MP3 player listening sound pressure levels among 10 to 17 year old students[1]

S.E. Keith[1], D.S. Michaud[2], K. Feder[2], Ifaz Haider[3], L. Marro[4], E. Thompson[5], A. Marcoux[6]

1 Health Canada, Environmental & Radiation Health Sciences Directorate, Consumer and Clinical Radiation Protection Bureau, Consumer & Industrial Products Division, Ottawa, Ontario, Canada, K1A 1C1
2 Health Canada, Environmental & Radiation Health Sciences Directorate, Consumer and Clinical Radiation Protection Bureau, Health Effects and Assessments Division, Ottawa, Ontario, Canada, K1A 1C1
3 Carleton University, Faculty of Engineering and Design, Department of Mechanical and Aerospace Engineering, Ottawa-Carleton Institute for Biomedical Engineering, Minto Centre 3034, Ottawa, Ontario, Canada, K1S 5B6
4 Health Canada, Environmental & Radiation Health Sciences Directorate, Environmental Health Science and Research Bureau, Population Studies Division, Biostatistics Section, Ottawa, Ontario, Canada, K1A 0K9
5 University of Ottawa, Faculty of Social Sciences, School of Psychology, Ottawa, Ontario, Canada, K1N 6N5
6 University of Ottawa, Faculty of Health Sciences, Department of Audiology and Speech Language Pathology, Ottawa, Ontario, Canada, K1H 8M5

INTRODUCTION

Our lab has recently reported that, if played at maximum volume settings for prolonged durations, portable digital audio players are capable of causing hearing impairment among users (Keith et al. 2008). At maximum volume settings, the sound level output ranged from 101 to 107 dBA, which, after 3 to 12 minutes, would exceed the most protective occupational noise exposure level limits set in Canada, of 85 dBA Lex(8hr) with a 3-dB exchange rate (Canadian Centre for Occupational Health and Safety 2009).

We also reported that measured sound levels from portable digital audio players among a small sample of 28 university subjects ranged from 55 to 85 dBA (McNeill et al. 2010). When considered in combination with self-reported duration of daily usage, none of the subjects used their device at a level that exceeded an 85 dBA Lex(8hr) under typical listening conditions. Nevertheless, self-reported tinnitus was associated with measured volume output levels and how long people owned their device.

The primary objective of this study was to build upon our previous work by investigating whether subjects listen to their devices at sound levels that would increase their risk of hearing impairment when their duration of listening has been taken into account.

METHODS

Subjects

This study included 248 subjects aged 10 to 18 (110 males, $\bar{x}$ = 12.75, *SD* = 1.74; 138 females, $\bar{x}$ = 12.45, *SD* = 1.67), recruited from within Ottawa public and private schools. A total of 29 subjects (17 males, 12 females) had to be removed from the

[1] The full manuscript with the same title has been submitted to the *Journal of the Acoustical Society of America* 03/28/2011

analysis because they did not: i) use headphones (4 males, 3 females); ii) provide listening durations (2 females); have a device with them at the time of testing (12 males, 7 females); and iii) one male had to be removed because he was above the age of 17 at the time of testing. The current analysis is therefore based on 219 subjects aged 10 to 17 (93 males, $\bar{x}$ = 12.87, *SD* = 1.69; 126 females, $\bar{x}$ = 12.55, *SD* = 1.69) from 15 participating private and public schools. The participation rate was 11 %. This low participation rate may be related to distribution of consent forms by hand from teacher to student to parent, and the need for consent from both student and parent. This study was approved by the human research ethics board at Health Canada. Data collection took place between October 2009 and May 2010.

Sound level measurements and Lex calculation

A detailed characterization of the sound level measurements has previously been documented by Keith et al. (2008) and McNeil et al. (2010).Using a Bruel & Kjaer type 4128 HATS, two 32s measurements of L_{Aeq}(32s) were taken for both typical and maximum settings. The daily exposure level, Lex(8hr), was calculated from subjects' self-reported duration of use per week (in hours), using a 3 dB exchange rate. Background sound level measurements were between 40 and 52 dBA.

Initially, sound level recordings were taken from two of the subject's favourite songs at their typical listening setting. For each measurement, subjects were instructed to load one of their favourite songs on their MP3 player and set their device at the level they would normally or typically listen to it. At this point subjects listened through both earphones in the quiet (≤ 52 dBA) testing environment. Then, subjects with earbuds or insert earphones were instructed to place their right earbud/earphone on the manikin while keeping the left in their own ears. They then listened to the output of the manikin using an appropriately equalized (ISO 11904-2 (2004)) Koss ESP950 circumaural electrostatic monitoring headphone on their right ear. Subjects were then asked to adjust the fit of their right earbud on the manikin until the song sounded the same in the Koss monitoring headphones and their left earbud. By implementing this procedure, to the best of the subject's ability, the sounds measured by the manikin matched the earphone output from their MP3 players.

After measuring two songs at their typical listening setting, subjects played two more songs at their maximum volume setting. The maximum volume measurements were carried out identically to the typical volume measurements described above, with one difference. The subjects marked their maximum volume setting on an 82 mm x 7 mm horizontal bar labelled 0 to 100. They then set their MP3 player to that volume setting. A volume based on visual recollection was expected to provide an estimate of maximum listening volume, without being biased by the background noise at the time of testing.

Statistics

Sound level results, in tables include the mean ($\bar{x}$), medians (*M*), minimum value, maximum value and the associated interquartile range (IQR; 75th percentile minus 25th percentile). Statistical differences between group means were analyzed using the *t*-test, with an alpha level of 0.05. Assumptions for the t-test were verified using the Anderson-Darling test for normality and Bartlett test for equal variance between groups. When assumptions of normality and equal variance were not satisfied, the Kruskal-Wallis (KW) χ^2 non-parametric test was applied. Proportional differences in

groups were tested using chi-square test of independence, with Yates correction for 2x2 contingency tables. The Pearson correlation coefficient was used to assess the linear relationship between two variables. When the assumptions of bivariate normality and linear relationship were not satisfied for the variables, then the non-parametric Spearman correlation coefficient was applied.

RESULTS

Portable digital audio player use

Of the 219 subjects in the final analysis, 216 (98.6 %) specified the type of device they used. Further 172 subjects (78.5 %) specified the type of headphones/earphones used (see Table 1).

Table 1: Frequency and percentage of different types of portable digital audio players and earphones/headphones

Type of portable digital audio player	Frequency (%) N=219	Reported type of earphones/headphones	Frequency (%) N=219
Apple iPod Nano	87 (39.7)	Earbuds	89 (40.6)
Apple iPod Classic	55 (25.1)	Insert canal	44 (20.1)
Apple iPod Touch	22 (10.0)	Circumaural	12 (5.5)
Apple iPod Shuffle	7 (3.2)	Supra-aural	5 (2.3)
Apple iPhone	4 (1.8)	Supra-aural and earbuds	12 (5.5)
Sony PSYC	4 (1.8)	Supra-aural and insert canal	1 (0.5)
Other	34 (15.5)	Circumaural and earbuds	3 (1.4)
Do not know	3 (1.4)	Circumaural and insert canal	5 (2.3)
Missing	3 (1.4)	Other	1 (.5)
		Missing	47 (21.5)

The history of MP3 player use varied from 1-4 weeks (<1 %) to more than 5 years (11 %). About 5 % reported using their device for less than 6 months and 4 % indicated between 6 months and 1 year. Fifty-one percent of the subjects used their device between 1 and 3 years and 28 % used it between 3 and 5 years. The mean daily usage ranged from 0.014 hours to 12 hours and was not statistically different between males ($\bar{x}$ = 1.13, *SD* = 1.35) and females ($\bar{x}$ = 1.06, *SD* = 1.71) (KW χ_1^2 =3.17, p=0.0751).

Measured equivalent free-field sound levels

Sound level results are provided in Table 2 for all subjects and for males and females separately. When typical sound levels were considered with the derived duration of daily use, 3.2 % of the subjects surpassed the most stringent and common occupational noise limit in Canada of 85 dBA Lex(8hr) with a 3 dB exchange rate. If it was assumed that subjects' total listening time was done at their maximum sound level

settings, 8.7 % would exceed this limit. The average self-reported maximum volume settings measured about 7 dBA higher than subjects' typical volume settings. The correlation between the two settings was 0.805, $p < .0001$.

Personal variables

Gender was examined as a potential personal variable that could influence the listening habits of users of MP3 players. On average, males preferred to listen to their iPods or MP3 players at slightly higher volume settings compared to females for 3 of the 4 measured values, Leq(32s) maximum condition (KW χ_1^2 =4.37, p=0.0366), Lex(8hr) typical (KW χ_1^2 =5.04, p=0.0247) and Lex(8hr) max (KW χ_1^2 =5.68, p=0.0171) (see Table 2). There was no statistical difference between the percentage of males and females listening to their iPods or MP3 players greater than 75 dBA or 85 dBA, whether for Leq(32s) or Lex(8hr).

Table 2: Energy average sound levels (dBA) for typical and maximum sound level settings and calculated time-weighted average eight hour exposure level, Lex(8hr)

	n[a]	Mean	SD[b]	SEM[c]	Min[d]	Max[e]	Median	IQR	percent above (%)	
									75 dBA	85 dBA
All subjects										
Leq(32s)[f] Typ	219	68.6	11.5	0.8	45	113	68	15	26.0	5.0
Leq(32s)[f] Max	219	76	12.9	0.9	49	113	76	18	52.1	21.5
Lex(8hr) Typ	219	57.0	14.0	0.9	29	110	56	18	9.6	3.2
Lex(8hr) Max	219	64.3	15.7	1.1	30	110	65	22	22.4	8.7
Females										
Leq(32s) Typ	126	67.8	12.2	1.1	45	113	66	15	22.2	6.4
Leq(32s) Max	126	74.5	13.8	1.2	49	113	74	19	46.8	18.3
Lex(8hr) Typ	126	55.7	14.9	1.3	29	110	54	18	11.9	4.0
Lex(8hr) Max	126	62.5	16.8	1.5	30	110	62	24	18.3	10.3
Males										
Leq(32s) Typ	93	69.6	10.5	1.1	50	100	69	16	31.2	3.2
Leq(32s) Max	93	77.7*	11.5	1.2	51	105	78	14	59.1	25.8
Lex(8hr) Typ	93	58.8*	12.4	1.3	35	91	58	20	6.5	2.2
Lex(8hr) Max	93	66.8*	13.7	1.4	35	101	69	17	28.0	6.5

* Significant difference to corresponding groups from females, $p < 0.05$. [a]n, the number of subjects; [b]SD, standard deviation; [c]SEM, standard error of the mean; [d]Min, minimum subject listening level; [e]Max, maximum subject listening level; [f]Leq(32s), the average of two 32 second sound level measurements at subjects' typical (Typ) and maximum (Max) volume settings

DISCUSSION

Based on the sound levels associated with typical usage in our study: i) nearly 74 % of the subjects listened at levels less than 75 dBA L_{eq} which would pose no known risk to hearing even if listened to for 8 hours per day, ii) 9.6 % exceeded 75 dBA Lex(8hr), and 3.2 % were above a damage-risk criterion level of 85 dBA Lex(8hr) with a 3 dB exchange rate. If we made the cautious assumption that subjects listened maximum volume settings for their entire self-reported listening duration, 22.4 % of them exceed 75 dBA Lex(8hr) and 8.7 % would yield a Lex(8hr) exposure level above 85 dBA. These values seem to be far less than that reported by most others (Williams 2005; Kumar et al. 2009; Ahmed et al. 2007). It is plausible that in our study

the quiet classroom conditions resulted in subjects selecting a typical volume setting that was lower than it would have otherwise been if background noise levels were higher. Background noise levels may bias the listening levels. To reduce the influence of the low background noise on measurement of maximum listening levels, the subjects first placed a line through a bar intended to represent their maximum volume conditions. They then set the volume indicator on their device to the same location. However, we were unable to determine what fraction of daily listening duration was at these worst-case listening levels. Subjects may have had difficulty recalling their maximum volume settings. Furthermore, the issues of social desirability, which occurs when subjects respond as they think they "should" or how "good" people would, could have been involved. Subjects may not have wanted to play their devices loudly in front of researchers. These shortcomings are the same as those we reported in McNeill et al. (2010) and will continue to be a source of uncertainty in future studies that follow the same methodology.

CONCLUSIONS

1. Under the conditions of the current study, the percentage of subjects with exposures above 85 dBA, Lex(8hr) was about 3 % and 9 %, using the measured typical and maximum sound levels, respectively, when both were combined with self-reported typical listening durations.
2. Tightness of fit, the influence of background sound levels and the proportion of time subjects listen to their device at their worst-case volume settings are all variables that need to be more carefully examined with questionnaires. This will improve the estimation of risk that MP3 player usage may pose to hearing.
3. Despite efforts to control important parameters, the magnitude of uncertainty in the current study was large enough to affect results and could, therefore, affect any conclusions drawn from these results. To improve the assessment of potential risks that may be associated with use of MP3 players, in future studies, further control and systematic characterization of the uncertainties will be needed.

REFERENCES

Ahmed S, Fallah S, Garrido B et al. (2007). Use of portable audio devices by university students. Can Acoust 35: 35-52.

Canadian Centre for Occupational Health and Safety (2009). What are the occupational exposure limits for workplace noise? www.ccohs.ca/oshanswers/phys_agents/exposure_can.html (date last viewed 3/2/11).

ISO 11904-2 (2004). Acoustics - Determination of sound immission from sound sources placed close to the ear - Part 2: Technique using a manikin.

Keith SE, Michaud DS, Chiu V (2008). Evaluating the maximum playback sound levels from portable digital audio devices. J Acoust Soc Am 123: 4227-4237.

Kumar A, Mathew K, Alexander SA et al. (2009). Output sound pressure levels of personal music systems and their effect on hearing. Noise & Health 11: 132-140.

McNeill K, Keith SE, Feder K et al. (2010). MP3 player listening habits of 17 to 23 year old university students. J Acoust Soc Am 128: 646-653.

Williams W (2005). Noise exposure levels from personal stereo use. Int J Audiol 44: 231-236.