker safety and health training methods. *Am J Public Health*, 96, 315–324.

Chermak G.D., Curtis L. & Seikel J.A. 1996. The effectiveness of an interactive hearing conservation program for elementary school children. *Lang Speech Hear Serv Sch*, 27, 29–39.

Chermak G.D. & Peters-McCarthy E. 1991. The effectiveness of an educational hearing conservation program for elementary school children. *Lang Speech Hear Serv Sch*, 22, 308–312.

Coelho C.B., Sanchez T.G. & Tyler R.S. 2007. *Tinnitus in children and associated risk factors*. In: B. Langguth & A.R. Møller (eds.) *Progress in Brain Research:* Elsevier, pp. 179–191.

Crandell C., Mills T.L. & Gauthier R. 2004. Knowledge, behaviors, and attitudes about hearing loss and hearing protection among racial/ethnically diverse young adults. *J Natl Med Assoc*, 92, 176–186.

Cuijpers P. 2002. Effective ingredients of school-based drug prevention programs: A systematic review. *Addictive Behaviors*, 27, 1009–1023.

Freimuth V.S. & Quinn S.C. 2004. The contributions of health communication to eliminating health disparities. *Am. J. Public Health*, 94, 2053–2055.

Griest S.E., Folmer R.L. & Martin W.H. 2007. Effectiveness of "Dangerous Decibels," a school-based hearing loss prevention program. *Am J Audiol*, 16, S165–181.

Henderson E, Testa M.A, Hartnick C. 2011. Prevalence of noise-induced hearing-threshold shifts and hearing loss among US youths. Pediatrics, 127, e39–e46.

Kim M.G., Hong S.M., Shim H.J., Kim Y.D., Cha C.I. et al. 2009. Hearing threshold of Korean adolescents associated with the use of personal music players. *Jonsei Med J*, 50, 771–776.

Knobloch M.J. & Broste S.K. 1998. A hearing conservation program for Wisconsin youth working in agriculture. *J Sch Health*, 68, 313–318.

Kujawa S.G. & Liberman M.C. 2006. Acceleration of age-related hearing loss by early noise exposure: Evidence of a misspent youth. *J Neurosci*, 26, 2115–2123.

Ladd V.J. 2009. School nurses: Positive deviant leaders in the school setting. *The Journal of School Nursing*, 25, 6–14.

Lass N.J., Woodford C.M., Lundeen C., Lundeen D.J. & Everly-Myers D.S. 1986. The prevention of noise-induced hearing loss in the school-aged population: A school educational hearing conservation program. *J Aud Res*, 26, 247–254.

Lin H., Furman A., Kujawa S. & Liberman M. 2011. Primary neural degeneration in the guinea pig cochlea after reversible noise-induced threshold shift. *JARO*, 12, 605–616.

Lukes E. & Johnson M. 1998. Hearing conservation: Community outreach programs for high school students. *AAOHN J*, 46, 340–343.

Martin W.H. 2008. Dangerous Decibels: Partnership for preventing noise-induced hearing loss and tinnitus in children. *Semin Hear*, 29, 102–110.

Martin W.H., Martin G.Y., Griest S.E. & Lambert W.E. 2008. How loud is your music? Beliefs and practices regarding use of personal stereo systems. *9th International Congress on Noise as a Public Health Problem (ICBEN)*.

Martin W.H., Sobel J., Griest S.E., Howarth L. & Shi Y.B. 2006. Noise induced hearing loss in children: Preventing the silent epidemic. *Journal of Otology*, 1, 11–21.

Martin W.H., Thorne P.R., Meinke D.K., Welch D., Sobel J.L. et al. 2012. Developing a national approach to NIHL and tinnitus prevention *NHCA 37th Annual Hearing Conference*. New Orleans.

Neufeld A., Westerberg B.D., Nabi S., Bryce G. & Bureau Y. 2011. Prospective, randomized controlled assessment of the short- and long-term efficacy of a hearing conservation education program in Canadian elementary school children. *The Laryngoscope*, 121, 176–181.

Niskar A.S., Kieszak S.M., Holmes A.E., Esteban E., Rubin C. et al. 2001. Estimated prevalence of noise-induced hearing threshold shifts among children 6 to 19 years of age: The third national health and nutrition examination survey, 1988–1994, United States. *Pediatrics*, 108, 40–43.

Ory M.G., Jordan P.J. & Bazzarre T. 2002. The behavior change consortium: Setting the stage for a new century of health behavior-change research. *Health Education Research*, 17, 500–511.

Portnuff C.D.F. & Fligor B.J. 2006. Sound output levels of the iPod and other MP3 players: Is there potential risk to hearing? *Noise-Induced Hearing Loss in Children*. Cincinnati, USA.

Prochaska J.O., Redding C.A., Harlow L.L., Rossi J.S. & Velicer W.F. 1994. The transtheoretical model of change and HIV prevention: A review. *Health Education Quarterly*, 21, 471–486.

Reding D.J., Fischer V., Gunderson P., Lappe K., Anderson H. et al. 1996. Teens teach skin cancer prevention. *J Rural Health*, 12, 265–272.

Robson L.S. Institute for Work & Health, National Institute for Occupational S. & Gibson Library Connections I. 2010. A systematic review of the effectiveness of training & education for the protection of workers. Toronto, Ont.; Cincinnati, Ohio: Institute for Work & Health; National Institute for Occupational Safety and Health.

Roeser R.J., Coleman T. & Adams R.M. 1983. Implementing an industrial hearing conservation program in the schools. *Journal of School Health*, 53, 408–411.

Snyder L.B., Hamilton M.A., Mitchell E.W., Kiwanuka-Tondo J., Fleming-Milici F. et al. 2004. A meta-analysis of the effect of mediated health communication campaigns on behavior change in the United States. *Journal of Health Communication*, 9, 71–96.

Sobel J. & Meikle M. 2008. Applying health behavior theory to hearing-conservation interventions. *Seminars in Hearing*, 29, 81–89.

Starkey F., Audrey S., Holliday J., Moore L. & Campbell R. 2009. Identifying influential young people to undertake effective peer-led health promotion: The example of A Stop Smoking In Schools Trial (ASSIST). *Health Education Research*, 24, 977–988.

Tisdal C. & Perry D.L. 2004. Going APE! at the Exploratorium Chicago, USA: Selinda Research Associates, Inc.

USFWS 2006. 2006 national survey of fishing, hunting, and wildlife-associated recreation errata sheet for national report. In*:* U.F.a.W. Service (ed.).

Vogel I., Brug J., Van Der Ploeg C.P.B. & Raat H. 2011. Adolescents risky MP3-player listening and its psychosocial correlates. *Health Education Research*, 26, 254–264.

Weichbold V. & Zorowka P. 2007. Can a hearing education campaign for adolescents change their music listening behavior? *Int J Audiol*, 46, 128–133.

WHO 1997. Strategies for prevention of deafness and hearing impairment. Prevention of noise-induced hearing loss. No. 3 in series. Geneva: Report of a World Health Organization-Prevention of Deafness/Hearing Impairment Informal Consultation, www.who.int/pbd/pdh/Docs/NOISEREP_V08.pdf, p. 6.

Williams W., Beach E.F. & Gilliver M. 2010. Clubbing: The cumulative effect of noise exposure from attendance at dance clubs and night clubs on whole-of-life noise exposure. *Noise & Health*, 12, 155–158.

Supplementary Appendix

Dangerous Decibels project questionnaire to be found online at http://informahealthcare.com/doi/abs/10.3109/14992027.2012.743048.