Accepted for publication in *Ear and Hearing* 20 May 2012

Estimating young Australian adults' risk of hearing damage from selected leisure activities

Objective. Several previous studies have attempted to estimate the risk of noise-induced hearing loss from loud leisure noise. Some of these studies may have over-estimated the risk because they used noise estimates taken from the higher end of reported levels. The aim of the current study was to provide a realistic estimate of the number of young Australian adults who may be at risk of hearing damage and eventual hearing loss from leisure noise exposure.

Design. Average noise levels at five high-noise leisure activities, i) nightclubs; ii) pubs, bars and registered clubs; iii) fitness classes; iv) live sporting events; v) concerts and live music venues were calculated using 108 measurements taken from a large database of leisure noise measurements. In addition, an online survey was administered to a convenience sample of 1000 18- to 35-year-olds, who reported the time spent at these leisure activities, and the frequency with which they undertook the activities. They also answered questions about tinnitus, and their perceived risk of hearing damage. Although the survey data cannot be considered representative of the population of young Australian adults, it was weighted to this population in respect of age, gender, education, and location. The survey data and the average noise levels were used to estimate each individual's annual noise exposure, and in turn, an estimate of those at risk of hearing damage from leisure noise exposure.

Results. For the majority of participants (n=868), the accumulated leisure noise level was within the acceptable workplace limit. However, 132 participants or 14.1% (population weighted) were exposed to an annual noise dose greater than the acceptable workplace noise limit. By far, the main source of high-risk leisure noise was from nightclubs. Those with more leisure noise exposure experienced more tinnitus and perceived themselves to be more at risk than those with lower noise exposures.

Conclusions. It is recommended that nightclub operators reduce noise levels, display warnings, and provide earplugs for patrons and employees. Health promoters should focus their attention on those young adults who are most at risk and provide them with targeted practical advice about reducing their leisure noise exposure and avoiding hearing loss.

Occupational noise has long been identified as potentially damaging (particularly for those who work in high-noise industries) and Australian estimates suggest that around 12% of the workforce is at risk of hearing loss from occupational noise that exceeds accepted levels (Australian Safety and Compensation Council, 2006). Since the 1960s, noise exposure from leisure activities has been identified as a potential source of excessive noise that may also contribute to long-term hearing loss (e.g., Rintelmann & Borus, 1968; Lipscomb, 1969). However, reliable estimates of those exposed to risky levels of leisure noise are difficult to achieve. This is because of a lack of reliable data regarding participation in leisure activities, which is further exacerbated by our tendency to change leisure habits as we move through different phases of life.

In order to estimate the size of the risk of leisure-noise-induced hearing loss, we need to first identify those leisure activities, such as attendance at nightclubs and popular music concerts that result in excessive noise exposure. Since there are no specific noise exposure guidelines available for leisure environments, it is necessary to use workplace noise standards as the yardstick for identifying excessively loud leisure activities. Quantifying the accumulated exposure to leisure activities which exceed the guidelines and then calculating how many people are receiving excessive noise from these activities is required to produce a realistic estimate of the risk of noise-induced hearing damage from leisure activities.

In most countries, including Australia, the UK and Canada, the workplace noise limit is set at 85 dBA continuous equivalent noise level (L_{Aeq}) over 8 hours, with an ‘exchange rate’ of 3 dB. This means that for every 3 dB increase in L_{Aeq}, exposure time must be halved.

For example, if the L_{Aeq} is 88 dBA, the maximum exposure time is reduced to four hours, at 91 dBA, two hours and so on (Standards Australia, 2005). It is important to realise that workplace noise limits do not guarantee a perfectly safe environment, nor do they ensure that no hearing loss will result from such exposure. Rather, such limits are designed to minimise the society-wide risk of noise-induced hearing loss to an 'acceptable' level. Different jurisdictions set their noise limits at different levels depending on the level of risk deemed acceptable. In the US, the National Institute for Occupational Safety and Health recommends a workplace limit of 85 dBA, with an exchange rate of 3 dB,(NIOSH, 1998), but the regulator, the Occupational Safety and Health Administration, sets a limit of 90 dBA, with an exchange rate of 5 dB (OSHA). A noise level of 85 dBA, is considered an 'action' level, which requires that employees undergo annual audiometry and wear hearing protection. Meanwhile in Europe, the limit is set at 87 dBA, with a 3-dB exchange rate (European Parliament and Council, 2003), with employers required to provide information and training about noise minimisation and hearing protection whenever noise levels exceed 80 dBA.

Using these various workplace noise limits as a guide, several researchers have attempted to estimate how many people are exposed to excessive leisure noise and are therefore at risk of hearing damage. Jokitulppo and colleagues (1997) estimated that around 50% of Finnish teenagers were at risk of hearing damage from leisure noise exposure in excess of an 85 dBA risk limit. However, 50% is likely to be an over-estimation because, in calculating adolescents' noise exposure from 11 pre-determined leisure activities, the authors used the "highest" noise levels reported in the literature. For example, the noise level for television viewing was 100 dBA, which is much higher than levels typically reported (e.g., Neitzel et al (2004a) reported average television noise levels of only 74.7 dBA). Since television watching was the adolescents' most popular leisure activity, using an improbably high noise level would have resulted in a significant over-estimation of adolescents' overall noise exposure. Similarly, a recent study of Dutch secondary school students estimated that half the adolescents assessed were at risk, using a noise exposure benchmark of 80 dBA per day (Vogel et al., 2010). In this study, adolescents were questioned about three leisure activities: music-listening behaviour (via personal stereo player (PSP) or stereo), discotheque visits, and attendance at pop concerts. The noise levels used to calculate leisure noise exposure were based on estimates rather than actual measurements and because they were also at the higher end of reported levels, i.e., 100 dBA for discotheques and 105 dBA for pop concerts, this is likely to have resulted in an over-estimation of the risk.

Notwithstanding the possibility that these studies of teenagers may be over-estimating actual risk levels, studies of leisure noise exposure in older participants suggest that leisure noise exposure, and therefore the proportion of those at risk, declines as age increases. For example, a UK study of 18-25-year-olds reported that 18.8% of participants were exposed to 'significant' leisure noise, defined as noise equivalent to 50 years working in an 80 dBA environment (Smith et al., 2000). Amongst a group of US construction workers with a mean age of 28.6, 19% were estimated to be exposed to annual leisure noise in excess of an 85 dBA risk limit (Neitzel et al., 2004b). With older Finnish adults aged between 24 and 55 years, 9% were at risk of hearing damage from noise exposure in excess of an 85 dBA limit (Jokitulppo & Björk, 2002).

To date, there have been no Australian studies of the risk from excessive leisure noise. In order to provide an estimate of Australians at risk, a study was designed that attempted to address some of the problems of earlier studies. First, rather than using estimated or previously published noise levels to calculate noise exposure, this study used noise levels of five known high-noise leisure activities (nightclubs; pubs, bars and registered clubs; fitness classes; live sporting events; and concerts and live music venues) measured contemporaneously with the administration of an online questionnaire to provide an estimate of the proportion of young adults at risk of hearing damage. These five activities were chosen because they are commonly undertaken by young Australians, whereas another known high-noise activity, firearm use, was excluded because ownership and use of firearms is rare in Australia (Graduate Institute of International and Development Studies, 2007; Australian Bureau of Statistics, 2010a). Listening to PSPs was also excluded because although this leisure activity is widespread, and some PSP users may listen at unsafe levels (Williams, 2005; Williams, 2009), there was no way for this questionnaire to determine the volume levels and exposure times for individuals using PSPs, and estimates would have introduced unacceptable error. The study focussed on those aged between 18 and 35 because this is the age at which people are most likely to participate in the selected leisure activities. In Australia, entry into licensed premises such as pubs, clubs and nightclubs is allowed from the age of 18, participation in gym and group fitness activities is highest amongst those aged 16-29 (Fitness Australia, 2009), and attendance at sports events and popular music performances is highest amongst those aged 15-34 years of age (Australian Bureau of Statistics, 2009; 2011).

The study was conducted in two parts. In Part 1, the aim was to determine the average noise levels at five common high-noise leisure activities using a recently compiled database of leisure noise exposures (see Beach et al., 2010). These averages were then used in Part 2, where the aim was to determine how much time young adults spend in these environments. A questionnaire was conducted in which respondents reported the time spent at various leisure activities and the frequency with which they undertook the activities. These data were then combined with the average noise levels from Part 1 to calculate personal noise exposures and in turn, an estimate of those at risk of hearing damage from their leisure noise exposure.

PART 1: LEISURE ACTIVITY NOISE LEVELS

MATERIALS AND METHODS

Noise levels from i) nightclubs; ii) pubs, bars and registered clubs; iii) fitness classes; iv) live sporting events; and v) concerts and live music venues were extracted from a large database of leisure noise exposures, compiled by the authors between 2009 and 2011 (Beach et al., 2010). Known as the NOISE (Non-Occupational Incidents, Situations and Events) database, as at December 2011, it contained close to 2000 noise measurements from a diverse range of leisure-related events and activities. The noise measurements were undertaken by the three authors and numerous other volunteers employed by, or associated with the National Acoustic Laboratories or Australian Hearing, mostly in Sydney. For each measurement, volunteers wore calibrated CEL-350 dBadge personal sound exposure meters (Casella-CEL, Bedford, UK), in accordance with the relevant measurement standards (Standards Australia, 2005). Dosimeters were positioned at the lapel or as near as possible to the ear, and participants were advised to use their discretion to ensure the dosimeters were unobtrusive so as not to attract attention. The dosimeters logged sound levels (L_{Aeq}) between 65 and 140 dBA at 1-minute intervals and the data were later downloaded using supplied software with ISO protocols (ISO 1999, 1990).

Detailed records of each measurement, including the time, date, duration, venue characteristics, and details of the main noise sources have been entered in a Microsoft Access database. The measurements are organised under seven broad categories (attendance at entertainment venues; arts and cultural activities; attendance at sports venues; active recreation and sport; travel; domestic activities; other) each of which has multiple subcategories (see Beach et al., 2010). The database was searched for events which occurred in 2009/2010 which matched the criteria shown in Table 1. One hundred and eight relevant measurements from i) nightclubs; ii) pubs, bars and registered clubs; iii) fitness classes; iv) live sporting events; v) concerts and live music venues were identified. This list of events was vetted to ensure that adults aged 18-35 years could reasonably be expected to attend these events.

-----Table 1 about here-----

RESULTS AND DISCUSSION

As shown in Table 2, average noise levels at the five leisure activities ranged from 84 dBA to 97 dBA. The average recorded noise levels were similar, albeit slightly lower, than those reported elsewhere, as shown in the final column of Table 2. The likely reason for this is that the noise levels reported here were calculated from a wide range of disparate events, encompassing a relatively large range of dBA levels, whereas noise levels in other studies typically arise from more homogenous samples, e.g., the ‘sporting event’ noise level of 93 dBA is derived from 15 events, including Australian Rules and rugby league football (some of which were finals), soccer matches (some of which were international events), and a moto gp race, whereas the comparative figures relate to a small number of sport events of just one type, e.g., three ice hockey finals; (Hodgetts & Liu, 2006) or two stock car race events (Kardou & Morata, 2010). Using an average derived from a wide range of events is likely to provide a more realistic estimate of actual noise exposure than estimates used in earlier studies (e.g., Vogel et al., 2010) although this method is not without its pitfalls. In some cases, using an average noise level may result in an over- or under-estimate of noise exposure for those individuals who attend leisure activities that are consistently above or below the average levels obtained. A difference of just 3 dB either halves or doubles an individual’s noise exposure for that activity, and this can significantly affect the calculation of overall noise dose. However, since it is impractical to measure actual noise exposure of 1000 young adults located throughout Australia, using the averages presented here is considered a suitable compromise for calculating this estimate.

-----Table 2 about here-----

PART 2: PERSONAL LEISURE NOISE EXPOSURE LEVELS

In Part 2 of this study, the average noise levels, shown in Table 2, were used in conjunction with questionnaire results to estimate participants' personal leisure noise exposure levels, and, in turn, a risk estimate for this sample.

MATERIALS AND METHODS

In collaboration with the authors, a questionnaire was developed by Inside Story, a market research company engaged by Australian Hearing. The online questionnaire comprised 25 questions and took approximately 15 minutes to complete. See supplemental digital content for details. Participants were invited to complete a survey "about important issues facing our community" and were not provided with any information about the survey's subject matter or intended purpose. After providing their demographic information, respondents were asked to provide information about their participation at five leisure activities (questions 1 and 2) which are relatively common amongst young adults, and which have been identified in the literature as high-noise activities: nightclub or dance music venue; pub or registered club; fitness class set to music; sporting event; music concert or live music venue. The order of presentation of the five activities was rotated between participants. Respondents were also asked how often they experienced symptoms of hearing damage, such as tinnitus or ringing in the ears (question 3). Participants were also questioned about their perceived risk of hearing loss (question 4) and use of 'ipods' (question 5). Participants were also asked a series of questions about their attitudes towards noise and hearing loss, and these results will be published separately.

Participants

In December 2009, 24,470 members of an online panel of people aged 18-35 were invited to take part in an online survey. The panel was compiled by an independent online research company, which recruits research participants to the panel via print media advertisements, online marketing initiatives, direct mail, and personal invitations; and ensures that the composition of the panel is in line with general population statistics provided by the Australian Bureau of Statistics. The survey remained open for a two-week period, during which 1,347 panel members (5.5%) agreed to complete the survey. Possible reasons for the lower than expected response rate include the relatively short period of time the survey was open; the difficulty in engaging young adults, particularly males, in research of any type; the increasing tendency for young people to be distracted from 'traditional' email communication by competing social media platforms; and the likelihood that many young people would have been either taking exams or on vacation during the survey period.

Twelve respondents were excluded because they indicated they were outside the required age range, and a further 325 failed to complete the survey. Surveys from an additional 10 respondents (0.04%) were excluded because quality control procedures identified that the survey responses were not bona fide. Thus, a final sample of 1,000 was achieved. No respondents were excluded because age, location or gender quotas were full. Rather, the sample was weighted in line with population data from the Australian Bureau of Statistics (2006) to ensure it was representative of the Australian population in respect of age, gender, education, and location. The weighted and unweighted percentages for each of these demographic categories are shown in Table 3. Although every attempt was made to ensure the final sample reflected general population characteristics, individuals in the population did not have an equal chance of participating and thus, the sample is a convenience sample that cannot be considered representative of the population of 18- to 35-year-old Australians.

-----Table 3 about here-----

Data Analysis

Participants were asked how many times per year they attended each type of leisure activity (nightclub; pub/registered club; fitness class; sporting event; concert/live music venue) and the duration of their average visit to each of these. They were provided with four options: less than 1 hour, between 1-3 hours, between 3-5 hours, or more than 5 hours, and these were coded as 0.5, 2, 4, and 6 hours respectively. These data were then analysed in a 4-step process. First, for each participant, the noise exposure (E) was calculated for each leisure activity, using the self-reported average visit duration and the L_{Aeq}s obtained in Part 1. E, expressed in Pascal squared hours (Pa^2h), is a measure of noise level (L_{Aeq}) over time (T) and is calculated using the formula: $E = 4\ T\ 10^{\ 0.1(LAeq - 100)}$ (Standards Australia, 2005). For example, if a participant reported that they attended a pub (where the average L_{Aeq} is 84) for an average of between 3-5 hours per visit (coded as '4' hours) their noise exposure was calculated as: $E = 4 \times 4 \times 10^{\ 0.1(84 - 100)} = 0.40\ Pa^2h$.

Second, the noise exposure levels were compared to workplace noise exposure levels using the method described by Williams et al. (2010) The aim of this method is to compare noise exposure from particular events to the maximum workplace noise level in Australia, $L_{Aeq,8h}$ = 85 dBA (WHO, 1980). Conveniently, an $L_{Aeq,8h}$ of 85 dBA is equivalent to 1.01 Pa^2h and hence this exposure level will be referred to as 1 'acceptable daily exposure' (or 1 ADE) (Williams et al., 2010). Thus, in the previous example, a pub visit of 4 hours' duration is equivalent to 0.40 ADE.

The third step was to calculate the total number of ADEs each person accumulates over a year, using the self-reported frequency data. For example, if a person attended a pub for 4 hours per visit, once per week and a nightclub for 5 hours per visit, once per month, then their annual noise exposure = $[4 \times 4 \times 10^{0.1(84-100)}] \times 52 + [4 \times 5 \times 10^{0.1(97-100)}] \times 12 =$ 141.2 Pa^2h or 141.2 ADEs.

The final step was to express the total annual exposure as a proportion of acceptable yearly exposure (AYE) in the workplace. As described in Williams et al. (2010) each productive working year is taken to be 220 days. This is calculated by subtracting weekends (104 days), annual leave (20 days), sick leave (10 days) and estimated time spent in non-noisy work (11 days or 1 day per working month) from 365. Thus, 1 AYE is equal to 220 x 1.01 Pa^2h = 222.2 Pa^2h.

Using the example above, an annual noise exposure of 141.2 ADEs is equivalent to 141.2/222.2 = 0.64 AYE. If it is assumed that this person is not exposed to excessive noise from other work or high-noise leisure activities (i.e., those not included in this questionnaire) then this annual noise dose of 0.64 AYE can be considered 'acceptable'.

For all data analysis procedures, i.e., analyses of variance, calculation of percentages and *z*- and *t*-statistics, all data were weighted for age, education, gender and location. In the presentation of results, weighted figures are used throughout, except where raw, unweighted numbers of participants (designated 'n') are shown.

RESULTS

The majority of participants (n = 868) accumulated less than 1 AYE as a result of their reported participation in the five leisure activities. However, 132 participants (14.1%; 95% CI, 12.1% – 16.4%) were exposed to an annual noise dose of more than 1 AYE. Around half of these were exposed to more than twice the noise allowable per year and three of these were receiving more than six times the allowable annual noise dose from these activities alone. When those with noise exposure >1 AYE were compared to those with noise exposure <1 AYE , there was a significant difference in the occurrence of tinnitus (a higher number indicates more frequent occurrence), $M_{>1AYE} = 1.47$, $M_{<1AYE} = 0.89$, $t(998) = 5.34$, $p<0.001$; 95% CI, .30 - .65. Thus, those with higher noise exposure experienced more tinnitus than those with low exposure. There was also a significant difference in the perceived risk levels of the two groups: 46.8% (95% CI, 40.8% – 57.1%) of those with higher noise exposure rated themselves as being at medium, large or very large risk of hearing loss, whereas only 25.3% (95% CI, 22.5% – 28.3%) of those with low noise exposure rated themselves at a medium or higher level of risk, $z = 5.26$, $p < 0.001$.

Gender, Education and Age trends. In order to examine the effect of gender, education, and age on leisure noise exposure, a 3-way ANOVA was performed. The three factors were: gender (F or M), age group (18-24, 25-29, 30-35) and highest education level attained (PS, S, T, or U, where PS = some primary or secondary education; S = completed secondary education; T = completed a trade or technical qualification; U = completed a university degree). The dependent variable was AYE (weighted). Because the distribution of AYEs was highly skewed, the transformation $AYE^{1/4}$ was used so that the residuals more closely approximated a normal distribution. The ANOVA results revealed a main effect of age, $F(2,976) = 14.46$, $p < .001$, with the mean AYE for each age group decreasing as age increased, as shown in the left panel of Figure 1. There was also a significant gender x education interaction, $F(3,976) = 2.82$, $p < .04$. The transformed, weighted data, shown in Figure 2, indicate little difference in the noise exposure of males and females who completed secondary education, a trade qualification, or a university degree. However, amongst those who did not complete secondary school, males had higher noise exposure than females. In other words, males with higher educational attainment received less noise exposure than those with lower educational attainment, whereas for females, the pattern was reversed: females with higher educational attainment received more noise exposure than those with lower educational attainment.

Sources of Noise. As shown in Figure 3, the major contributor to noise exposure was nightclub attendance. Amongst the 132 participants whose annual noise dose exceeded 1 AYE, 120 of them received the majority of their annual noise dose from nightclub attendance. For the remaining 12 participants, the main noise source was either concerts/live music venues or attendance at sporting events.

DISCUSSION

The results show that 14.1% of 18-35-year-old Australians may be at risk of hearing damage from excessive leisure noise exposure at nightclubs and pubs/bars; fitness classes; sports events; and music concerts/live music venues. Not surprisingly, those deemed to be at-risk experienced a greater incidence of tinnitus than those with low noise exposure, and almost half of those at-risk recognised that their risk of hearing loss was at a medium level or higher. Younger adults were found to have more leisure noise exposure than older adults, a finding that reflects, not only common perceptions about noise exposure of young adults, but also previous research which has found a significant difference in the leisure noise exposure of younger versus older adults (Jokitulppo & Björk, 2002).

Similar leisure noise exposure levels were found for males and females except when education levels were low. In this case, males experienced more leisure noise exposure than females. This is an interesting result which warrants further investigation, particularly because previous studies have reported mixed findings for the effects of gender. Jokitulppo and Bjork (2002) found no difference in leisure noise exposure between males and females, whereas Smith et al. (2000) found that males had significantly more social noise exposure than females. Unfortunately, neither study explored the effect of education level on leisure noise exposure, but it may be that lower education levels are associated with less awareness about noise damage generally, although it is not clear why this would lead to greater noise exposure in males than females.

The 14.1% estimated proportion of young adults at risk from leisure noise exposure should be considered in light of the calculation methods used. Firstly, the results may have been affected by the use of average noise levels. If participants were regularly exposed to higher than average noise levels, then their annual noise dose would be higher than calculated here. Equally, if participants were regularly exposed to lower than average noise levels, then their annual noise dose would be lower than calculated here. The method of coding exposure duration as one of four categories (0.5, 2, 4 or 6) may also have resulted in an over- or under-estimate of noise exposure for some participants, whose actual exposure time was consistently greater or less than the categories used.

Limitations relating to the sample should also be considered when interpreting the results. Because a convenience sample of young adults was used, the results cannot claim to be representative of the population of Australian 18- to 35-year-old adults. Furthermore, as with all voluntary surveys, there is the possibility that self-selection bias may have affected the results, and that those who completed the survey may have had a particular interest in the topic. However, efforts were taken to conceal the subject matter of the questionnaire, and we have found that where national attendance figures are available, they correspond well with data obtained in this survey. For example, the Australian Bureau of Statistics (2010b) reports that 51% of 18- to 34- year-olds attend a sporting event at least once per year while our study found that 54.2% of 18- to 35-year-olds did so. Unfortunately national figures are not available for the other four leisure activities, but the similarity between attendance figures for sports events suggests that the study sample was not dissimilar from the population of interest, and certainly there is no reason to believe the sample was biased towards clubbers or those with a particular interest in leisure noise.

As noted earlier, this study did not include noise exposure from other less common high-noise leisure activities (such as riding a motorbike and firearm use), or listening to music at high volume on home stereos or PSPs. If a full range of leisure activities had been included in this study, then the estimated proportion of young adults at risk may have been higher. In addition to boosting the overall proportion of those at risk, including additional music-related high-noise activities would likely have increased the noise exposure of those already at risk because we would expect those who attend nightclubs, live music events and concerts to also spend time listening to music privately on home stereos and/or PSPs. In a large multidimensional scaling analysis of attendance at cultural events by Australian adults, Bennett et al., (1999) showed that nightclubs, live bands, and rock concerts formed a 'cluster' whereby attendance at one of these events indicated a significantly greater likelihood of attendance at other events within the cluster. Thus, it is reasonable to assume that this pattern of music consumption would also be correlated with time spent listening to music privately. Although this question was not examined directly in the current study, there was some evidence for the existence of a music-related leisure pattern. When participants were asked whether they used an 'ipod', results showed that those with high noise exposure (which was predominantly from nightclubs) were significantly more likely to use an 'ipod' than those with low noise exposure (68.2% versus 43.7%, $z = 5.26$, $p < 0.001$). This relationship may have been even stronger if the question had referred to PSPs generally, rather than 'ipods' specifically.

Although this study did not examine the full range of participant's leisure noise exposure, the results correspond well with previous studies that did attempt to examine the full range of leisure activities in a similar age group (Smith et al., 2000; Neitzel et al., 2004b). In the current study, 17.8% of 18-24-year-olds were at-risk (see right panel of Figure 1). This proportion is comparable to the 18.8% of 18-25-year-olds estimated to be at risk by Smith et al. (2000) and also the 19% of young adults estimated to be at risk by Neitzel et al. (2004b) This suggests that using a small set of high-noise leisure activities is an effective method for calculating how many people are exposed to excessive leisure noise and may therefore be at risk of hearing damage because (despite any potential problems related to the use of average noise levels) the activities chosen here are those most likely to be the significant contributors to risk.

While the focus of this study was leisure noise exposure, the contribution of noise experienced at work cannot be discounted. An Australian workplace exposure surveillance study found that approximately 57% of young workers aged between 15 and 24 reported exposure to loud noise in their work environments, compared to 32-40% for those aged 35 and above (Safe Work Australia, 2010). Furthermore, when comparing five high-risk industries, Safe Work Australia concluded that workers employed in Hospitality and Entertainment, an industry dominated by younger workers, are “at greatest risk of unprotected noise exposure and damaged hearing” (p.51, Timmins & Granger, 2010). If young people are experiencing high levels of occupational and leisure noise exposure, then the risk of hearing damage is likely to peak during this time. More research is required to determine the overlap between occupational and leisure noise exposure and the relative contribution of these noise sources to overall exposure, but it is certain that including occupational noise in exposure calculations would increase the magnitude of risk for some young people, and it would also extend the proportion of young people at risk beyond the 14.1% reported here.

It is encouraging that the age trends evident in these results show that by the time adults reach their mid-20s, participation in high-noise leisure activities has dropped considerably (in parallel with the age-related drop in occupational noise levels (Safe Work Australia, 2010). This means that for many people, although their leisure noise exposure may be higher than 1 AYE during their early adulthood when they regularly participate in high-noise leisure activities, their overall lifetime leisure noise exposure may be quite low because any high exposures that may have occurred will be offset by the reduction in noise exposure in later years. Thus, it appears that only the small minority that continue with high-noise leisure pursuits into their 30s (around 8%) will experience sufficient leisure noise exposure to accumulate a significant lifetime risk. Having said that, there is little research available on the effect of age on the risk of hearing loss from noise exposure. Recent animal studies (Ohlemiller et al., 2000; Kujawa & Liberman, 2006) have suggested that noise exposure sustained by younger animals is more damaging than noise experienced as an adult. Thus, it may be possible that noise exposure during adolescence and early adulthood is of greater concern than noise experienced later. Longitudinal or retrospective studies which include detailed noise histories are needed to explore this issue further.

Importantly, this study confirms that nightclubs are a major source of high leisure noise levels for young adults, a finding previously noted by other researchers (Smith et al., 2000; Jokitulppo & Björk, 2002; Vogel et al., 2010). If nightclubs had been omitted from this study, the percentage of young adults at risk would drop to just 1.5%, and although only 83 participants attended nightclubs once per week or more, all but 3 of these participants recorded noise exposure >1 AYE. The prominence of nightclubs in these results arises because of their very high noise levels. In order to reduce the risk to those who attend nightclubs, it is vital that nightclub attendees are made aware of the risks and nightclub operators begin to take responsibility for their staff and patrons. In New South Wales, occupational health and safety legislation (WorkCover NSW, 2001) explicitly states that employers must eliminate risks to the health or safety of, not only employees, but also "any other person legally at the employer's place of work.” At the very least, and as per the recommendations of the recent Senate Inquiry into Hearing Health in Australia (Australian Senate Community Affairs References Committee, May 2011), the time has come for nightclubs to display warnings about noise levels, and ensure free or low-cost earplugs are available for employees and patrons.

Conclusions

At least 14.1% of 18-35-year-old Australians may be at risk of hearing damage from leisure noise, and many of them already suffer from tinnitus. Although it is encouraging that 46.8% of those with high noise exposure recognise they are at risk, the remaining 53.2% also need to be made aware of the risk inherent in their leisure noise exposure. Furthermore, it is vital that all those at risk receive targeted practical advice about how to reduce their noise exposure and avoid hearing loss in the future.

ACKNOWLEDGEMENTS

The authors would like to thank Wendy Mellor from Inside Story who developed and distributed the questionnaire; and Gillian Crowhurst and Rena Richmond from Australian Hearing, who initiated this study. Thanks also to Mark Seeto for assistance with data analysis. This project was funded by the Australian Government's Office of Hearing Services under its Hearing Loss Prevention Program.

REFERENCES

Australian Bureau of Statistics (2006). Census of Population and Housing Available from http://www.abs.gov.au/websitedbs/censushome.nsf/home/census

Australian Bureau of Statistics (2009). *Arts and Culture in Australia: A Statistical Overview, Australia, 2009 (cat no. 4172.0)*. Canberra.

Australian Bureau of Statistics (2010a). *Participation in Sport and Physical Recreation, Australia, 2009-10 (cat no. 4177.0)*. Canberra.

Australian Bureau of Statistics (2010b). *Spectator Attendance at Sporting Events, Australia, 2009-10 (cat no. 4174.0)*. Canberra.

Australian Bureau of Statistics (2011). *Sports and Physical Recreation: A Statistical Overview, Australia, 2011 (cat. no. 4156.0)*

Australian Safety and Compensation Council (2006). *Work-related noise-induced hearing loss in Australia*. Canberra: Australian Safety and Compensation Council.

Australian Senate Community Affairs References Committee (May 2011). *Hear us: Inquiry into hearing health in Australia*. Canberra.

Beach, E.F., Williams, W. & Gilliver, M. (2010). The contribution of leisure noise to overall noise exposure *20th International Congress on Acoustics, ICA*. Sydney. Available at: www.acoustics.asn.au/conference_proceedings/ICA2010/cdrom-ICA2010/index.htm.

Bennett, T., Emmison, M. & Frow, J. (eds.) (1999). *Accounting for tastes: Australian everyday cultures*. Melbourne: Cambridge University Press.

European Parliament and Council, (2003). Directive 2003/10/EC of the European Parliament and of the Council. *Official J. Europ. Union*, *15*.

Fitness Australia (2009). 2008 Fitness Industry Profile Report. Melbourne: Fitness Australia.

Graduate Institute of International and Development Studies (2007). *Small Arms Survey 2007: Guns and the City*. Geneva: Cambridge University Press.

Hodgetts, W.E. & Liu, R., (2006). Can hockey playoffs harm your hearing? *Can. Med. Assoc. J.*, *175*, 1541-1542.

ISO 1999 (1990). *Acoustics - Determination of occupational noise exposure and estimation of noise-induced hearing impairment (ISO 1999:1990)*. Geneva: International Organisation for Standardisation.

Jokitulppo, J.S. & Björk, E.A., (2002). Estimated leisure-time noise exposure and hearing symptoms in a Finnish urban adult population *Noise Health*, *5*, 53-62.

Jokitulppo, J.S., Björk, E.A. & Akaan-Penttilä, E., (1997). Estimated leisure noise exposure and hearing symptoms in Finnish teenagers. *Scand. Audiol.*, *26*, 257-262.

Kardou, C. & Morata, T.C., (2010). Occuptional and recreational noise epxosures at stock car racing circuits: An exploratory survey of three professional race tracks. *Noise Control Eng. J.*, *58*, 54-61.

Kujawa, S.G. & Liberman, M.C., (2006). Acceleration of age-related hearing loss by early noise exposure: Evidence of a misspent youth. *The Journal of Neuroscience*, *26*, 2115-2123.

Lipscomb, D.M., (1969). Ear damage from exposure to rock and roll music. *Arch. Otolaryngol. Head Neck Surg.*, *90*, 545-555.

Neitzel, R., Seixas, N., Olson, J., et al., (2004a). Nonoccupational noise: exposures associated with routine activities. *J. Acoust. Soc. Am.*, *115*, 237-245.

Neitzel, R., Sexias, N., Goldman, B., et al., (2004b). Contributions of non-occupational activities to total noise exposure of construction workers *Ann. Occup. Hyg.*, *48*, 463 - 473.

NIOSH (1998). *Occupational noise exposure: Revised criteria*. Cincinnati, Ohio: National Institute of Occupational Safety and Health.

Ohlemiller, K.K., Wright, J.S. & Heidbreder, A.F., (2000). Vulnerability to noise-induced hearing loss in 'middle-aged' and young adult mice: a dose–response approach in CBA, C57BL, and BALB inbred strains. *Hear. Res.*, *149*, 239-247.

OSHA *Occupational noise exposure (29 CFR 1910.95)* Washington DC: US Department of Labor.

Rintelmann, W.F. & Borus, J.F., (1968). Noise-induced hearing loss and rock-and-roll music. *Arch. Otolaryngol. Head Neck Surg.*, *88*, 377-385.

Safe Work Australia (2010). *National hazard exposure worker surveillance: Noise exposure and the provision of noise control measures in Australian workplaces*. Canberra: Safe Work Australia.

Smith, P., Davis, A., Ferguson, M., et al., (2000). The prevalence and type of social noise exposure in young adults. *Noise Health*, *2*, 41-56.

Standards Australia (2005). *Australian/New Zealand Standard AS/NZS 1269.1: 2005 Occupational noise management Part 1: Measurement and assessment of noise immission and exposure*. Sydney: Standards Australia.

Timmins, P. & Granger, O. (2010). *Occupational Noise-Induced Hearing Loss in Australia - Overcoming barriers to effective noise control and hearing loss prevention*. Canberra: Safe Work Australia.

Vogel, I., Verschuure, H., van der Ploeg, C.P., et al., (2010). Estimating adolescent risk for hearing loss based on data from a large school-based survey. *Am. J. Public Health*, *100*, 1095-1100.

WHO (1980). *Environmental Health Criteria 12 NOISE*. Geneva: World Health Organization.

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

Williams, W., (2009). Trends in listening to personal stereos. *Int. J. Audiol.*, *48*, 784-788.

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.

WorkCover NSW (2001). *Occupational Health and Safety Regulation*. Sydney: WorkCover.

FIGURE LEGENDS

Figure 1: Left panel: Weighted Mean Acceptable Yearly Exposure (AYE) for each age group. Right panel: Weighted percentage of participants in each age group with noise exposure >1AYE. Error bars indicate one standard error.

Figure 2: Mean Acceptable Yearly Exposure (AYE) for males and females who have undertaken some primary or secondary education (PS); completed secondary education (S); completed a trade or technical qualification (T); or completed a university degree (U). Means have been weighted and transformed. Males = grey, Females = black. Error bars indicate one standard error.

Figure 3: Percentage of the total noise contributed by each of the five leisure activities.

LIST OF SUPPLEMENTAL DIGITAL CONTENT

Supplemental Digital Content.pdf

This document contains a copy of the survey questions and the response options.

Table 1: Search criteria for extracting noise level measurements for five common leisure activities from NOISE database

Search	Category	Subcategory/ies	Additional criteria and exclusions
i	attendance at entertainment venues	nightclubs/danceclubs	
ii	arts and cultural activities	popular music concerts OR gigs/live music performances OR classical music concerts	professional level only (not amateur), not child-oriented
iii	active recreation and sport	aerobics/fitness class	recorded music
iv	attendance at sports venues	football OR motor sports	professional level only (not amateur)
v	attendance at entertainment venues	pubs/bars OR registered clubs	

TABLE 2: Mean noise levels (L_{Aeq}) in dBA of five common leisure activities.

Activity	**n**	**Mean L_{Aeq}**	**Min L_{Aeq}**	**Max L_{Aeq}**	**Std Dev**	**Noise levels reported in other studies**
Nightclub	13	97	89	106	4.9	101 (Smith et al., 2000) 103.4 (Serra et al., 2007) 97(Goggin et al., 2008)
Pub, bar, or registered club	38	84	71	96	6.8	88.7 - 98.3 (Sadhra et al., 2002)
Fitness class	15	86	74	97	5.5	87.1 (Torre III & Howell, 2008) 89.6 (Nassar, 2001) 78 - 106 (Yaremchuk & Kaczor, 1999)
Sporting event	16	93	85	100	4.7	100.7, 103.1, 104.1 dBA (Hodgetts & Liu, 2006) 96.4, 99.6 (Kardou & Morata, 2010)
Concert or live music venue	26	92	82	105	7.3	91.9 - 99.8 dBA (Gunderson et al., 1997)
Total	108					

Table 3. Weighted and unweighted percentages for age, gender, education and location

	Total weighted n=1000 %	Total unweighted n=1,000 %		Total weighted n=1000 %	Total unweighted n=1,000 %
Age			**Location**		
18-24	40.0	33.7	NSW metro	24.6	18.0
25-29	30.6	34.3	NSW regional	8.3	11.0
30-35	29.4	32.0	VIC metro	18.7	20.9
Gender			VIC regional	6.3	6.8
Male	50.0	42.9	QLD metro	10.9	10.0
Female	50.0	57.1	QLD regional	9.0	10.3
Highest level of education			SA metro	6.1	5.5
Some secondary/primary	13.8	14.1	SA regional	1.9	1.9
Completed secondary	35.2	34.6	WA metro	7.9	8.8
Trade or technical qualification	23.3	23.7	WA regional	2.1	2.6
University degree/post graduate	27.7	27.6	NT metro	0.8	0.4
			NT regional	0.4	0.2
			TAS metro	1.2	1.2
			TAS regional	0.8	0.9
			ACT	1.0	1.5

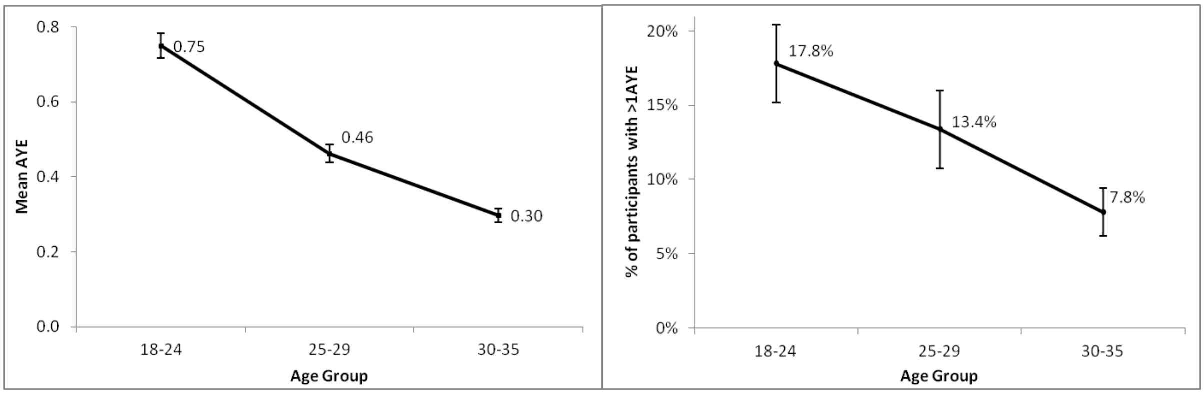

FIGURE 1

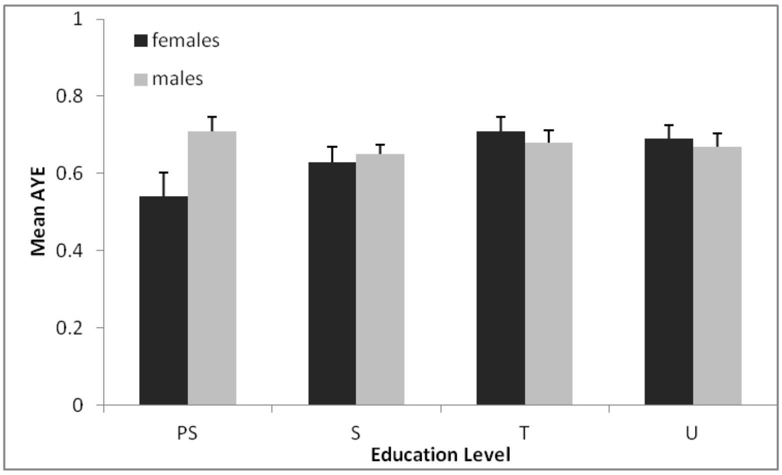

FIGURE 2

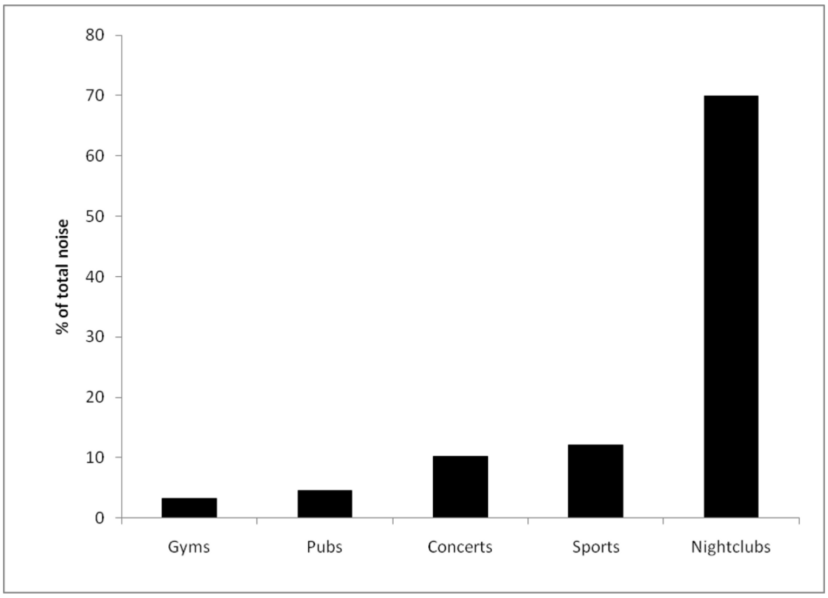

FIGURE 3