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Levels of Music Played by Caucasian and Filipino Musicians with and without Conventional and Musicians' Earplugs

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Abstract

Background: Some musicians may play the music louder while using earplugs thus reducing the effectiveness of the hearing protection offered by earplugs. In addition, the dynamic range (DR) of the music may be altered because of the use of earplugs with negative impact on perceived quality of music. There are some cultural differences in attitudes toward loudness, which may lead to differences in the loudness of music played by musicians from different cultures.

Purpose: To investigate the effect of the use of two different types of earplugs on the loudness and DR of music played by musicians of Caucasian and Filipino origins.

Research Design: Quasi-experimental repeated measures design.

Study Sample: Thirty six musicians with normal hearing within the age range of 18–49 yr. Fifteen were of Caucasian (eight men and 7 women) origin and 21 were of the Filipino (nine men and 12 women) origin.

Intervention: All participants received a brief educational session, which included information on music-induced hearing loss, the benefit of using earplugs, and the correct procedures for inserting and removing earplugs. They played music in five different conditions (three min each): Trial 1 of conventional and musicians' earplugs in random order, no earplug, and trial 2 of conventional and musicians' earplugs in random order.

Data Collection and Analysis: Maximum, minimum, average (average sound level measured over the measurement period; LAVG), and peak levels were recorded using a dosimeter while playing music in each of the five conditions. The DR was derived by subtracting the minimum values from the maximum values. A different measure of the dynamic range 2 (DR2) was derived by subtracting the LAVG value from the peak value. Mixed analyses of variance (ANOVA) (Cultural origin and Gender as nonrepeated variables) was performed on LAVG, DR, and DR2.

Results: Based on the LAVG levels yielded by them, 42–61% of the musicians may be at risk for hearing loss. The mixed ANOVA revealed some main effects of culture and some significant interactions involving cultural origin, the plug conditions, type of earplugs, and trial number.

Conclusions: Use of earplugs may vary the overall loudness of music, the DR, or the DR2 in some musicians depending on the type of earplugs and cultural origin, and the effect may change with practice.

Key Words: Caucasian, culture, earplugs, Filipino, hearing protection devices, loud music, musician

Abbreviations: ANOVA = analyses of variance; APV = assumed protection value; DR = dynamic range; DR2 = dynamic range 2, an alternate measure of dynamic range derived by subtracting the LAVG values from the peak values; HPD = hearing protection device; LAVG = average sound level measured over the measurement period; LSD = least significant difference; NIOSH = National Institute of Occupational Safety and Health; NRR = noise reduction rating; S = slow; SD = standard deviation

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Many musicians are exposed to excessively loud music. Such excessively loud sounds can damage various structures in the ear, including the stria vascularis, spiral ligament, sensory hair cells, synapses between the hair cells and the auditory neurons, leading to hearing loss and other related symptoms. A major effect of hearing loss is difficulties in communicating with other individuals, which can negatively impact the performance in educational, vocational, and social settings. Other effects of hearing loss include difficulties in hearing nonspeech sounds, such as warning signals and music. Hearing loss can specifically have a negative impact on the professional careers of musicians because their livelihood depends on listening to and playing musical instruments in tune with other musicians. In addition to hearing loss, damage to the inner ear can also lead to tinnitus or ringing in the ears. Approximately 39–79% of the musicians also report hyperacusis, which is a discomfort or annoyance associated with moderately high sound levels that are typically considered comfortable by the general population. Another symptom associated with damage to the ear is distortion, which can be defined as pure tones, overtones, and/or harmonics that are not perceived in their original form but as distorted, unclear, fuzzy, and/or out of tune. Up to 24% of the musicians report distortion when they are presented with pure tones in research laboratory settings (reviewed in Rawool, 2012a).

Because of the negative effects of exposure to excessive loud sounds, the National Institute of Occupational Safety and Health (NIOSH) in the United States conducts research and makes recommendations to minimize exposures to hazardous noise to prevent hearing loss and other symptoms. NIOSH has recommended a criterion exposure level of 85 dBA for the eight-hour work day; the noise dose is assumed to be 100% with such exposure. NIOSH recommends an exchange rate of 3 dB. Thus, with an increase in the criterion exposure level of 85 dBA by 3 dB to 88 dBA is assumed to lead to a 100% noise dose within four hours (half of eight hours). A further increase by 3 dB to 91 dBA is assumed to lead to 100% noise dose within two hours (half of four hours). NIOSH recommends control of all exposures in such a way that the daily noise doses are below 100%. This recommendation is expected to protect the hearing of approximately 85–90% workers (reviewed in Rawool, 2012b).

Partially based on the research conducted by NIOSH, the Occupational Safety Health Administration (OSHA, 1983) in the United States, regulates work settings with hazardous noise exposures. When the eight-hour time-weighted average level is equal to or greater than 85 dBA, action is required in terms of implementation of a hearing conservation program. Hearing protection device (HPD) use is recommended at or above 85 dBA but is not required until the time-weighted average exceeds 90 dBA. A 100% noise dose is assumed with an eight-hour exposure to noise levels of 90 dBA. The exchange rate included in the OSHA regulation is 5 dB. Thus, if the exposure is increased by 5 dB from 90 to 95 dBA, then the exposure should be limited to half of eight or four hours. A further increase of 5 dB to 100 dBA requires further halving of the exposure duration to two hours from four hours. These criteria are expected to protect the hearing of about 71–79% of workers (reviewed in Rawool, 2012b). In addition, under OSHA regulations, unprotected workers may not be exposed to maximum sound levels greater than 115 dBA, measured with a Slow (S) response rate and to peak sound levels greater than 140 dBZ.

Several strategies can be used to follow the NIOSH recommendation or the OSHA regulation, including playing music at lower levels, acoustically treating music venues and taking appropriate breaks (reviewed in Rawool, 2012a). An important strategy is to use HPDs while playing music. HPDs are effective in minimizing hearing loss at least in some cases (Hoffman et al, 2006).

Several varieties of HPDs are available (reviewed in Rawool, 2012c). Conventional HPDs are readily available and are relatively less expensive (e.g., Clarity earplugs). However, the music level reduction (attenuation) provided by such earplugs is usually not uniform across frequencies (pitches); higher pitched sounds are attenuated more than low-pitched sounds which can alter music quality. Another HPD option is musicians' earplugs (e.g., ER20-XS high fidelity earplugs). Although more expensive than some other earplugs, the musicians' earplugs are capable of providing relatively less variation in attenuation across frequencies compared with the Clarity earplugs (for details, see Rawool, 2012a and Figure 1). More specifically, the range of attenuation values across frequencies is 7.6 dB (25.1 to 17.5) for the musicians' earplugs, which is narrower than the range of 16.4 dB (41.5 to 25.1) for the Clarity earplugs. Assumed protection values (APVs), such as those in Figure 1, are provided by manufacturers to provide a conservative estimate of the attenuation provided by the earplugs in real-world situations. APVs are typically derived by subtracting one or two standard deviations (SDs) from the mean attenuation values. All values in Figure 1 including APVs are from the packages of the earplugs. The APVs in Figure 1 are derived by the manufacturers of the relevant plugs, by subtracting one SD from the mean attenuation values at each frequency.

Some investigators have suggested that some musicians may play the music louder while using HPDs to compensate for the loss of loudness due to HPDs (Chesky et al, 2009), thus reducing the effectiveness of HPDs. Another possibility is that the musicians may keep the loudness of loud passages similar but may increase the loudness of soft passages. This may result in a reduced dynamic contrast or range leading to a reduction in the

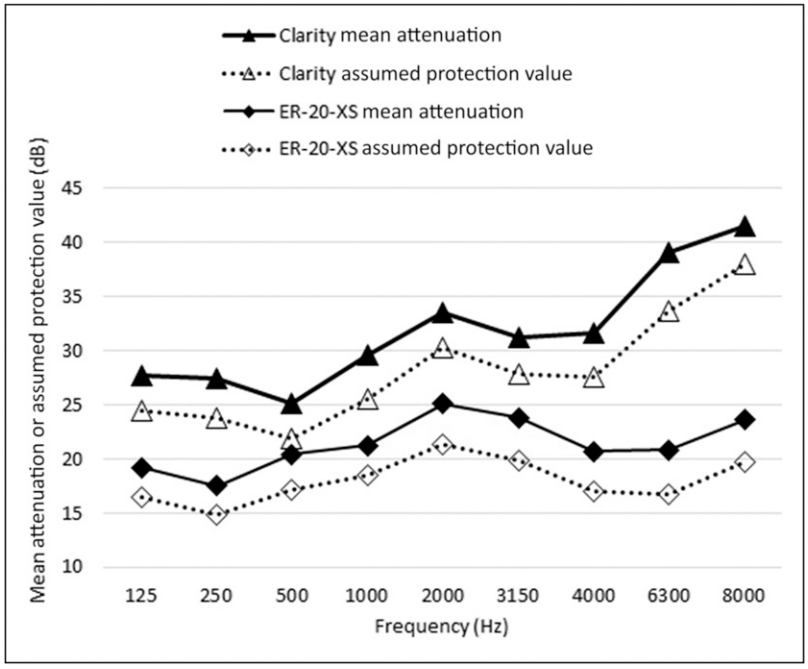

Figure 1. Attenuation (dB) provided by the two earplugs.

perceived quality of music. The current research project is designed to investigate if musicians change the music levels or dynamic range (DR) of the music when they use two different types of earplugs compared with not wearing any earplugs. One of the earplugs is designed for musicians and the other is a regular earplug, which is closely matched to the musicians' earplug in appearance, style, and attenuation. To our knowledge, effects of different types of earplugs on the loudness or DR of music have not been previously reported.

Research to plan and appraise health programs must take into account differences across different cultures or country of origin and gender. One study showed that young adults who consider loud noise levels or hearing loss as unproblematic are less likely to use HPDs compared with other participants and show significantly more deteriorated hearing (Keppler et al, 2015). Widén et al (2006) surveyed the attitudes of 17- to 21-yr-old Swedish and American students toward noise and the use of HPDs at concerts. The Swedish population consisted of 230 students from upper secondary schools in Boras, Sweden, and the American population consisted of 251 students from a community college in Gainsville, Florida. Men from the United States had more positive (loud noise or hearing loss is perceived as being unproblematic) attitudes toward noise than men from Sweden, and men in general had a slightly more positive attitude toward noise than women. Participants with negative attitudes toward noise were 12.45 times more likely to report the use of HPDs than individuals with a positive attitude toward noise. Country of origin and attitudes explained 50% of the variance in the use of HPDs in this study (Widén et al, 2006). In addition to not using HPDs, individuals who have positive attitudes toward loud sounds could play music at louder levels. These studies suggest that the attitudes and thus levels may vary depending on the cultural origin and gender. Inclusion of a different ethnicity group can allow generalization of the findings to different ethnicity groups rather than just one group. Thus, we decided to measure levels of music played by musicians from two different cultural backgrounds. According to the Migration Policy Institute (http://www.migrationpolicy.org/data/state-profiles/state/demographics/US), the Philippines has been among the top five countries of origin of immigrants to the United States since 1990. The Filipino immigrant population in the United States has increased from 105,000 in 1960 (1.1% of all immigrants) to 1,844,000 in 2013 (4.5%). The second author of this project is originally from the Philippines, and thus, we had easier access to musicians of Filipino origin. Therefore, we included Filipino and Caucasian musicians to investigate any influence of cultural origin on music levels.

METHODS

Participants

Thirty six adults within the age range of 18–49 yr participated in the study. Fifteen of the participants were of Caucasian (eight men and seven women) origin and 21 participants were of the Filipino (nine men and 12 women) origin. Most of the Filipino individuals were either born in the United States, or moved to the United

States at a young age. Most of the Filipino musicians learned to play by listening to music through various means and playing their instruments. Some started playing music in Philippines before moving to the United States and others started playing it after moving to the United States. In addition to club performances, they frequently perform at gatherings or events (e.g., weddings) primarily attended by individuals of Filipino origin. All of the Filipino musicians are from a closed-knit Filipino community, and thus, relatively high cultural influence is expected.

Only individuals fluent in English were included in the study to ensure adequate understanding of all instructions. Only participants with at least three yr of experience in playing at least one musical instrument and who either did not use earplugs or used earplugs inconsistently were included in data analyses. Although the participants were not paid, they received a free hearing evaluation and free pairs of conventional and musicians' earplugs. The participants completed a screening questionnaire to rule out occupational noise exposure, history of chronic ear canal and middle ear problems, use of ototoxic medications, and any neurological conditions.

Audiological Evaluation

Otoscopy was performed to examine the ear canals and eardrums. Individuals with significant eardrum or ear canal abnormalities were excluded from the study. Tympanometry was conducted to evaluate the middle ear function. Individuals with middle ear dysfunction were excluded from the study to minimize discomfort after earplug insertion. Air conduction thresholds were established at 0.25, 0.5, 1, 2, 3, 4, 6, and 8 kHz to document the auditory sensitivity of each participant because hearing loss may have an impact on music levels. Only individuals with auditory sensitivity within 20 dB HL were included in the current data analyses.

Brief Educational Session

Musicians were oriented to hearing loss, benefits of using earplugs and the correct procedures for inserting earplugs to ensure correct insertion of earplugs, and adequate motivation for using earplugs. To ensure similar instruction across participants, we used following YouTube video clips related to each of the topics.

Video clip #1: Title: Video about Hearing and How it Works | MED-EL (the video is by http://www.medel.com). We showed this clip beginning at 1:50 min after the initiation of the video clip.

Link: https://www.youtube.com/watch?v=flIAxGsV1q0

The clip includes information about hearing and how it works using Images and animations of the inner ear. It illustrates the arrangement of hair cells using the analogy of keys of a piano and provides a brief introduction to three types of hearing loss.

Video clip #2: (1:34 min): Title: How Hearing Loss Occurs (from growsmartfoundation)

Link: https://www.youtube.com/watch?v=mMiwxUUj7Xg

Description: This clip provides contrasting images and animations of normal hair cells and damaged hair cells. It uses animations to illustrate the damage caused by repeated exposures to loud sounds using seagrass (hair cells) and ocean waves (sound waves) analogy.

Video clip #3: (Only the first 48 sec of the video clip is shown)

Title: Benefits of Wearing Ear Plugs for Musicians (produced by York ENT Surgical Consultants)

Link: https://www.youtube.com/watch?v=29BpzFZbMnQ

Description for first 48 sec: Laura Spinelli, an audiologist, discusses symptoms caused by music produced by a variety of musical instruments (rock bands and symphonies) including ringing in ears and difficulty in hearing family members and enjoying music.

Video clip # 4: (First 2:00 min)

Title: Fitting 3M™ E-A-R™ Earplugs (Premolded and Push-Ins style)

Link: https://www.youtube.com/watch?v=7iiR_waoec8

Description: Elliott Berger, a division scientist for 3M's Personal Safety Division, demonstrates fitting and insertion of premolded and push-in style earplugs with the assistance of an ear canal animation.

Earplug Selection

Both earplugs were selected based on the ease in purchasing, assumed affordability and ease in inserting and removing the earplugs. For the musician style, we purchased the ER20-XS High Fidelity 3-flange earplugs at the cost of $15.00 for each pair. For the conventional style, we purchased the Clarity 656 multiple-use corded earplugs at the cost of $1.70 for each pair. The Clarity earplugs were selected based on their noise reduction rating (NRR) of 21, which is closer to the NRR of the ER20-XS earplugs of 13 compared with other commercially available earplugs. In addition, the two earplugs are similar in style. The mean attenuation values provided on the packaging of the earplugs are shown in Figure 1. The APV in Figure 1 was derived by subtracting the SD data available on the packaging from the mean attenuation value.

Earplug Insertion

Both earplugs were purchased in two different sizes to allow proper fit in all ear canals. In discussion with participants, the musicians' earplugs were referred to as gray or white, and the conventional earplugs was referred to as green or blue depending on the color/size. Both earplugs were corded before handing them

to the participants. The participants were requested to place the cords around their necks for convenient insertion and removal in between different conditions. After each insertion, the investigators performed a visual check to assess the adequacy of the insertion in each ear. When the depth of the insertion was considered inadequate, the participants were instructed to remove and reinsert the earplug. Participants received the earplug model information only at the end of data collection.

Music Performance

Musicians were requested to play music five different times (three min each) under each of the condition shown in Figure 2. They used the instrument of their choice to play music of their choice in each of the five conditions. The variety of musical instruments used by the musicians is shown in Table 1.

Dosimetry

A dosimeter from 3M Quest Technologies (Model NoisePro DLX) was used for recording music levels. The dosimeter was calibrated using the AC-300 acoustic calibrator before and after each set of measurements for each participant to ensure accuracy of measures. Based on the calibration performed by the manufacturer, the measurement accuracy of both the dosimeter and the acoustic calibrator was within 0.19 dB. Maximum, minimum, average, and peak levels were recorded using the dosimeter while playing music for three min in each of the conditions shown in Figure 2. The microphone

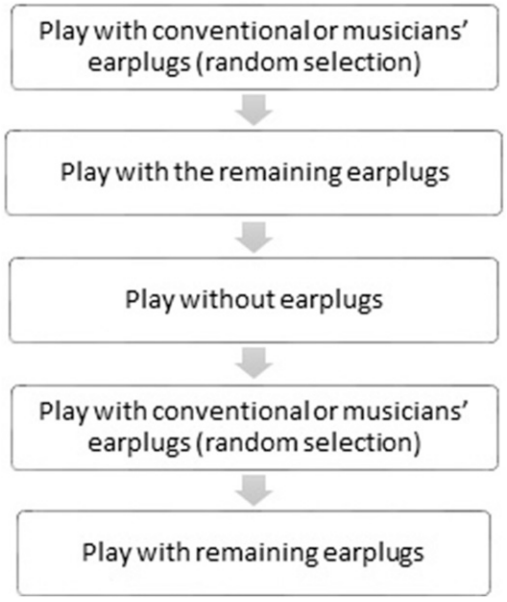

Figure 2. Different conditions for playing music and conducting dosimetry.

Table 1. The Various Musical Instrument Played by the Participants

Caucasian Men	Caucasian Women	Filipino Men	Filipino Women
Alto Saxophone	Cello	Bass Guitar (2)	Flute
Clarinet	Euphonium	Guitar (6)	Guitar (7)
Guitar (2)	Horn	Piano	Piano (3)
Oboe	Piccolo		Violin
Trombone	Trombone		
Trumpet	Violin (2)		
Tuba			

of the dosimeter was clipped on the top garment on the shoulder of the participant away from the neck while avoiding contact of the clothing with the windscreen of the microphone.

The dosimeter was set to the criteria set by the American Conference of Governmental Industrial Hygienists (ACGIH, 1995). The exchange rate was 3 dB, the time weighting was an S response, the frequency weighting was dB(A), the threshold/criterion level was 80 dB, and the criterion time was eight hours. The dosimeter provides automatic recording of several values. For the current project, we used the following values.

LASmax (dBA)

Maximum value of the A-frequency-weighted and S-time-weighted sound level over the measuring period.

LASmin (dBA)

The lowest (minimum) value of the A-frequency-weighted and S-time-weighted sound level during the measurement interval.

Average sound level measured over the measurement period (LAVG) (dBA)

The average sound level measured over the measurement period. Any sound below the threshold of 80 dBA is not included in this average. Because of the use of an exchange rate of 3 dB, this is same as Leq.

Lpk (dBZ)

The peak sound level or the highest instantaneous sound pressure level recorded during a measurement interval, with a standard (zero-Z) frequency weighting. It is detected independently of dosimeter settings for response rate or weighting.

Analyses

Mixed analyses of variance (ANOVA) (Cultural origin and Gender as nonrepeated variables) was performed

Table 2. Number (%) of Musicians Possibly at Risk for Hearing Loss in Each of the Earplug Conditions

Criterion	Conventional Trial 1	Conventional Trial 2	Musicians' Trial 1	Musicians' Trial 2	No Earplug
LAVG > 85 dBA	22 (61.1)	21 (58.3)	22 (61.1)	22 (61.1)	21 (58.3)
LAVG > 90 dBA	17 (47.2)	15 (41.7)	18 (50)	19 (52.8)	16 (44.4)
Peak > 130 dBZ	5 (13.89)	1 (2.78)	5 (13.89)	5 (13.89)	2 (5.56)
Peak > 140 dBZ	2 (5.56)	1 (2.78)	1 (2.78)	2 (5.56)	1 (2.78)

Notes: The criterion sound level recommended by NIOSH is 85 dBA, and the OSHA regulation assumes a criterion level of 90 dBA time-weighted average. The Department of Defense (2004) requires separate hazard criteria when workers are exposed to steady-state noise with simultaneous exposure to impulse noise above 130 dB peak levels. Under OSHA regulations, unprotected workers may not be exposed to peak sound levels greater than 140 dBZ. The levels in the table are reported without regard to the use of HPDs because many musicians do not use earplugs or do not used them on a regular basis.

on LAVG, to determine if music levels increase while wearing earplugs. To determine if there was an impact of earplug use on the DR, two different measures were used. The DR was derived by subtracting the minimum values from the maximum values. A different measure of the dynamic range 2 (DR2) was derived by subtracting the LAVG value from the peak value. Mixed ANOVA was performed on both the DR and the DR2. Post hoc analyses were planned using the least significant difference (LSD) test. Significance level was set at 0.05.

RESULTS

Number of Musicians at Risk for Hearing Loss

Table 2 shows the number and percentage of musicians who could be at risk for hearing loss based on LAVG and peak levels using two different criteria. As shown in Table 2, 42–61% of the musicians may be at risk for hearing loss based on the LAVG levels yielded by them. Based on the peak levels, 3–14% of the musicians may be at risk for hearing loss. The maximum levels exceeded 115 dBA in one case, on the first trial while using the conventional earplug.

Mixed ANOVA on the LAVG

The mixed ANOVA (Cultural origin and Gender as nonrepeated variables) on the LAVG by assuming five repeated measures of earplug condition (Conventional Trial 1, Conventional Trial 2, Musicians' Trial 1, Musicians' trial 2, and no earplug) revealed only a significant effect of cultural origin (Table 3). None of the other main effects or interactions were significant. The LAVG of music played by Filipino musicians (mean = 76.59 dBA) was significantly lower ($p = 0.0150$) than the music played by Caucasian musicians (mean = 91.70 dBA). Overall, the group results suggest that the loudness of music does not increase with the use of earplugs. However, individual data analyses showed that approximately 8–31% of the participants yielded higher LAVG levels, and 16–31% of the participants yielded higher peak levels while wearing earplugs than the no-earplug condition (Table 4).

A second mixed ANOVA on the LAVG by using two nonrepeated variables (cultural origin and gender) and two repeated variables ([a] Earplug type: conventional versus musicians' earplugs and [b] Trials: first versus second trial) confirmed the significant effect of

Table 3. Mixed ANOVA (Nonrepeated Variables: Cultural Origin and Gender) Summary Statistics for LAVG Showing Only Significant Effects

ANOVA on LAVG Assuming Five Earplug Conditions (Conventional Trial 1, Conventional Trial 2, Musician Trial 1, Musician Trial 2, and No Earplug)						
1-CULORIGI, 2-GENDER, 3-PLUGNOPLUG						
	df Effect	MS Effect	df Error	MS Error	*F*	*p* Level
1	1	10,435.68	32	1,581.963	6.596665	0.015087
ANOVA on LAVG with Two Types of Earplugs (Conventional and Musician) and Two Trials (First and Second)						
1-CULORIGI, 2-GENDER, 3-PLUGTYPE, 4-TRIALS						
	df Effect	MS Effect	df Error	MS Error	*F*	*p* Level
1	1	7,897.106	32	1,197.087	6.596935	0.015085
134	1	396.1724	32	92.71841	4.272855	0.046895

Note: The repeated variables are either the earplug conditions (five levels) or the earplug type (two levels) and trial number (two levels).

Table 4. Number (%) of Musicians with Increased Music Levels with the Earplug Compared with the No-Earplug Condition

Measurement and Criterion	Conventional Trial 1	Conventional Trial 2	Musicians' Trial 1	Musicians' Trial 2
LAVG difference >3	11 (30.56)	7 (19.44)	7 (19.44)	11 (30.56)
LAVG difference >6	8 (22.22)	4 (11.11)	3 (8.33)	6 (16.67)
Peak difference >3	11 (30.56)	8 (22.22)	10 (27.78)	10 (27.78)
Peak difference >6	6 (16.67)	6 (16.67)	8 (22.22)	7 (19.44)

Note: LAVG difference = LAVG with plug − LAVG without plug; Peak difference = peak with plug − peak without plug.

cultural origin ($p = 0.0150$) and revealed a significant interaction ($p = 0.0468$) of cultural origin, plug type, and trial number (Figure 3). The LAVG of the music played by Caucasian musicians did not vary across the two types of earplugs or across the first and the second trials. However, the LAVG of the music played by Filipino musicians was lower on the second trial than the first trial with the conventional earplugs ($p = 0.0062$) and second trial with the musicians' earplugs ($p = 0.0095$). None of the other main effects or interactions were significant. These results suggest that the overall loudness of music may vary in some musicians depending on the type of earplug and cultural origin.

Mixed ANOVA on the DR

The mixed ANOVA (Cultural origin and Gender as nonrepeated variables) on the DR by assuming five repeated measures of earplug condition (Conventional Trial 1, Conventional Trial 2, Musicians' Trial 1, Musicians' trial 2, and no earplug) revealed a significant ($p = 0.0434$) effect of plug conditions (Figure 4). The LSD revealed a significantly ($p = 0.0397$) reduced DR on the second trial of the music played with the conventional earplugs compared with the no-earplug condition ($p = 0.0397$) and the first trial with both the conventional ($p = 0.0075$) and musicians' earplugs ($p = 0.0103$). There were significant interactions of cultural origin and plug condition ($p = 0.0095$) and cultural origin, gender, and plug condition ($p = 0.0065$) (Table 5). The LSD test revealed that the DR was significantly lower during the second trial with both conventional and musicians' earplugs ($p < 0.0132$) than the first trial of each earplug and the no-earplug condition for music played by Caucasian men. Similarly, the DR was significantly ($p < 0.0153$) lower on the second trial of each earplug than the first trial of each earplug in Caucasian women. In Filipino men, the DR was significantly ($p = 0.0027$) larger than the no plug condition only during the second trial with the musicians' earplugs (Figure 5).

A second mixed ANOVA on the DR by using two nonrepeated variables (Cultural origin and Gender) and two repeated variables ([a] Earplug type: conventional versus musicians' earplugs and [b] Trials: first and second trial) confirmed a significant interaction between cultural origin, gender and plug type ($p = 0.0079$). In addition, it showed a significant effect of trial with significantly lower DR during the second trial than the first trial ($p = 0.0040$). There was a significant interaction of cultural origin and trial ($p = 0.0075$) (Table 5). The LSD test showed that the DR of the music played by Caucasian musicians was significantly higher on the first trial than the music played by them during the second trial and the music played by Filipino musicians during both first and second trials. There were no significant differences in the DR of the music played by Filipino musicians across the two trials.

Mixed ANOVA on the DR2

The mixed ANOVA (Cultural origin and Gender as nonrepeated variables) on the DR2 by assuming five repeated measures of earplug condition (Conventional Trial 1, Conventional Trial 2, Musicians' Trial 1, Musicians' trial 2, and no earplug) revealed a significant ($p = 0.0012$) effect of cultural origin. The DR2 was significantly larger for music played by Filipino musicians than Caucasian musicians (Table 6). No other effects were significant.

A second mixed ANOVA on the DR2 by using two nonrepeated variables (Cultural origin and Gender) and two

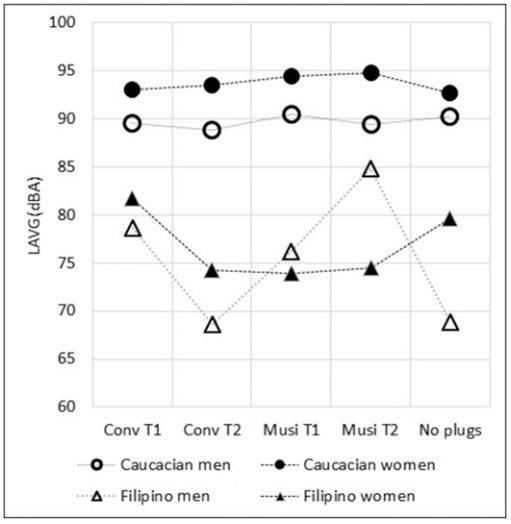

Figure 3. Mean LAVG levels across all variables. Conv = Conventional Earplugs; Musi = Musicians' earplugs; T1 = Trial 1; T2 = Trial 2.

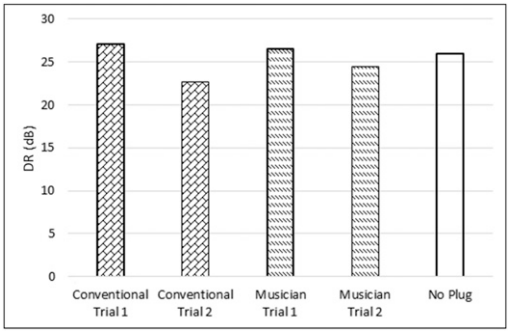

Figure 4. Mean DR values across various earplug conditions.

repeated variables ([a] Earplug type: conventional versus musicians' earplugs and [b] Trials: first and second trial) also showed a significant effect of cultural origin ($p = 0.0010$) with a larger DR2 yielded by Filipino musicians (mean = 42.18) than Caucasian musicians (mean = 23.81) (Table 6). In addition, there was a significant interaction between cultural origin, gender, plug type, and trial ($p = 0.0239$) as apparent in Figure 6.

DISCUSSION

The results suggest that 42–61% of the musicians may be at risk for hearing loss based on the LAVG levels yielded by them. Based on the peak levels, 3–14% of the musicians may be at risk for hearing loss (Table 2). These results confirm previous findings suggesting that some music levels are hazardously loud (Juman et al, 2004; McIlvaine et al, 2012; Rodrigues et al, 2015). We measured the music levels while only one musician was playing the music. The levels are expected to be higher when several musicians are performing and can vary from 75 to 129 dBA with peak levels ranging from 103 to 149 dBC (summarized in Table 9.2, Rawool, 2012a).

Effects of Earplug Use

There were no significant differences in the average loudness of music played with and without earplugs. Thus, earplugs are likely to provide some hearing protection in most cases. In real-life settings, the HPD attenuation is expected to be lower than that achieved by us because of training before earplug insertion and visual checks after insertion. With lower attenuation, music levels are likely to be even less affected by the use of earplugs than noted in the current study.

However, 8–31% musicians may increase the loudness of their music while playing earplugs (Table 4). Such musicians will benefit from counseling and practice to ensure adequate protection with earplugs. In laboratory settings, the amount of attenuation provided by earplugs is reflected in the NRR labeled on the packaging of the earplugs. However, OSHA (1983) recommends 50% derating of the labeled NRR of earplugs because when individuals use earplugs in real-life settings, the earplug insertion can be less than ideal. Thus, for the earplugs used in the current study, the derated NRRs will be 7.5 dB for the musicians' and 10.5 dB for the conventional earplugs. The NRR may be sufficient or insufficient based on the music levels yielded by each musician. In ideal situations, individual fit testing of HPDs (Schulz, 2011) for each musician is recommended.

There are two possible procedures for obtaining ear-specific real-ear attenuation data yielded by each of the types of earplug used in the current study in each ear. One of the procedures is the headphone-based real-ear attenuation at threshold. This procedure would have placed a much greater time demand from each participant with the requirement of at least four plugged threshold measures with each insertion for each ear. The fatigue resulting from such measures could have decreased the possibility of reliable thresholds leading

Table 5. Mixed ANOVA (Nonrepeated Variables: Cultural Origin and Gender) Summary Statistics on the DR Showing Only Significant Effects

ANOVA on DR (Maximum–Minimum) Assuming Five Earplug Conditions						
1-CULORIGI, 2-GENDER, 3-PLUGNOPLUG						
	df Effect	MS Effect	df Error	MS Error	*F*	*p* Level
3	4	142.1877	128	56.10614	2.534262	0.043371
13	4	196.3048	128	56.10614	3.498811	0.009544
123	4	209.7467	128	56.10614	3.73839	0.006534
ANOVA on DR with Two Types of Earplugs and Two Trials						
1-CULORIGI, 2-GENDER, 3-PLUGTYPE, 4-TRIALS						
	df Effect	MS Effect	df Error	MS Error	*F*	*p* Level
4	1	485.981	32	50.43803	9.635208	0.003975
14	1	410.7848	32	50.43803	8.144345	0.007515
123	1	274.8148	32	34.24901	8.024023	0.007923

Note: The repeated variables are either the earplug conditions (five levels) or the earplug type (two levels) and trial number (two levels).

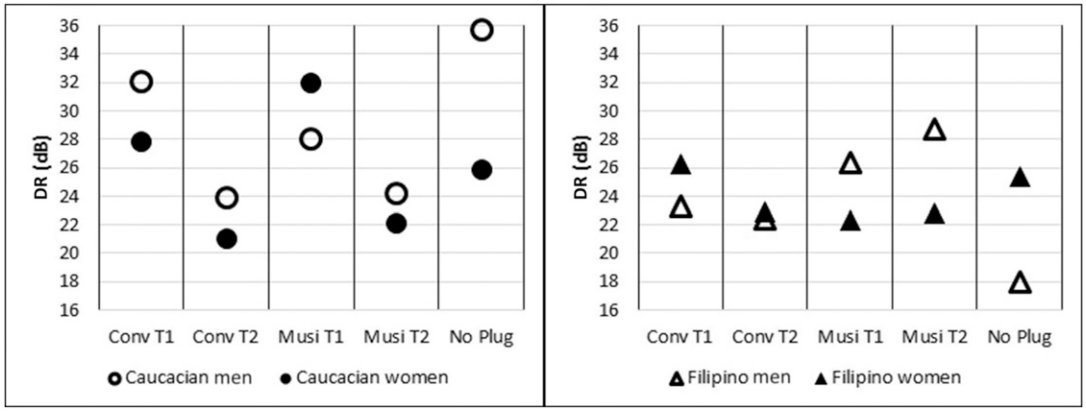

Figure 5. Mean DR values across all variables. Conv = Conventional Earplugs; Musi = Musicians' earplugs; T1 = Trial 1; T2 = Trial 2.

to unreliable headphone-based real-ear attenuation at threshold data. The second procedure is the microphone in the real-ear measure, which is a faster procedure but requires specially probed earplugs for accurate measures. To our knowledge, such specially probed earplugs are not available for the specific flanged earplugs used in the study.

In addition to the attenuation provided by the earplugs, several other characteristics of the earplugs including individual comfort, ease of insertion and removal, and ease of availability of the earplugs should be considered to ensure that the musicians would actually use the earplugs (Rawool, 2012c). Both DR and the DR2 may be altered with the use of earplugs at least in some musicians. In addition, with practice, both the DR and DR2 may change as shown by the trial effects apparent in Figures 4 and 5 at least in some musicians.

Effect of Culture

We found some significant main effects of culture and several interactions involving culture. To our knowledge, such cultural variations have not been previously reported. The music played by Caucasian musicians was louder (LAVG) than the music played by Filipino musicians. Such cultural differences should be considered in making earplug-related recommendations to avoid any overprotection, which could lead to the playing of louder music. Playing the music louder (e.g., hitting the drums or piano keys harder) can exacerbate upper extremity musculoskeletal problems (Yoshimura et al, 2008; Brandfonbrener, 2009). We also found a significantly larger DR2 for the music played by Filipino musicians than the music played by Caucasian musicians. Such differences can have an impact on the perceived quality of music. One possible reason for the differences in the loudness or DR2 is the differences in the instruments played by various musicians as shown in Table 1. There were a total of 17 different instruments played by 36 participants. The sample size is not sufficiently large to conduct analyses with instrument-specific data. Future studies with a larger sample size may be useful in determining any interactions between cultural origin and the type of musical instrument played by each participant.

Effect of Earplug Type

The LAVG of the music played by Filipino musicians was lower on the second trial than the first trial with the

Table 6. Mixed ANOVA (Nonrepeated Variables: Cultural Origin and Gender) Summary Statistics on the DR2 Showing Only Significant Effects

ANOVA on DR2 (Peak − LAVG) Assuming Five Earplug Conditions						
1-CULORIGI, 2-GENDER, 3-PLUGTYPE						
	df Effect	MS Effect	df Error	MS Error	*F*	*p* Level
1	1	15,294.68	32	1,202.658	12.71739	0.001164
ANOVA on DR2 (Peak − LAVG) with Two Types of Earplugs and Two Trials						
1-CULORIGI, 2-GENDER, 3-PLUGTYPE, 4-TRIAL						
	df Effect	MS Effect	df Error	MS Error	*F*	*p* Level
1	1	11,685.55	32	890.9514	13.11582	0.001001
1,234	1	703.0214	32	124.9862	5.624793	0.023892

Note: The repeated variables are either the earplug conditions (five levels) or the earplug type (two levels) and trial number (two levels).

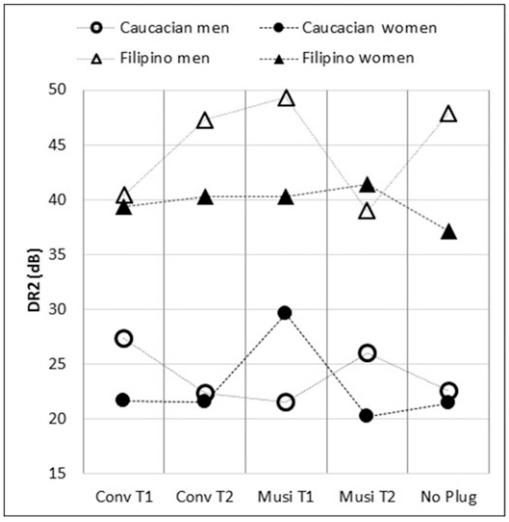

Figure 6. Mean DR2 values across all variables. Conv = Conventional Earplugs; Musi = Musicians' earplugs; T1 = Trial 1; T2 = Trial 2. Note that the DR2 is larger for the Filipino group.

conventional earplugs (p = 0.0062) and second trial with the musicians' earplugs (p = 0.0095). Similarly, there were some significant interactions involving the plug type for both the DR and DR2. These results suggest that with some types of earplugs, the overall loudness of music, the DR, and the DR2 may vary in some musicians depending on the type of earplugs and the trial number.

Effect of Practice (Trial Number)

The LAVG of the music played by Caucasian musicians did not vary across the first and the second trials. The DR was significantly lower during the second trial with both conventional and musicians' earplugs than the first trial of each earplug and the no-earplug condition for music played by Caucasian men. Similarly, the DR was significantly lower on the second trial of each earplug than the first trial of each earplug in Caucasian women. Such narrowing of the DR may reduce the quality of the music and may not be acceptable to some musicians especially while participating in competitions. Thus, some training may be necessary for Caucasian individuals for consistent and effective use of earplugs. The significantly lower DR obtained during the second trial for Caucasian musician may be related to the overall wider DR yielded by them than that yielded by Filipino musicians, as shown in Figure 5. The wider DR may be partially related to the maximum output of the specific musical instruments played by the Caucasian musicians. The maximum output yielded by the musicians across various musical instruments in the current study is shown in Figure 7 for comparison across instruments.

The LAVG of the music played by Filipino musicians was lower on the second trial than the first trial with the conventional earplugs, and there were no significant differences in the DR of the music played by Filipino musicians across the two trials. Overall, these results suggest that Filipino musicians may be able to maintain the DR of their music while lowering the LAVG levels. Note that the practice effects may also depend on the type of instrument played by each musician.

Limitations of the Study

The accuracy of the minimum noise levels is limited because of the fact that the noise floor of the electrical noise produced by the microphone is approximately 35 dB on A-weighting, and the sessions were conducted in a regular reverberant environment with noise floor around 65 dBA. Because the DR was calculated by subtracting the minimum levels from the maximum levels, the accuracy of the DR is limited for musicians with minimum levels below 65 dBA.

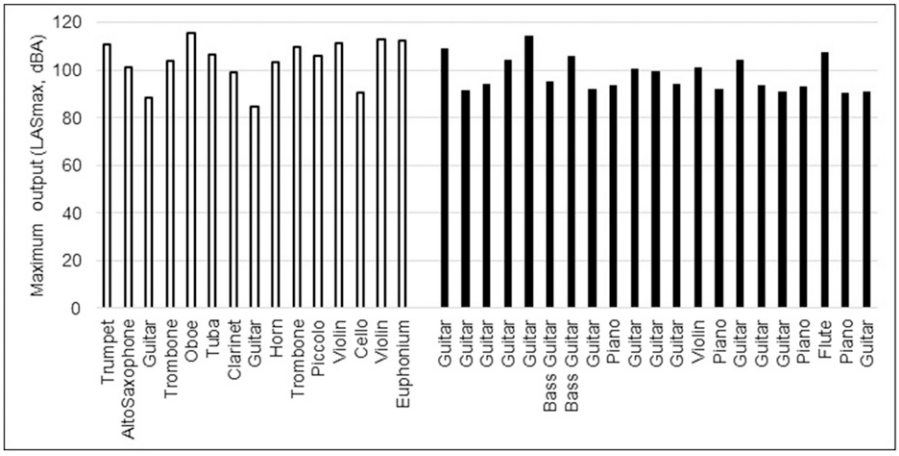

Figure 7. Maximum output (LASmax, dBA) yielded by 36 musicians across various musical instruments while playing music. The open bars show the maximum output yielded by Caucasian musicians and the closed bars show the output yielded by Filipino musicians.

There were only 15 Caucasian musicians and 21 Filipino musicians included in the study. The influence of culture noted in the current study needs to be confirmed in future studies with a larger participant pool. We asked participants to play the music only for three min in each condition to minimize fatigue or boredom. With longer practice in playing music with earplugs, the LAVG, DR, and the DR2 of the music may change as suggested by the trial effects apparent in Figures 3–6. The effect of practice in playing music with earplugs needs to be evaluated in future studies.

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