

**Children and Hearing Protection:
What is Available and Is It Used?**

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Abstract

For many noise exposures, the only feasible auditory defense is a hearing protection device (HPD); for many other exposures such devices are desirable or are the most convenient protective strategy. Their use and application in adult populations is well understood and documented, but in children and teenagers, such is not the case. This paper will summarize available data on HPD utilization and effectiveness in younger age groups and suggest if and how utilization could or should be improved. Considerations for measuring hearing protector effectiveness in children will be explored. HPDs will be described that are available for groups from neonatal infants in the hospitals, to youngsters accompanying their parents during noise-hazardous activities such as target shooting, hunting, or loud public events, and for teenagers involved in part-time noisy occupations. Safe listening is a habit that should be instilled at an early age and this paper will provide tools to help make that a reality.

Introduction

Noise is arguably one of the most pervasive environmental pollutants faced by children and adults. Virtually everything we do has noise as a by product and in many instances the noise is either annoyingly loud and/or hazardous to our hearing. Examples of the noisy activities that our children partake in, during which the use of hearing protection may be either advisable or absolutely necessary, are listed below.

- Shooting guns - target shooting, skeet, hunting
- Loud public events - concerts, night clubs, auto racing, tractor pulls, sporting events, etc.
- Using power tools – saws, routers, power sanders, etc.
- Yard work – mowing, leaf blowing, chain saws, edging, etc.
- Farm work – tractors, combines, feed areas, grain dryers, etc.
- Recreational vehicles – motorcycles, 4-wheelers, snowmobiles
- Educational settings – music performance, music rehearsal, vocational schools
- Noisy part-time jobs

For an exhaustive list of over 1700 different noise level measurements see the Noise Navigator™ database by Berger, et al. (2006).

In spite of the pervasiveness of noise in society, the consumer market for hearing protection would appear to be small. Estimates by Aearo Technologies suggest that 90% of the market is accounted for occupational and military sales, with the remaining 10% disproportionately directed towards the adult consumer market in the U. S., though in Europe the balance between the adult and children's consumer markets appears more equal.

Use Rates of Hearing Protection

When one examines whether or not children wear hearing protection devices (HPDs) at times that are warranted, the answer is disappointing. Data from 23 studies published between 1985 and 2006 are summarized in Table I and presented graphically in Slides 5 and 6 in the accompanying PowerPoint presentation. Not only are use rates low, typically averaging less than 25%, but note especially in Slide 4 the low use rates by instructors in vocational schools, who should be setting good examples in the otohazardous environments in which they teach on a daily basis.

Anthropometry

Few data appear in the literature on ear canal size, especially for younger populations. The papers that deal with such issues normally look at ear canal length and volume, whereas the important parameter for fitting earplugs is the diameter of the ear canal. Earplugs unlikely to be inserted deeply enough that the length of the ear canal becomes an issue. In Slide 6 data are presented from my laboratory on over 1000

subjects describing earcanal diameter and head width (using bitracion breadth as the relevant measurement). With the exception of the youngest age group in which there were only 10 subjects, the other groups are well populated. The data suggest, Ballachanda's (1995) observation that the shape and size of the earcanal and pinna attain adult scale by age 7 - 9 notwithstanding, that earcanal size and head width increase as a function of age up through the early 20s.

Measuring Performance

A review of the literature revealed no data that I could discover on the attenuation of HPDs for children. This probably stems from the difficulty of working with children to take measurements according to the standard paradigms, as well as the fact that the exact magnitude of children's attenuation is normally not a critical factor.

In spite of the common supposition that children's earcanals are softer than mature ears, Pirzanski and Berge (2005) found that the reverse was true. They drew their conclusion by comparing ear impressions on 80 ears from children less than 12 years of age (out of 1486 earcanals in the total study including all ages), made with both high-viscosity and low-viscosity silicones in the same earcanal. The greater the difference between the two sets of impressions, the softer the earcanal was presumed to be. By this measure, children's earcanals were the firmest. They also examined closed-jaw and open-jaw impressions and determined that children's earcanals were less affected by mandibular motion. These two observations suggest that children's earcanals, if they can be fitted by a correctly sized earplug, are likely to be similarly protected as their adult counterparts, perhaps even more so.

An issue of much greater concern is use rates and percent wearing time. Much more would be gained if these rates could be increased than if the actual attenuation of the devices were improved. For example, using the commonly accepted 3-dB exchange rate one can compute the attenuation of a 25-dB plug, if it is not worn all of the time in noise. Using it 90% of the time reduces its effectiveness to only 10 dB and if it is worn only 75% of the time the effectiveness diminishes to 6 dB, a reduction of 19 dB. Clearly this area is ripe for improvement.

Slides 7 and 8 provide an overview of the situation.

Hearing Protector Recommendations for Various Age Groups

Few products are specifically targeted towards children or younger age users, but a number of fine products designed for adults that are either available in multiple sizes or are sized smaller to begin with, provide options to fit children with hearing protection. Slides 9 through 18 provide specific recommendations with comments about the pros and cons of the various devices suggested.

Parents should trial the products on their kids to see what fits and is comfortable. Use the fittings tips found in Berger (1988) to determine when products are well fitted and providing good sound blockage. Although all products are labeled with a Noise Reduction Rating (NRR) per the U. S. Environmental Protection Agency (1979), the numbers are based on optimum fitting in idealistic conditions and provide little useful guidance to either adult or younger-age users. Simply use the NRR as a guide that the device was designed for and tested for noise reduction. Use the guidance in Berger (1988) and working closely with your child to establish if the device fits well and blocks sound. Equally, or perhaps more important, than the amount of noise the device can block is that it be fitted well and always worn when in hazardous noise, as discussed in the preceding section.

Conclusions

Though products are available that can protect children's hearing when they are exposed to noise, the existence of such products is only a small part of the solution to the problem. As with adult users of safety products it is key that children be taught an awareness of the importance of good hearing, the hazards of noise, and be provided techniques to determine when their ears may be at risk. Furthermore they must be given training on the means to protect themselves, either by reducing the frequency, severity, and/or duration of their exposures, or by wearing hearing protection. This can be accomplished, but it requires skill and diligence. The good news is that at least a few of the existing studies reviewed in this report suggest that use trends may be improving and that training and motivation can be effective.

References

- Allonen-Allie, N. and Florentine, M. (1990). "Hearing Conservation Programs in Massachusetts' Vocational/Technical Schools," *Ear and Hearing* 11(3), 237-240.
- Ballachanda, B. B. (1995). *The Human Ear Canal*, Singular Pub. Grp., Inc., San Diego, CA, p. 18.
- Bennett, J. A. and English, K. (1999). "Teaching Hearing Conservation to School Children: Comparing the Outcomes and Efficacy of Two Pedagogical Approaches," *J. Educ. Audiol.* 7, 29-33.
- Berger, E. H. (1988). "EARLog #19 – Tips for Fitting Hearing Protectors," *Sound and Vibration* 22(10), 22-25 and available at < http://www.e-a-r.com/hearingconservation/earlog_main.cfm>
- Berger, E. H., Neitzel, R., and Kladden, C. A. (2006). Noise Navigator™ database, at <<http://www.e-a-r.com/pdf/hearingcons/NoiseNav.xls>>
- Bogoch, I. I., House, R. A., and Kudla, I. (2005). "Perceptions About Hearing Protection and Noise-Induced Hearing Loss of Attendees of Rock Concerts," *Canad. J. Pub. Health* 96(1), 69-72.
- Broste, S. K., Hansen, D. A., Strand, R. L., and Stueland, D. T. (1989). "Hearing Loss Among High School Farm Students," *Am. J. Pub. Health* 79(5), 619-622.
- Chermak, G. D., Curtis, L., and Seikel, J. A. (1996). "The Effectiveness of an Interactive Hearing Conservation Program for Elementary School Children," *Lang., Speech, and Hearing Services in Schools* 27(1), 29-39.
- Chermak, G. D. and Peters-McCarthy, E. (1991). "The Effectiveness of an Educational Hearing Conservation Program for Elementary School Children," *Lang., Speech, and Hearing Services in Schools* 22(1), 308-312.
- EPA (1979). "Noise Labeling Requirements for Hearing Protectors," Environmental Protection Agency, Fed. Regist. 44(190), 40 CFR Part 22, 56130-56147.
- Knobloch, M. J. and Broste, S. K. (1998). "A Hearing Conservation Program for Wisconsin Youth Working in Agriculture," *J. Sch. Health* 68(8), 313-318.
- Korpert, K. (1999). "Hearing Thresholds of 15 to 18 Year Old Pupils and Apprentices," *J. Acoust. Soc. Am.* 105(2), Pt.2, p. 1009.
- Laitinen, H., Suzuki, Y., Iwata, K., Bjork, E., Myyrylainen, P., and Jokitulppo, J. (2001). "Comparison Between Noisy Leisure Activities of Japanese and Finnish Young People," in *Proceedings of Inter-Noise 2001*, edited by R. Boone, Nederlands Akoestisch Genootschap (NAG), Maastricht, The Netherlands, paper 551.
- Lankford, J. E., Mikrut, T. A., and Jackson, P. L. (1991). "A Noise-Exposure Profile of High School Students," *Hearing Instr.* 42(12), 19-24.
- Lass, N. J., Woodford, C. M., Lundeen, C., Lundeen, D. J., Everly-Myers, D. S., McGuire, K., Mason, D. S., Paknik, L., and Phillips, R. P. (1987). "A Hearing-Conservation Program for a Junior High School," *Hearing J.* 40(11), 32-40.

- Lass, N. J., Woodford, C. M., Lundeen, C., Lundeen, D. J., and Everly-Meyers, D. S. (1987). "A Survey of High School Students' Knowledge and Awareness of Hearing, Hearing Loss, and Hearing Health," *Hearing J.* 40(6), 15-19.
- Lewis, D. A. (1989). "A Hearing Conservation Program for High-School-Level Students," *Hearing J.* 42(3), 19-24.
- Mercier, V., Luy, D., and Hohmann, B. W. (2003). "The Sound Exposure of the Audience at a Music Festival," *Noise & Health* 5(19), 51-58.
- Nadler, N. B. (1995). "Hearing Conservation in the Vocational Classroom," *Hear. Rehab. Qtrly.* 20(3), p. 12-15 and 21.
- Peppard, A. R. and Peppard, S. B. (1992). "Noise-Induced Hearing Loss: A Study of Children at Risk," *Hearing J.* 45(3), 33-35.
- Pirzanski, C. and Berge, B. (2005). "Ear Canal Dynamics: Facts Versus Perception," *Hearing J.* 58(10), 50-58.
- Plakke, B. L. (1985). "Hearing Conservation in Secondary Industrial Arts Classes: A Challenge for School Audiologists," *Lang., Speech, and Hearing Services in Schools* 16, 75-79.
- Plakke, B. L. (1991). "Hearing Conservation Training of Industrial Technology Teachers," *Lang., Speech, and Hearing Services in Schools* 22, 134-138.
- Widen, S. E., Holmes, A. E., and Erlandsson, S. I. (2006). "Reported Hearing Protection Use in Young Adults from Sweden and the USA: Effects of Attitude and Gender," *Int. J. Audiol.* 45(5), 273-280.
- Widen, S. E. O. and Erlandsson, S. I. (2004). "The Influence of Socio-Economic Status on Adolescent Attitude to Social Noise and Hearing Protection," *Noise & Health* 7(25), 59-70.
- Woodford, C. M., Lawrence, L. D., and Bartrug, R. (1993). "Hearing Loss and Hearing Conservation Practices in Rural High School Students," *J. Agr. Education*, Winter, 77-84.
- Woods, B. G. and Rimmer, T. W. (1996). "Hearing Protector Utilization by Employees of Small Lawn Maintenance Business," *Am. Ind. Hyg. Conf.*, Washington, DC, paper 371.
- Zeigler, M. C. and Taylor, J. A. (2001). "The Effects of a Tinnitus Awareness Survey on College Music Majors' Hearing Conservation Behaviors," *Med. Prob. Perf. Artists* 16(4), 136-143.

**For additional reference materials on hearing and hearing protection
please visit me on the web at:**


www.e-a-r.com/hearingconservation

Table I - Twenty-three (23) studies conducted from 1985 though 2006 providing estimates of use rates of HPDs.**The categories are: students, teachers, recreational/music, farming, and lawn maintenance**

Author	Year	Country	Type	Subjects	%Wearers	%Plugs	Comments
Korper	1999	Austria	apprentices, age 15-18	41470	18	43	data from 1977
					77		data from 1997; pref. for muffs may be due to varying noise exposures where muff use is easier
Bennett et al.	1999	US	2nd grade	126	34		asked re use with respect to lawn mowing, shooting, monster truck races, and snow mobiling
Chermak et al.	1996	US	4th grade	48	15	100	"do you wear earplugs when you are around power saws or drills?"
Chermak et al.	1991	US	3rd/4th grade	12	50		when shooting firearms
Lankford et al.	1991	US	high-school students	426	10		used HPDs "while in loud sound environments"
Lass et al.	1987	US	students age 11-15	236	13	100	"do you ever wear earplugs to protect your hearing," survey given to students in science class
Lass et al.	1987	US	students age 15-18	101	16	100	survey given to students in health classes; rate is those saying they "never wore earpugs to protect hearing"
Lewis	1989	US	high-school students	1529	15	100	"do you ever wear earplugs to protect your hearing"
Nadler	1995	US	high school vocational classroom	364	6		values represents those who sometimes wore HPDs
					81		subsequent to 4-session educational program with teacher support
Peppard et al.	1992	US	7th grade	4121	0		exposures included shooting, go-karts, firecrackers, lawn care and music; 29 students identified with NIHL
Woodford et al.	1993	US	ag students, grade 9-12	127	4		always wear HPDs around machinery and guns; increased to 22% w/sometimes included
Zeigler et al.	2001	US	college music majors	246	3		reported number is while playing music; 6% wore HPDs for other loud noises - rock concert, lawny mower etc.
Allonen-Allie et al.	1990	US	vocational teachers	21	65		65% defined as occasional use; 50% of students resisted using HPDs; HPDs required 1/2 as often as other safety
Plakke	1991	US	industr. arts teachers	278	5		never use = 33%
Plakke	1985	US	industr. arts teachers	146	3		never use = 62%
Laitinen et al.	2001	Finland	youth avg age = 18	1071	5		percent use is avg. of often and always, and avg'd across playing music, discos, sports w/music, concerts
		Japan	youth avg age = 18	1390	1		percent use is avg. of often and always, and avg'd across playing music, discos, sports w/music, concerts
Bogoch et al.	2005	Canada	large rock concerts	2044	3		85% experienced tinnitus post concert; 42% said would wear earplugs if provided free at door
Mercier at al.	2003	Switzerland	music festival	601	5		avg age ~ 28; 34% used plugs sometimes; avg Leq = 95 dBA; 15% of responders found sound too loud
Widen et al.	2004	Sweden	students 13-19	1547	21		measured use at pop concerts and discos; tabled number is avg. of two
Widen et al.	2006	Sweden	students age 17-21	179	61		measured use at concerts; those with "worry" about noise and tinnitus more like to be wearers
		US	students age 17-21	203	9		(see prior line) US students viewed noise more positively than Swedish students
Broste et al.	1989	US	farming	643	9		high-school age workers
Knobloch et al.	1998	US	farming	375	23		baseline data for 7th - 9th grade students
					87		same students 3 years later after intervention; free HPDs, audiograms, mailing to students, most useful
Woods and Rimmer	1996	US	lawn maintenance	>51	19		all companies which were observed nominally required use of HPDs
					23.5		



NOTE: %wearers = percentage of noise-exposed subjects wearing HPDs by criterion of study, usually wearing devices 100% of time. See comments for more info.

NOTE: %plugs = percentage of wearers of HPDS who use earplugs as opposed to earmuffs.



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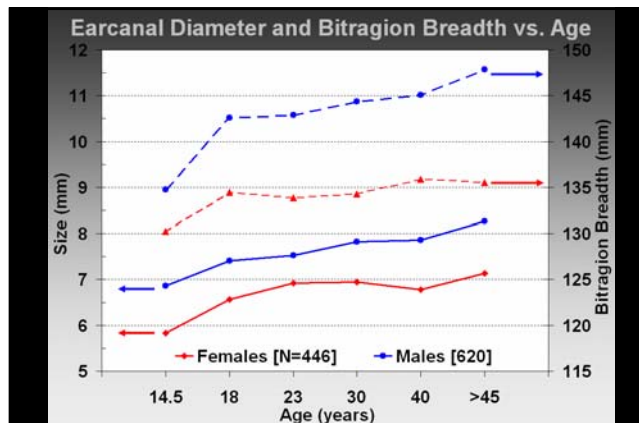
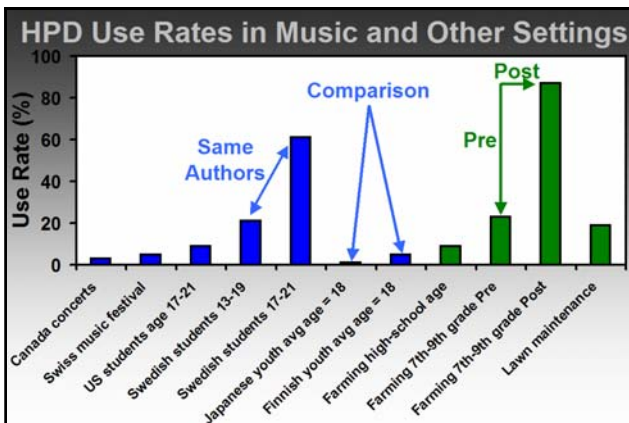
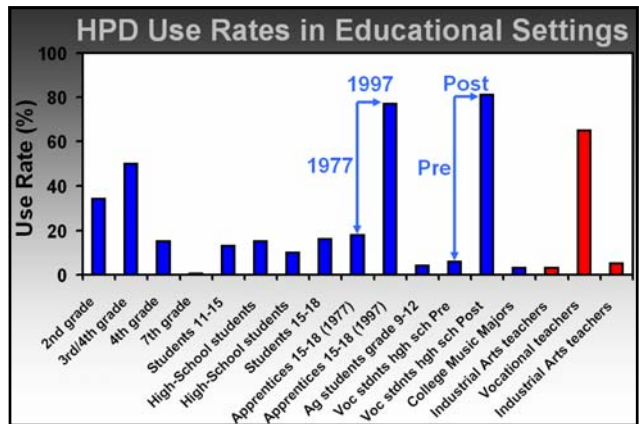
When Should Hearing Protection be Worn

- Shooting guns - target shooting, skeet, hunting
- Using power tools – saws, routers, power sanders, etc.
- Yard work – mowing, leaf blowing, chain saws, edging, etc.
- Farm work – tractors, combines, feed areas, grain dryers, etc.
- Loud public events - concerts, night clubs, auto racing, tractor pulls, sporting events (?), etc.
- Recreational vehicles – motorcycles, 4-wheelers, snowmobiles
- Educational settings – music performance/rehearsal, vocational
- Noisy part-time jobs




Market Estimates

- Occupational and Military hearing protection market – 90%
- Consumer, adult – 9% U. S. (6% Europe)
- Consumer, children – 1% U. S. (4% Europe)





Measuring Performance (I)



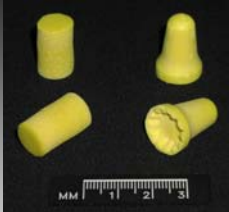
- No data (?) in the literature on attenuation in children
- The **Gold Standard** in measuring attenuation is REAT (Real-ear attenuation at threshold)
 - Difficult to implement with children
- Other methods are available but they too are difficult to implement in the smaller earcanals of younger children
- Pirzanski & Berge study suggests children's canals are firmer and less affected by mandibular motion

Measuring Performance (II)




- Since children's exposures do not normally require maximum levels of attenuation, precise estimates of attenuation are not critical
- %-age use time is the much more critical parameter; increasing use rates to 100% would provide substantial gains in effective protection
- If attenuation data for children age 5 and up are needed, best approach is REAT evaluations with surrogates - teenagers (15 – 18), especially those with smaller earcanals

Earplugs for Ages 5 – 15 Foam




- Classic® Small vinyl foam earplug
- E-Z-Fit® polyurethane foam earplug
- Notes:
 - Tends to be most comfortable
 - Takes more time to insert than other styles
 - May require parental assistance because of difficulty in rolling down and insertion
 - Corded versions available to reduce loss of plugs
 - Classic Small can be used for swimming

Earplugs for Ages 5 – 15 Premolded



- Howard Leight Fusion® earplugs (small)
- North Com-Fit™ earplugs (small)
- Swimming E•A•R® Plugs – Youth
- Notes:
 - Easier to insert for kids, but less comfortable than foam
 - Caution: careful removal is necessary
 - Corded versions available for Fusion and Com-Fit
 - Can be used for swimming

Earplugs for Ages 5 - 15 Malleable and Custom



- Malleable silicone pellets – Mack's® Pillow Soft® Earplugs
- Custom earmolds
- Notes:
 - Pellets rely on stickiness and cap canal at entrance, thus poor retention and large occlusion effect
 - Custom molds comfortable, but can be difficult to make and may need regular replacement as children grow

Earplugs for Ages 5 - 15 Canal Caps



- 3M™ Banded Hearing Protector 1310
- E•A•R Caps® semi-inserts
- Notes:
 - Easy to use and store around neck
 - Band can be bumped, making noise and/or losing seal
 - May be too large for smaller ears
 - Less attenuation and more occlusion effect
 - Visually apparent, may be positive or negative

Earmuffs for Ages 5 - 15

- Economy E•A•R® Muff
- Peltor Junior™ earmuff
- Notes:
 - Easy to use
 - Can get in the way
 - Visually apparent – may be positive or negative
 - No small-cupped muffs on market today (?)



HPDs for Children Under 5

- No products specific to this age range
- Malleable plugs recommend against tearing in half
- Risk of swallowing or choking
- Use corded plugs and pin to child's clothing
- Use earmuffs, but ...



A European Experience




When heads get really small

Concept Development



Infants and Newborns

- Natus MiniMuffs® adhesive earmuffs
- Notes
 - About 10-dB of noise reduction
 - Suggested for NICUs, and during use of ventilators, MRIs, or transport

