Quantifying the risks from listening to personal stereos

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ABSTRACT

Currently there has been and is a lot of discussion generated by articles in the popular press concerning the possible future hearing loss developed by individuals who listen to personal stereo players (PSP). How much of this concern is real and how much is unreal perception from media publicity? In this work PSP users were approached in their natural environment and questioned about their use while the equivalent at ear L_{Aeq} was measured. From this information an $L_{Aeq,8h}$ was calculated for comparison to the workplace noise exposure regulations commonly in place in New Zealand and Australian jurisdictions. The results indicate that approximately 25% of a cross section of typical users could be considered to be at risk. Is this significant and how does this compare to workplace noise exposure?

INTRODUCTION

Constant exposure to loud noise/sound will cause noise injury and subsequent damage to hearing over time the level of hearing loss depending on the total exposure (loudness x time) (WHO: 1980; ISO 1999: 1990). However, there is still considerable debate as to what degree of noise injury occurs from "leisure" noise – leisure being that time spent at one's own disposal. It is agreed that there is some level of risk to hearing from leisure noise exposure (Axelsson: 1995; Maassen, Babisch, Bachman, Ising, Lehnert, Plath, Plinkert, Rebentisch, Schuschke, Spreng, Stange, Struwe and Zenner: 2001; Smith, Davis, Ferguson and Lutman: 2000) and that further studies of specific activities are warranted. Neitzel, Seixas, Olson Daniell and Goldman: (2004) concluded that for construction industry workers *"the predominance of noise exposure stems from occupational, rather than nonoccupational, activities"* (p 245).

Because of the obvious close coupling to the ear For many years there has been considerable discussion and concern regarding the effects on hearing of the regular use of the Personal Stereo Player (PSP) (Carter, Waugh, Keen, Murray and Bulteau: 1982; Catalano and Levin: 1985; Rice, Breslin and Roper: 1987; Clark: 1990; Meyer-Bich: 1996; LePage and Murray: 1998). Only one of these studies (Rice, Breslin and Roper: 1987) went into the "streets" and measured the actual levels from individuals who were using their devices at the time. In the remaining studies individuals were either queried about the subjective level to which they set their volume (how loud/how long) or asked to set the level of an equivalent device in a laboratory setting. These 'laboratory' studies then implied that in the future, at least to a limited extent, there will be an increased incidence of hearing loss due to PSP use.

However, some work (Turunen-Rise, Flottorp and Tvete :1991) suggests that "the risk of acquiring permanent noise-induced hearing loss (NIHL) from use of PCP [personal cassette players] is very small for what we found to be normal listening conditions" (p 239). It is this apparent risk/no-risk conflict that gave rise to the study reported here. What is the listening level set in daily practice by users and how long do they listen? It was felt that measurements of PSP noise exposure levels should be taken in 'real world' situations rather than extrapolations made from laboratory tests. These measurements should preferably be performed in areas where users experience relatively high background noise and where levels would be set to maximum values or 'worst case conditions'. The results may then be, if anything, an overestimate of the risk of noise injury but they would give a representative real world starting point.

EXPERIMENTAL METHOD

The experimental setup was arranged similar to that used by Rice, Breslin and Roper (1987) with actual measurement technique followed the requirements outlined in *AS/NZS 1269.1* and *ISO/DIS 11904-2*. Rather than utilise an artificial ear, a head and torso simulator was employed in order to appear more 'user friendly' in the street to participants and passers by.

The procedure utilised a Knowles Electronics Manikin for Acoustic Research (KEMAR) torso and head (satisfying ANSI S3.36-1985), fitted with a Zwislocki artificial ear simulator (satisfying ANSI S3.25–1979), was used to measure the equivalent at ear diffuse field level to which the user was exposed. The measuring instrumentation consisted of a B&K 4134 pressure response microphone with a 2639 preamplifier fitted to a 2804 power supply and a 2231 Integrating Sound Level Meter. The instrumentation was field calibrated at the commencement and conclusion of each measurement day.

The earphones of the PSP under test are carefully placed over the 'ears' of the manikin, only one of which was in use, and while the PSP was playing, the noise level under the headphone was recorded.

The noise parameter measured was the equivalent continuous A-weighted noise exposure over the sample time T, $L_{Aeq,T}$. The sample time was set at 120 seconds (*ie* 2 minutes). This was considered to be a reasonably representative time period and of sufficiently short duration so as not to take too much of the participants time.

Individuals passing by in the street who were using a PSP at the time were approached and asked if they would be willing to participate. This was the only selection criteria. Those who responded positively account for the distribution in gender, age, etc, of the sample. If the individuals were willing to participate then the (unchanged) level of their PSP was measured. While the noise level was being measured the subject was asked to respond to a short questionnaire. These questions included: hours per day of use; years of use; age; incidence of tinnitus; self-reported/family expressed hearing loss; conversational difficulty in background noise; and occupation.

Two measurement sites were chosen at public areas where individuals would be regularly on the move, usually commuting to or from work, to places of study or to meet friends. The locations were close to public transport interchange areas (train, bus and tram hubs) and near busy traffic intersections. The first site was in Melbourne, adjacent to Flinders Street Station, the main Melbourne commuter railway station, adjacent to a busy traffic, bus and tram intersection. The second site was outside the Sydney Town Hall, in the centre of Sydney, directly above a major underground commuter railway station and adjacent to a busy pedestrian, traffic and bus intersection. One day was spent taking measurements at each site.

These sites were chosen to represent not just places where a wide selection of people regularly pass but areas where individuals experience high levels of environmental noise and would be more likely to have the volume levels on their PSP at the loudest preferred setting. So the results would be expected to represent the upper levels of exposure that would reasonable be expected. The long term background noise level at both measurement sites fluctuated over the course of the 'measurement day' (9:30 am to 4:00 pm). Five minute samples of the A-weighted equivalent continuous background noise level, L_{Aeq}(b/g), were taken when the opportunity arose, typically once in the morning, afternoon and at around midday (six measurements in all). The mean A-weighted background noise level was 73.2 dB (SD = 2.3) with a range of 71.1 to 76.0 dB.

While this is the mean background noise level at the measurement site this may not be the mean background level experienced by the users as they were moving about during their activities. The background noise experienced by the subjects could be higher or lower depending on whey are at any particular time. The level of the volume of their PSP would only be expected to be adjusted where they are in a particular environment for a longer time.

Subjects were chosen at random from those passing by the measurement location. They were a mixture of 15 females and 40 males ranging in age from 15 to 48 years (mean = 23.6 years, SD = 5.7 years). There was a wide range of occupations with the majority being from the 'white collar' area or students. This would be expected of the population sampled as both locations were well within the city central business district.

RESULTS

Of the individuals sampled the measured A-weighted equivalent continuous noise level, $L_{Aeq,T,}$ under the headphones ranged from 73.7 dB to 110.2 dB with a mean of 86.1 dB (SD = 7.9). With a mean A-weighted background noise level of 73.2 dB this implies a signal to noise ratio (S/N) of about 13 dB. However, while this may seem high as noted above the mean background noise level at the measurement site may not necessarily accurately represent the background noise level experienced by the subject over the past while, as they are moving about their business. For example, they may have just alighted from a noisy train, tram or bus onto a busy street or moved from a quiet office into a comparatively noisy street.

The given listening time per day ranged from 40 minutes to a reported 13 hours (mean = 2.38 hrs, SD = 2.14 hrs) and the number of years of using ranged from less than a month to an estimated 15 years (mean = 5.6 years, SD = 4.52 years).

The main parameter calculated from the collected data was the eight hour equivalent continuous A-weighted noise exposure ($L_{Aeq,8h}$) and is defined as *"that steady state sound pressure level which would in the course of an eight hour period deliver the same A-weighted sound energy as that due to the actual noise on any particular representative working day"* (see AS/NZS 1269.1: 2005). Mathematically it is calculated from the equation:-

$$L_{Aeq,8h} = L_{Aeq,T} + 10 \log_{10} [T/8],$$

where T is the actual exposure time in hours; and

$L_{Aeq,T}$ is the equivalent continuous A-weighted noise exposure over the time period T.

The results of this process are presented in *Figure 1* and can be seen to approximate a normal distribution as indicated by the superimposed curve. The mean $L_{Aeq,8h}$ was 79.8 dB with a standard deviation of 9.0 dB.

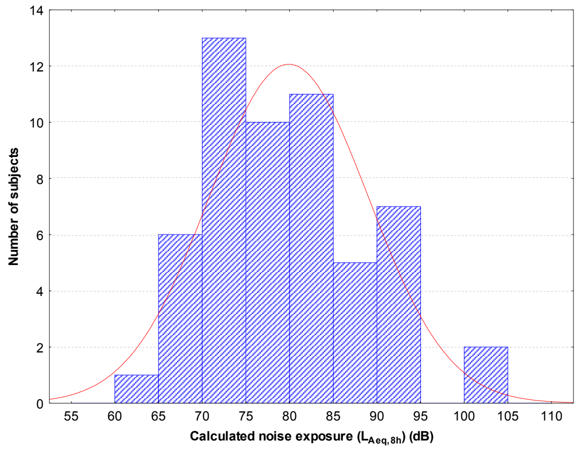

Figure 1 *Distribution of the equivalent continuous eight hour noise exposure ($L_{Aeq,8h}$)*

There is now a simple comparison able to be made of the noise exposure experienced by PSP users to noise exposure recommendations used for workplace noise exposure regulations in common use around the globe (I-INCE: 1997). *Figure 2* shows a scattergram of the calculated continuous equivalent eight hour noise exposure with indicators at 75 and 85 dB. It is considered that "a*t $L_{Aeq,8h}$ levels of 75 dB and lower, even prolonged occupational noise exposure will not result in noise-induced hearing impairment"* (WHO: 1999).

In many jurisdictions an $L_{Aeq,8h}$ of 85 dB is considered to be the level of acceptable risk for noise exposure in the workplace (I-INCE: 1997) while 75 dB is considered to represent a negligible risk.

The average calculated daily exposure with respect to age is also shown in *Figure 2*. While the average exposure is 79.8 dB and the majority of the population fall below the 'acceptable' risk level of 85 dB there is still approximately 25% of the population beyond this level that could be classified as being at risk.

There is a statistically significant difference in exposure levels between females and males clearly shown demonstrated in *Figure 3* (p = 0.023). The mean exposure level $L_{Aeq,8h}$ for females was 75.3 dB (SD = 7.1 dB) and for males was 80.6 dB (SD = 10.1 dB).

There was no indication by any participant that they had difficulty hearing normal conversation in background noise.

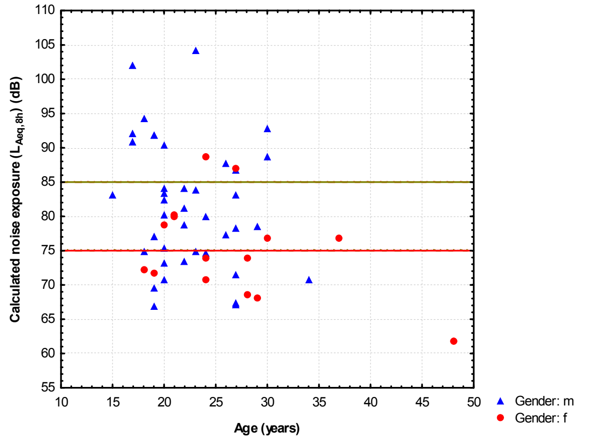

Figure 2 *Calculated daily noise exposure from PSP use with respect to age for females and males and in relation to the 'safe' (= 75 dB) and 'acceptable risk' (= 85 dB) criteria*

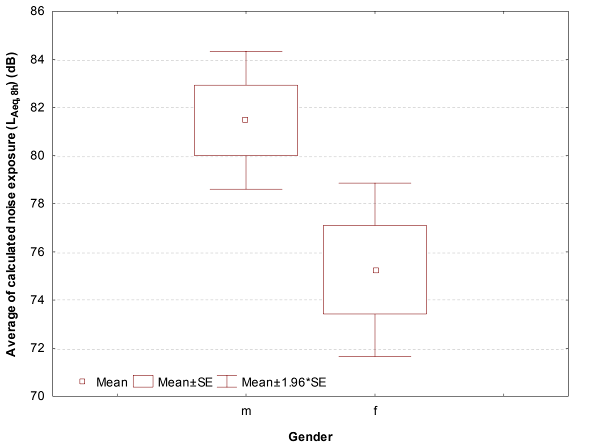

Figure 3 *Average calculated eight hour equivalent continuous noise exposure levels for females and males,\ showing the mean, box = +/- one standard error and bars = +/- 1.96 SE*

However, twelve participants indicated that they felt that they had some sort of hearing loss that they felt was significant.

Thirty nine individuals indicated that they did not experience tinnitus, with 12 indicating occasionally and three frequently. One student (17 years) did not respond to the tinnitus question because of an existing high frequency hearing loss present since birth. He currently used a digital ITE hearing aid in conjunction with listening to his PSP.

There was no statistically significant correlation found between self-reported tinnitus and noise exposure for the 'never' and those who experienced tinnitus 'occasionally'. The mean $L_{Aeq,8h}$ for these two groups was 78.1 dB (SD = 8.6) and 82.1 dB (SD = 8.3) respectively. The three subjects with reported frequent tinnitus were not included due to their small number.

Subjects who self-reported no hearing loss had a mean $L_{Aeq,8h}$ of 79.2 dB (SD = 8.4) while those who did self-report a hearing loss had a mean 81.7 dB (SD = 11.3). There was no statistically significant difference between the two groups. There was also no correlation between the number of years of use of PSPs and the self-reported levels of tinnitus experienced.

DISCUSSION

The average of the calculated $L_{Aeq,8h}$ from the use of a PSP ($L_{Aeq,8h}$), 79.8 dB, was found to be well below the noise exposure level commonly set at the level of acceptable risk for workplace noise exposure (85 dB) but above the level considered to represent negligible risk (75 dB). Males showed a statistically significant tendency toward greater noise exposure levels compared to females, 80.6 dB compared to 75.3dB. The noise exposure level appeared to decline with the increasing age of subjects, however, this is heavily dependent on the small number of individuals sampled above the age of 30 years, *ie* 3 subjects.

The incidence of self-reported tinnitus was not correlated with noise exposure level, although three individuals who did report that they *'frequently'* experienced tinnitus did have high exposure levels. However, other individuals who were exposed to similar levels *'never'* or only *'occasionally'* reported experiencing tinnitus. There was a slight indication that the reported incidence of tinnitus did increase with increasing years of use of a PSP, but with the limited sample size reporting *'frequently'* experienced tinnitus this indication cannot be considered significant. There was no correlation between the number of years of use of a PSP at a high level of exposure and the self-reported incidence of tinnitus.

With respect to self-reported hearing loss, those individuals who felt they had a *'significant'* loss experienced a similar range of noise exposure levels compared to those who self-reported no hearing loss.

The two individuals who experienced exposure levels well above 100 dB (101.9 and 104.2 dB) are, fortunately, the exception and not the rule. At the time of measurement the $L_{Aeq,T}$ levels seemed to be excessively high (99.8 and 110.2 dB respectively) and it was suggested that benefit would be obtained from decreasing the volume. A third subject exhibited a high $L_{Aeq,T}$, but the time of use per day was only around one hour resulting in an at risk exposure level of 91 dB.

More generally, the results indicated that once the PSP user has the volume set such that the $L_{Aeq,T}$ is above 90 dB, their $L_{Aeq,8h}$ will quickly rise above the 85 dB level placing them at risk of possible future hearing loss. While this may not be a hard and fast rule, it does offer the starting point of an education opportunity, viz to *"keep the volume below 85"*. Encouraging a reduction in volume is an effective strategy as for every 3 dB decrease in volume the risk is halved. This is a more realistic path than a request for complete abstention.

LIMITATIONS

In any study of this nature there are limitations on the sample population. Not all individuals who are approached in the street are willing to pause to answer questions and let the level of their PSP be measure. Thus the validity of any conclusion is constrained to populations that match the sample statistics. The sample population was primarily white collar workers or students who would not normally be exposed to high noise levels in their day-to-day work activities. Thus no estimate can be made of work related noise exposure and consequently of total daily noise exposure.

However, as the measurements in this survey were carried out in areas of high background noise the results can be considered to represent those that would be encountered under worst case conditions. An individual using a PSP while walking along a suburban street or in parkland, not experiencing such high background noise could be reasonably expected to use a lower PSP volume compared to the users sampled in this study. So the results presented in this study could be considered to represent the upper limits of exposure that could be expected to occur across society as a whole.

CONCLUSION

While some individuals do expose themselves to significant risk of noise injury by using earphone levels at high settings, the data collected within the limitations of this study does not to indicate that for the majority of typical users there is a significantly increased risk of hearing loss due to PSP use alone. While this project did not attempt to influence listeners in their use of PSPs, the results do demonstrate that there is a need for an education/information programme for the 25% of the user population that falls above the level of risk that has been deemed to be acceptable by work place regulations.

[This work has been more fully reported in Williams (2005)]

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