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Risk Factors for Distortion Product Otoacoustic Emissions in Young Men with Normal Hearing

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Abstract

The purpose of this study was to evaluate the possible effects of risk factors on distortion product otoacoustic emissions (DPOAEs) in young adult men with normal hearing. Four hundred thirty-six United States Marine recruit men (mean age = 19.2 years ± 1.8 years; age range = 17 - 29 years) participated in this study. Questionnaires were given to each recruit to obtain demographic data and history of noise exposure, solvent exposure, smoking history, and hearing-related histories. Otoscopy, tympanometry, pure-tone air-conduction audiometry (2.0 – 8.0 kHz) and DPOAEs (2.3 - 8.0 kHz) were measured. DPOAE levels were lower in Not Hispanic or Latino recruits, in heavy smokers, in recruits who reported loud live music exposure and ringing in their ears after noise exposure. These differences were not statistically significant at all frequencies. Recruits with multiple risk factors had the lowest DPOAEs as compared to recruits with fewer, or no, risk factors; these differences were not statistically significant. Obtaining risk factor data as part of an audiometric evaluation is important even though the individual may have normal hearing.

Key Words: risk factors, distortion product otoacoustic emissions, normal hearing, young men

Abbreviations: DPOAEs = distortion product otoacoustic emissions; HISP = Hispanic or Latino; MCRD = Marine Corp Recruit Depot; Not HISP = Not Hispanic or Latino

Sumario

El propósito de este estudio fue evaluar los posibles efectos de los factores de riesgo sobre las emisiones otoacústicas por productos de distorsión (DPOAE) en hombres adultos jóvenes con audición normal. Cuatrocientos cuarenta y seis reclutas masculinos de la Marina de los Estados Unidos (edad media de 19.2 años ± 1.8; rango de edad = 17 - 29 años) participaron del estudio. Los cuestionarios se entregaron a cada recluta para obtener datos demográficos e historias de exposición a ruido, exposición a solventes, historia de fumado, e historias relacionadas con la audición. Se realizaron otoscopias, timpanometrías, audiometrías de tonos puros por vía aérea (2.0 – 8.0 kHz) y DPOAE (2.3 – 8.0 kHz). Los niveles de las DPOAE fueron más bajos en reclutas no hispánicos o no latinos, en fumadores fuertes, en reclutas que reportaron exposición a música fuerte en vivo, y ruidos en los oídos después de exposición a ruido. Estas diferencias no fueron estadísticamente significativas en todas las frecuencias. Los reclutas con múltiples factores de riesgo tuvieron las DPOAEs más bajas, comparados con los reclutas con menos o ningún dato

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de factores de riesgo; estas diferencias no fueron estadísticamente significativas. Obtener datos de factores de riesgo como parte de una evaluación audiométrica es importante aunque los individuos tengan audición normal.

Palabras Clave: factores de riesgo, emisiones otoacústicas por productos de distorsión, audición normal, hombres jóvenes

Abreviaturas: DPOAE = emisiones otoacústicas por productos de distorsión; HISP = hispano o latino; MCRD = Puesto de Reclutamiento del Cuerpo de la Marina; Not HISP = no hispano o no latino

One of the most recognized risk factors for hearing loss is occupational noise exposure (Abel, 2005; Clark, 1992; Nelson et al, 2005). There are, however, other risk factors for hearing loss such as exposure to fire arms (Kryter, 1991; Nondahl et al, 2000; Prosser et al, 1988), loud music (Bray et al, 2004; Swanson et al, 1987), inhaled cigarette smoke (Burr et al, 2005; Cruickshanks et al, 1998; Nomura et al, 2005; Noorhassim and Rampal, 1998; Palmer et al, 2004), solvents (e.g., styrene) (Sliwinska-Kowalska et al, 2003), and numerous leisure-related noises (Clark, 1991; Dalton et al, 2001; Jokitulppo et al, 2006; Jokitulppo et al, 1997). One result that is consistent across the studies that identify such risk factors is that a greater degree of hearing loss occurred with more exposure to a specific risk factor or combination of risk factors.

Most of the research that has been completed on risk factors for hearing loss has been based on measures of pure-tone audiometry. An alternative to pure-tone audiometry is the measurement of evoked otoacoustic emissions (OAEs), which allows for examination of the responses of the outer hair cells (OHCs) within the cochlea to stimuli presented in the ear canal (Kemp, 1978). Evaluating the integrity of the OHCs may provide early indications of cochlear dysfunction before any discernable increase in pure-tone thresholds occurs (Attias et al, 1995; Attias et al, 2001; Desai et al, 1999; Hall and Lutman, 1999; Prasher and Sulkowski, 1999; Seixas et al, 2004). Distortion product OAEs (DPOAEs) are one type of evoked OAE measure in which two primary frequencies (f_1 and f_2 where $f_2 > f_1$) are simultaneously presented within the ear canal and the resulting distortion products are generated in the cochlea and measured within the ear canal (Kemp, 1979). The DPOAE that tends to have the highest level, and is subsequently measured most often clinically, occurs at the $2f_1$-f_2 frequency (Gaskill and Brown, 1990).

The risk factors for pure-tone hearing loss are, not surprisingly, also risk factors for decreases in DPOAEs (Attias et al, 2001; Seixas et al, 2004). However, most of this research involves the effects of noise on OAEs (Attias et al, 1995; Attias et al, 2001; Desai et al, 1999; Hall and Lutman, 1999). For example, after accounting for age and sex, Seixas et al (2004) reported that regular use of firearms was significantly associated with a decrease in DPOAE levels at 2.0 kHz in young adults. Similarly, at 2.0 and 4.0 kHz, DPOAEs significantly decreased approximately 0.25 dB per year of solvent exposure, while noise exposure due to working in the construction industry was associated with a significant DPOAE decrease at 6.0 kHz. Although the participants in Seixas et al (2004) were young adults (mean age = 27 years), some of them still had pure-tone thresholds greater than 25 dB HL at 4.0 kHz and higher. Seixas et al (2004) did report that non-white participants had significantly higher DPOAE levels at 2.0 kHz compared with white participants; the specific ethnic or racial characteristics of the non-white participants, however, were not detailed.

Attias et al (1995) examined click-evoked OAEs (CEOAEs) in military personnel, who generally have a high degree of noise exposure. They described one subset of the participants with bilateral thresholds ≤ 20 dB HL from 0.25 through 8.0 kHz. Even though these participants had normal hearing, the percentage of no-response emissions increased with increased frequency to a maximum of almost 35% at 4.0 kHz. However, the prevalence of no-response emissions was significantly lower than the prevalence of no-response emissions in participants with a history of military noise exposure. An interesting finding in this study was that when participants with normal hearing were stratified into those with 0 dB HL thresholds and those with 5-20 dB HL thresholds, the participants with the higher normal thresholds had significantly more no-response emissions. Hence, even a small increase in pure-tone thresholds had a significant effect on the presence of CEOAEs.

Thus, both DPOAEs and CEOAEs have been shown to be useful to illustrate changes in OHC function as a result of certain risk factors and the subsequent effect on hearing sensitivity. However, additional research is needed to identify possible patterns of OHC function across a broad range of frequencies in individuals with specific risk factors. This is important because some risk factors are modifiable, like smoking and time spent in noisy environments without hearing protection, and if risk factors cannot be avoided, the importance of hearing conservation programs can be emphasized.

The purpose of the present project was to examine the effects of certain risk factors (e.g., ethnicity, smoking, noise exposure, and solvent exposure) on DPOAEs in young adults with hearing within normal limits. It is important to evaluate what the possible DPOAE differences are in individuals with specific risk factors in order to determine who may be more likely to develop hearing loss earlier as a result of those risk factors. The primary goal was to document the possible changes in DPOAEs due to risk factors to enable a better understanding of how hearing changes because of these factors.

METHODS

Participants

Four hundred thirty-six young United States Marine recruit men (mean age = 19.2 years ± 1.8 years; age range = 17 - 29 years) volunteered for this project. These recruits were from various ethnic and racial backgrounds and were in good health as determined by an admission physical required for initiation of military training. Based on participants' responses to a questionnaire (see Procedures below), there were 116 (26.6%) Hispanic or Latino (HISP) and 320 (73.4%) Not Hispanic or Latino (Not HISP) (Table 1). As shown in Table 1, recruits also provided specific data regarding their racial background. Overall, there were 317 (85.0%) White, 23 (6.2%) American Indian or Native American, 15 (4.0%) Asian, 11 (3.0%) Black or African-American, and 7 (1.9%) Native Hawaiian or Pacific Islander recruits in this study. Because some of the recruits did not answer the racial question, the number of recruits in the racial categories does not equal the number of recruits in the separate ethnic categories. The recruits were participating in a 12-week Marine training program, and toward the end of the 4th week of this program, the drill instructors brought a platoon of recruits to the Branch Medical Center at the Marine Corp Recruit Depot (MCRD) in San Diego, California. The drill instructors allowed the recruits the opportunity to volunteer for this study during the last 2 hours of a training day.

Table 1. Ethnic and subsequent racial categories for the young recruits that participated in the current study are shown.

	Ethnic Categories		
	Hispanic or Latino (n=116)	Not Hispanic or Latino (n=320)	
Racial Categories			Total
American Indian/Alaska Native	8	15	23
Asian	1	14	15
Native Hawaiian or Other Pacific Islander	3	8	11
Black or African American	1	6	7
White	43	274	317

Procedures

This study was approved by the Naval Medical Center, San Diego Institutional Review Board. After informed consent was obtained, a questionnaire was given to the recruits. This questionnaire was a demographic and noise-exposure history questionnaire that included questions regarding hearing history of the recruit and his family members, smoking history, and exposure to certain solvents. The recruits were asked about their ethnic and racial backgrounds (as mentioned above); specifically, they were asked to mark only one answer with respect to ethnicity (Answers: Hispanic or Latino, Not Hispanic or Latino) and to mark all that apply for race (Answers: American Indian or Native American, Asian, Black or African-American, Native Hawaiian or Pacific Islander, White). The ethnic and racial categories are based on the National Institutes of Health policy for reporting ethnicity and race data. Noise-exposure questions included assessing how many times the recruit had been exposed to specific noises (e.g., power tools, gun fire, recreational vehicles, live or recorded music) during the past year. The recruit had five choices for the noise-exposure questions: 0, 1-2, 3-5, 6-10, and >10 number of times exposed. There was one tinnitus-related question which was, Did you experience ringing in your ears after exposure to loud noise? (Answers: Yes, No). Smoking history was evaluated using three questions: 1) Have you ever smoked cigarettes? (Answers: Yes, No); 2) Have you smoked cigarettes during the past year? (Answers: Yes, No); and 3) In the past two months, how many packs of cigarettes did you smoke daily? (Answers: None, 0.5, 1, 2 or more). Lastly, exposure to solvents was determined with the question, Were you frequently (several times a week) exposed to solvents (oil based paints, lacquers, toluene, xylene Stoddard solvent, etc)? (Answers: Yes, No).

Navy Corpsmen performed otoscopy and tympanometry measures on the recruits following extensive training on these procedures. A certified audiologist was accessible to the Corpsmen if any problems occurred. Tympanometry measures were completed using an Interacoustics Impedance audiometer (Model #AT235) to rule out any middle ear pathology that might affect further testing. Certified audiologists collected pure-tone hearing sensitivity and DPOAE data in four double-walled, sound-attenuated booths located within the MCRD medical center. Pure-tone threshold data were acquired using Interacoustics AC41 clinical audiometers and TDH-39P earphones for conventional octave and interoctave frequencies (i.e., 2.0 through 8.0 kHz). DPOAEs were measured at 12 frequencies using Starkey DP2000 software loaded on Dell Latitude D600 laptop computers. Recording parameters for DPOAEs were as follows: 1) f_2 included 2.3, 2.5, 2.8, 3.1, 3.5, 4.0, 4.5, 5.0, 5.6, 6.3, 7.1, and 8.0 kHz; 2) f_2/f_1 ratio = 1.2; and 3) L_1 = 65 dB SPL and L_2 = 55 dB SPL. Absolute DPOAE levels at $2f_1 - f_2$ and noise levels for each test frequency were saved for off-line analysis.

Daily calibration was completed for the TDH-39P earphones in all four sound booths using OSCAR electro-acoustic ear simulators. Daily calibration for DPOAE equipment was completed using a frequency response of a 2 cc syringe that approximated a human ear canal. Specifically, each DPOAE laptop had a 2 cc syringe assigned to it. The frequency response of that syringe was determined before data collection began and was matched to the frequency response of the syringe that was saved in the database. The frequency responses needed to be similar before data collection started. A complete acoustic calibration of all audiometric equipment was done once prior to, twice during, and once after data collection.

Data Analysis

DPOAEs were considered present if the absolute DPOAE level was ≥ -15 dB SPL and the DPOAE level-to-noise ratio was ≥ +6 dB. These levels were then compared across the ethnicity, and individual risk factor variables, and then a cumulative risk factors variable. Because not all recruits answered the race question and there were few American Indian or Alaskan Native, Asian, Black or African-American, and Native Hawaiian or Other Pacific Islander participants, only the broader ethnicity variable (i.e., HISP vs Not HISP) was used. Repeated measures (DPOAE frequency) ANOVAs were used to examine the relationship between DPOAE levels (dependent variable) and the various risk factors (independent variables). If certain risk factors demonstrated an effect (or trend) on DPOAEs, then subsequent repeated measures ANOVAs for pure-tone threshold data were completed to determine whether differences in DPOAEs were a result of differences in pure-tone thresholds. A final repeated measures ANOVA was used to examine possible effects of multiple risk factors on DPOAEs. Interactions between ethnicity and any risk factor were included in any analysis when necessary. Lastly, all categorical data were analyzed using chi-square (χ^2) test of association.

RESULTS

All 436 recruits had normal hearing sensitivity across all the frequencies tested in that no recruit had a single threshold above 25 dB HL at any frequency in either ear and there was no evidence of a middle-ear pathology based on tympanometry measures. Preliminary statistical analysis of DPOAEs for both ears revealed no significant differences across ears at any frequency. Therefore, only right ear data are presented here. Means and standard deviations of absolute DPOAE levels across the 12 frequencies measured for HISP and Not HISP recruits are shown in Figure 1. The Not HISP recruits had consistently lower DPOAE levels across all frequencies tested, and the differences ranged from 0.1 dB at 4.0 kHz to 1.7 dB at both 7.1 and 8.0 kHz. The differences were statically significant at 7.1 [$F(1,434)=5.14$, $p<0.05$] and 8.0 kHz [$F(1,434)=5.92$, $p<0.05$]. A subsequent repeated measures ANOVA of pure-tone threshold data demonstrated no significant differences for ethnicity; in fact, the difference in the mean pure-tone threshold at 8.0 kHz was only 0.2 dB between HISP and Not HISP recruits.

For the exposure to loud live music or recordings question, the data were dichotomized into two times or less in the past year to represent no, or very little, exposure, and three times or more in the past year to represent more, or possibly a lot of, exposure (recall that the greatest possible answer was >10 times). Few recruits (<10%) reported no exposure to loud live music; thus, this group was combined with recruits who reported exposures of 1-2 times in the past year. Four recruits did not answer this question. Means and standard deviations of absolute DPOAE levels for the music variable are shown in Figure 2, which demonstrates a decrease between 1.2 and 1.6 dB in DPOAE levels starting at 4.5 kHz for the recruits who reported loud music exposure three or more times in the past year. These recruits had significantly lower DPOAEs at 4.5 kHz

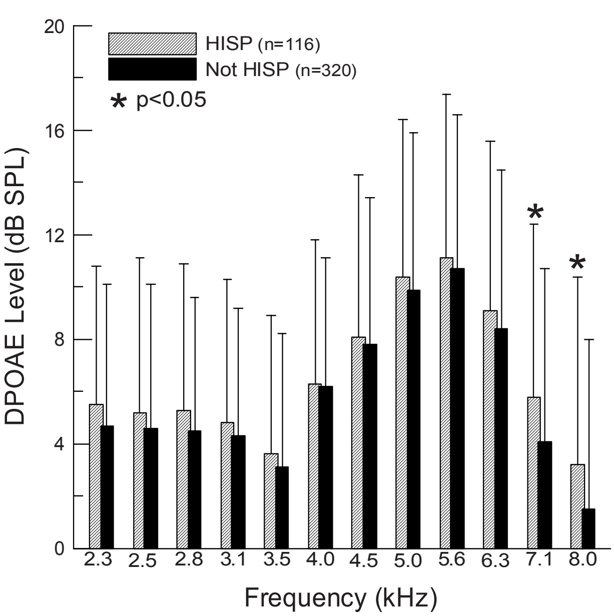

Figure 1. Means and standard deviations of DPOAE levels across the frequencies measured for Hispanic or Latino and Not Hispanic or Latino recruits are shown. Asterisks (*) indicate significant differences at $p<0.05$.

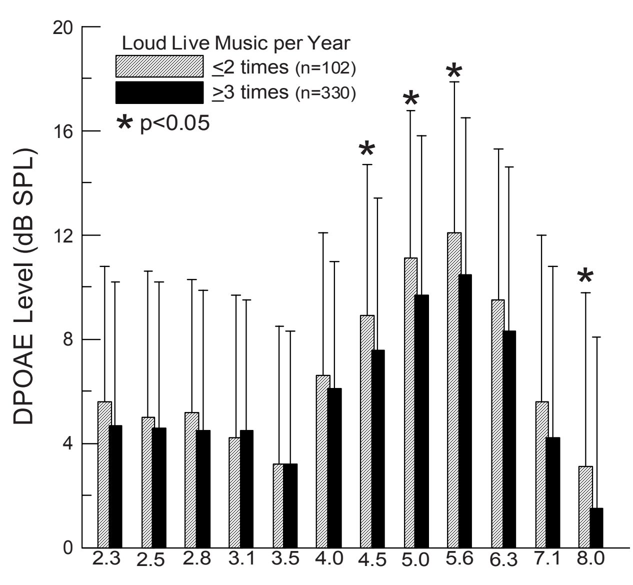

Figure 2. Means and standard deviations of DPOAE levels across the frequencies measured for the two groups who reported loud live music exposure are shown. Four recruits did not answer this question. Asterisks (*) indicate significant differences at $p<0.05$.

[F(1,430)=3.97, p<0.05], 5.0 kHz [F(1,430)=3.95, p<0.05], 5.6 kHz [F(1,430)=5.63. p<0.05], and 8.0 kHz [F(1,430)=4.69, p<0.05] compared to the recruits who reported exposure to loud music two or less times within the past year. Notably, differences at 6.3 and 7.1 kHz almost reached statistical significance. Once again, a subsequent repeated measures ANOVA of pure-tone threshold data for reported loud music exposure revealed no significant differences between the two groups. The mean differences in pure tones were 0.1 to 1.8 dB, and it is possible that the 1.8 dB poorer threshold at 4.0 kHz in the three or more times group may have contributed to the DPOAE difference. In contrast, there was only a mean pure-tone threshold difference of 0.7 dB between groups at 8.0 kHz, but there was still a significant difference in DPOAEs at 8.0 kHz.

Recall that a follow-up question to the noise-exposure questions was whether recruits reported tinnitus in their ears after loud noise. Means and standard deviations of DPOAE levels for those recruits who reported No and Yes to having experienced tinnitus after loud noise exposure can be seen in Figure 3. DPOAEs were lower in recruits who reported tinnitus by about 0.4 to 0.6 dB from 2.3 kHz through 3.5 kHz and 0.6 to 1.4 dB from 6.3 kHz through 8.0 kHz. At 8.0 kHz, the recruits who reported tinnitus after noise exposure had significantly lower DPOAEs [F(1,434)=4.64, p<0.05] compared to those recruits who did not report tinnitus. A repeated measures ANOVA revealed no significant differences for mean pure-tone thresholds at any frequency for the tinnitus variable. In fact, the largest difference in thresholds was at 4.0 kHz where recruits who reported tinnitus had a 0.8 dB higher mean threshold compared to recruits who did not report tinnitus.

DPOAEs were analyzed across responses to the question regarding the number of packs of cigarettes smoked daily. Because so few recruits reported three or more packs a day, those data were combined with the two packs a day group, to create a '2-or-More Packs' group. Means and standard deviations of DPOAEs for the four types of smoker are shown in Figure 4. Forty-one recruits did not answer this question and were not included in this analysis. There were no significant differences in absolute DPOAE levels for any frequency across the

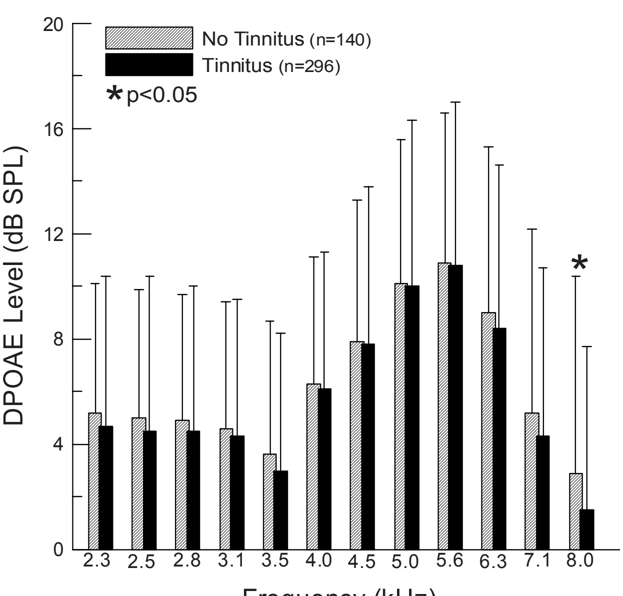

Figure 3. Means and standard deviations of DPOAE levels across the frequencies measured for recruits who reported having experienced tinnitus in their ears after loud noise exposure. Asterisks (*) indicate significant differences at p<0.05.

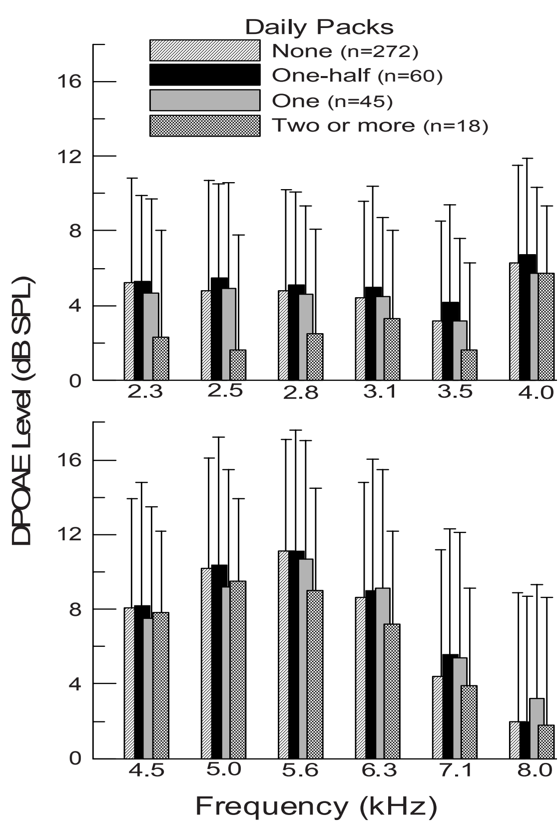

Figure 4. Means and standard deviations for DPOAE levels across the frequencies measured for number of packs of cigarettes smoked per day are shown. Forty-one recruits did not answer this question.

four groups. Recruits who reported smoking 2-or-More Packs of cigarettes daily, however, generally had the lowest DPOAEs compared with the other three groups. A repeated measures ANOVA was completed with pure-tone data, and it revealed no significant differences in mean pure-tone thresholds for any frequency. The recruits in both the 1 Pack and the 2-or-More Packs groups had mean thresholds of approximately 1-2 dB poorer compared to the other two groups at all frequencies except for 6.3 kHz where the mean difference was similar across the four groups. The small and insignificant difference in pure-tone thresholds across groups may have contributed to the differences seen in DPOAE levels.

There were neither significant differences nor increasing or decreasing patterns in DPOAE levels for both recruits who reported ever smoking and those who reported smoking during the past year (data not shown). Similarly, DPOAE levels were similar, though not significantly different, across the number of times recruits reported being exposed to noise from power tools, gunfire without hearing protection, or engine noise from recreational vehicles, farm equipment, motorcycles, or outboard motors. Lastly, DPOAEs were similar regardless of whether or not recruits reported being frequently exposed to solvents.

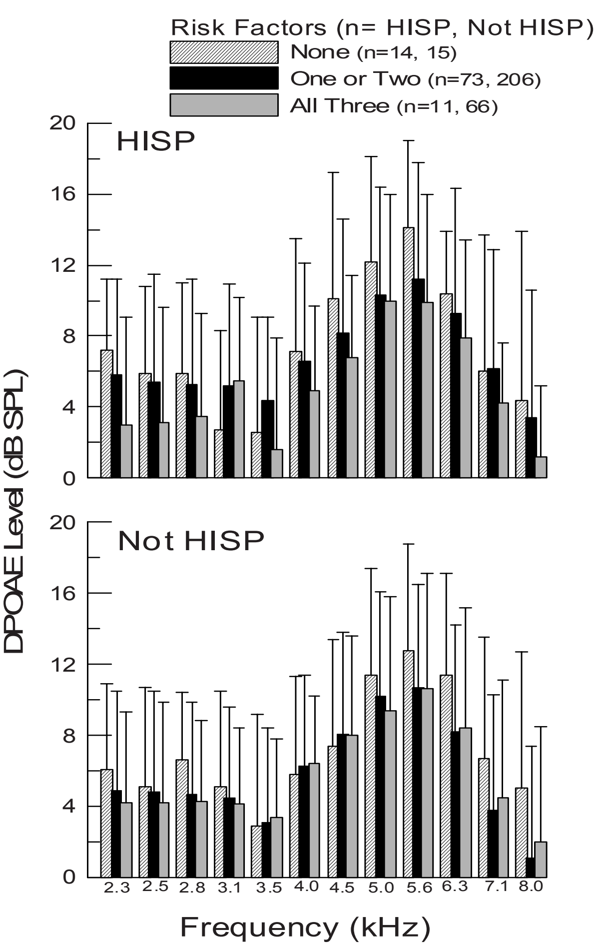

Figure 5 . Means and standard deviations (in parenthesis) for DPOAE levels across the frequencies measured for the number of risk factors reported by Hispanic or Latino (top panel) and Not Hispanic or Latino (bottom panel) recruits are shown.

Based on the DPOAE differences for ethnicity, self-reported smoking status (smoker or not within the last 2 months), noise exposure from loud live music (2 times or less in the past year or 3 times or more in the past year), and experiencing ringing after noise exposure, a repeated measures ANOVA was used to evaluate the effects of the combination of these risk factors. There were significant interactions for ethnicity by risk factors variable for various frequencies and, because of this, the final ANOVA was stratified by ethnicity. Means and standard deviations for DPOAE levels across the number of risk factors reported for HISP recruits and Not HISP recruits are shown in Figure 5. Because of the various missing risk factor data described above, only 385 recruits were included in this final analysis. The risk factor variable was defined in three ways: 1) None; 2) One or two; and 3) All three. For most frequencies (with the exception of 3.1 kHz), HISP recruits who reported all three risk factors had lower DPOAEs compared with HISP recruits who reported no risk factors. The risk factors main effect was not significant at any frequency although there was a trend for decreasing DPOAEs with more risk factors. The main effect for risk factors, however, was significant for 4.0 kHz pure-tone thresholds [$F(2,93)=6.28$, $p<0.05$], and a post-hoc analysis revealed a significant difference in pure-tone thresholds for HISP recruits with no risk factors and those with all three risk factors. The mean difference at 4.0 kHz was approximately 11 dB although the mean difference for DPOAE levels for these two groups was 2 dB.

The pattern of DPOAE levels was somewhat similar across the frequencies measured for the Not HISP recruits and the number of risk factors reported. For these recruits, DPOAEs were lower at most of the frequencies in recruits that reported all risk factors compared to those recruits who reported no risk factors. But for three frequencies, 3.5, 4.0, and 4.5 kHz, DPOAE levels were slightly higher in recruits who reported all three risk factors. Once again, the risk factor main effect was not significant. A subsequent repeated measures ANOVA for pure-tone threshold data showed a significant risk factor main effect at 6.3 kHz [$F(2,283)=3.71$, $p<0.05$] and the post-hoc analysis revealed a significant difference at this frequency between Not HISP recruits with no risk factors and those with one or two risk factors. The mean difference was slightly above 5 dB whereas the difference in DPOAEs was only 2 or 3 dB at 5.6 and 6.3 kHz, respectively.

There was no consistent trend when comparing DPOAE levels for each ethnicity and number of risk factors. For the recruits with no risk factors, both the HISP and Not HISP groups had higher DPOAEs for six frequencies tested. For recruits who reported one or two of the risk factors, the HISP recruits had higher mean DPOAEs at all frequencies. This trend shifted considerably for those who reported all three risk factors. With the exception of 3.1 and 5.0 kHz, the HISP recruits had lower DPOAEs compared to the Not HISP recruits.

After examining the risk-factor variables across ethnicity, Not HISP recruits reported smoking within the past 2 months significantly more [$\chi^2(1)=4.64$, $p<0.05$] compared to HISP recruits. Similarly, Not HISP recruits reported significantly more [$\chi^2(1)=6.24$, $p<0.05$] tinnitus in their ears after noise exposure than HISP recruits did. There was a higher percentage of HISP recruits who reported exposure to loud music 2 or fewer times, but this difference was not significant. The percentage of Not HISP recruits reporting all three risk factors was significantly higher [$\chi^2(2)=13.10$, $p<0.05$] than the HISP recruits, although the HISP recruits still had lower mean DPOAEs for all frequencies.

DISCUSSION

The DPOAE levels for the young adults with normal hearing in this study are similar to the levels reported previously (e.g., Gorga et al, 1993). To date, however, the present study is one of the first investigations of the effects of specific risk factors on DPOAE levels in participants with pure-tone thresholds of 25 dB HL or better for 2.0 through 8.0 kHz. In the individual risk factor analyses, DPOAEs were lower in Not HISP recruits, in heavy smokers (2-or-More Packs of cigarettes a day), lower for higher frequencies (4.5 kHz and above) in recruits who reported loud live music exposure 3 or more times in the past year, and lower for most frequencies in recruits who reported ringing in their ears after loud noise exposure. In all the groups with lower DPOAEs, the mean pure-tone thresholds were at most 2 dB poorer, which may account for the difference in DPOAEs. When the individual risk factors were evaluated in combination, both HISP and Not HISP recruits with all three risk factors had the lowest DPOAEs compared to those groups with fewer, or no, risk factors. Even though the percentage of HISP recruits who reported all three risk factors was significantly lower compared to the Not HISP recruits with three risk factors, the HISP recruits had lower DPOAEs across 10 of the 12 frequencies tested.

The results of the present study demonstrate a difference in DPOAEs for ethnicity such that HISP recruits had larger DPOAE levels compared to Not HISP recruits. This is somewhat similar to findings of Seixas et al (2004), who reported larger DPOAEs in non-white participants, though only at 2.0 kHz. For other risk factors, the results of their study and the present one are not consistent. For example, Seixas et al (2004), reported lower DPOAEs for participants, who were exposed to solvents and noise from regular firearm use and power tool use. Recruits in the current study, who reported exposure to solvents, gun fire, and power tools did not have lower DPOAEs. One possible reason for the lack of lower DPOAEs for these risk factors is the duration of exposure. The recruits in this study had a mean age of only 19 years and may not have had the years of exposure necessary to identify decreases in DPOAEs, as compared to the older participants in the Seixas et al (2004) study. Additionally, the participants in the Seixas et al (2004) study were, for the most part, employed in the construction industry; thus, their exposure to power tool noise and/or solvents was likely occupational rather than recreational.

Recruits who reported loud live music exposure 3 or more times and those who reported ringing in their ears after exposure to loud noise had lower high frequency DPOAEs. This high-frequency decrease for individuals with normal hearing is consistent with what has been reported previously for both DPOAEs (Attias et al, 2001) and CEOAEs (Attias et al, 1995; Attias et al, 2001). Attias and colleagues (1995; 2001) attributed this decrease in OAEs to everyday noise exposure although the specific type of noise was not determined, because the participants had normal puretone thresholds and did not report any hazardous noise exposure.

Clearly the risk factors examined in this study are possible for most individuals but may be more likely in military personnel, especially because of frequent exposure to gun fire and other impulse noises during training and active duty. Because most of the recruits in this study will become Marines, possibly be deployed, and be responsible for various noise-hazardous duties (e.g., infantry, pilot, mobile-support equipment operator), these men will be more at risk for hearing loss. In a survey of military personnel in Canadian Forces employed in air, land, and sea occupations, over 60% reported being exposed to solvents while rarely, if ever, wearing protective respiratory equipment (Abel, 2005). This combination of solvent and noise exposure may have contributed to a higher degree of hearing loss. Hearing loss is more likely for those military personnel who are deployed. The prevalence of noise-induced hearing loss after deployment and the resulting noise exposure or acoustic trauma was significantly higher compared with non-deployment noise-induced hearing loss (Helfer et al, 2005). Helfer et al (2005) suggested that noise-induced hearing loss is problematic even with hearing protection because in combat settings, intense levels are transmitted to the cochlea via bone conduction, and inhaled toxins are common. Because soldiers are involved in duties that are hazardous to hearing, it is important to understand how other risk factors (e.g., history of smoking, solvent exposure, recreational noise exposure, and previous occupational noise exposure) affect OAEs and subsequent hearing sensitivity.

The obvious limitation of this study is that only young adult men were participants; no analysis could be completed on the prevalence of risk factors in young women and the possible effects they may have on DPOAEs. Moreover, the risk factors for DPOAEs were determined from a self-reported questionnaire regarding exposure to various occupational and recreational noises, solvents, and smoking history. Recall bias is probably unlikely because the participants were young and the noise questions were asked based on how often they were exposed to the specific noise within the past year. Also, the smoking question for daily packs of cigarettes was based on only the past two months. Unfortunately, even with the well-designed questionnaire with categorical and dichotomous answers, the true assessment of any of the exposures could not be determined. Furthermore, the answers to the noise-exposure questions were numbers of times exposed without the determination of the actual level of the noise. The range of noise levels from power tool use, loud live music, and recreational vehicle engine noise is large (Clark, 1991; Neitzel et al, 2004), and without obtaining level data, misclassifications of exposure may have occurred.

The lack of consistent significant effects of risk factors on DPOAEs may have been a result of being exposed to the risk factor for only a short period of time. Again, recall that the recruits in this study had a mean age of 19 years, so it is unlikely that they had been using power tools, firing guns, using solvents, or smoking for many years. In the final analysis, the effect of multiple risk factors was examined; because of the significant ethnicity by risk factor variable interaction, this analysis was stratified by ethnicity. Such stratification led to smaller sample sizes within each ethnic group, then a subsequent break down for number of risk factors reported. The unfortunate consequence of this categorization of data was sample sizes of 14 and 15 HISP and Not HISP recruits reporting no risk factors, respectively, while only 11 HISP recruits reported all three risk factors. Although there was a somewhat consistent trend of decreasing DPOAEs with increased number of risk factors, it is not known how this trend may have changed with larger, or even equivalent, sample sizes across all the groups.

In summary, risk factors such as ethnicity, recreational noise exposure, and smoking did show a slight influence on DPOAEs in young male military recruits. These differences were not consistently statistically significant across the frequencies, but this is not surprising given that all the recruits in this study had pure-tone thresholds ≤25 dB HL at 2.0 through 8.0 kHz; in fact, mean thresholds varied from only 7 to 11 dB across those frequencies. It was expected that there would not be significant differences for all risk factors; rather, the purpose was to determine if subtle, underlying differences in DPOAEs for individual, and multiple risk factors, could be determined. The most interesting result is that HISP recruits who reported no risk factors had the highest DPOAE levels compared to the other groups, but the HISP recruits who reported all three risk factors had the lowest DPOAEs that were even lower than the Not HISP recruits with three risk factors. It is currently unknown as to why DPOAEs in HISP recruits seem more susceptible to these risk factors compared to DPOAEs in the Not HISP recruits, and this should be studied further. Lastly, these data demonstrate the importance of obtaining risk factor information and DPOAEs during any audiometric evaluation, even if it is known that the individual has normal hearing.

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