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Recreational Sound Risk For A University Student: Case Study

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RECREATIONAL SOUND RISK FOR A UNIVERSITY STUDENT: CASE STUDY

Capstone Document

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ABSTRACT

Concern about noise exposure in recreational settings is growing and unsafe levels of sound are frequently being experienced in a variety of non-occupational settings such as pubs, nightclubs, concerts, parties, and fitness classes. Damage to the auditory system may occur with regular participation in these loud activities. A case study was conducted to estimate sound exposure levels and risk associated with common activities. Findings demonstrated that pubs presented a hazardous sound environment, so information about health-oriented behavior is essential to effectively improve hearing conservation awareness for university students. Public awareness and personal hearing protection should be strongly considered to prevent hearing loss. Audiologists should encourage a healthy-hearing lifestyle and discourage exposure to loud sports without use of protection. Children and young adults should be properly educated about entertainment-related excessive sound exposure and encouraged to periodically monitor their hearing. Protection should be used in both ears during exposure to loud sound and prevention of hearing loss should be prioritized, especially in the young adult population, to avoid irreversible damage to the auditory system. Entertainment authorities should be encouraged to educate spectators about the excessive sound levels that are likely to be experienced at their events and should also make hearing protection easily accessible.

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CHAPTER 1

Introduction

Hazardous noise exposure is capable of causing damage to the auditory system. It is not clearly understood what type of noise and what specific duration of exposure leads to damage. Typically, young adults, are not well informed that recreational noise may be a source of damage. Common night-life activities can be loud and may cause hearing loss in the long run.

The aim of this project was to identify recreational noise exposures most commonly experienced by students and the overall risk associated with these activities. A risk checklist was developed to identify conditions with high-intensity recreational noise levels. The duration and frequency of recreational noise sources is much easier to measure and control, versus the intensity level (Fligor, 2010). Thus, a risk assessment chart was comprised of conditions experienced by students that may be used to identify hearing loss prevention strategies.

Literature Review

According to Ohlemiller (2012), the prevalence of noise-induced hearing loss (NIHL) in the young adult population has reportedly increased in recent years. A possible explanation is increased exposure to recreational noise. Recreational activities may cause exposure to sound with potentially hazardous intensity levels for several hours. Some people listen to loud sound at concerts or nightclubs and sport events and shoot firearms during hunting or target practice. Typically, exposure to recreational noise is unlikely to demonstrate immediate impairment due to the infrequent occurrence of the activities (Le Prell, 2016); however, recurring exposure to noise at a hazardous intensity levels will inevitably pose a substantial risk to the auditory system.

The World Health Organization (2015) estimates that 1.1 billion young people throughout the world may be at risk for acquired hearing loss due to unsafe listening practices, and nearly half of all teenagers and young adults ages 12–35 years old are being exposed to excessive sound levels. The incidence of NIHL that may be directly attributed to work-related exposures appears to be decreasing due to successful hearing conservation programs (HCPs) in the United States (Le Prell, 2016). Remarkably, NIHL resulting from recreational sound exposure appears to be increasing (Ohlemiller, 2012).

Sound Measurement

The National Institute for Occupational Safety and Health (NIOSH) recommendations and Occupational Safety and Health Administration (OSHA) standards are government criteria that provide guidelines for measurement of sound levels in America. The notable difference is that OSHA calls for the noise dosimeter to be set to an 80 decibel (dB) threshold, 90-dB criterion level, and 5-dB exchange rate. By contrast, NIOSH (1998) recommends use of an 80-dB threshold, 85-dB criterion level, and 3-dB exchange rate when measuring sound intensities. The NIOSH (1998) recommendations are more conservative than the OSHA regulation, due to a lower threshold value and 3-dB exchange rate.

Two instruments may be used to measure sound intensity levels. The first is a personal dosimeter, which is regarded as the “gold standard” approach for noise exposure monitoring and assessment. A personal noise dosimeter is preferred when individuals are mobile and targeted sound levels are variable. Dosimeters, when used under these conditions, should provide greater measurement accuracy and is capable of reporting multiple data points at specified time intervals, including the average noise level, peak noise level, and dose estimate.

There are a number of questionnaires that may be used to determine an individual’s perception of exposure to noise. A study conducted by Lopez (2014) attempted to develop a reliable instrument that could measure recreational noise exposure in young adults. The stages of validation for the questionnaire included semantic adaptation, validation of content and appearance, reliability, convergent validity, and construct validation. The semantic adaptation procedure required that the audience indicated whether a particular question with grammatical and semantic structure allowed for easy understanding. The validation of content and appearance were used to determine whether each question was "essential" for the instrument, while reliability was measured to determine the instrument's internal consistency. Convergent and construct validity ensured that the questionnaire was not too alike other ones and its factorial structure was confirmed. In turn, results obtained from the questionnaire were intended to detect the auditory behaviors of respondents that are at higher risk for NIHL. The *Recreational Hearing Habits Questionnaire* (Lopez, 2014), and various other questionnaires, are available to be used for estimation of recreational behavior.

Music

Fligor (2010) reviewed factors that may be attributed to recreational NIHL, mainly consisting of portable music players and personal listening devices. Damage to the auditory system depends on the intensity-level of sound, duration of exposure, and frequency of high-intensity activities. Research on portable music players has revealed that listeners generally listen at an intensity level of 75-105 dBA, and some of these individuals may be exposed to 15 minutes of music at 100 dBA, which is reportedly comparable to an industrial worker that is exposed in an 8-hour work day at 85 dBA (Daniel, 2007). A study done by Torre (2008) showed that over fifty percent of personal music system users reported listening for 1-3 hours, and ninety percent listened at a medium or loud volume. The average intensity levels for low, medium, loud, and very loud were 62, 72, 88, and 98 dB SPL, respectively. It can be inferred that individuals who use personal music devices may be over-exposed to loud sound.

The use of objective tests is more beneficial for examining the effects of noise exposure on the human auditory system. A study by Chong Lee et al. (2014) explored the relationship between leisure noise exposure through the use of personal music players and otoacoustic emissions (OAE) test results. Subjects were placed in a high-risk group if they reported listening to music at maximum, or near maximum, volume on a questionnaire. All others were placed in the low-risk group. Sound pressure levels (SPL) were measured at 85 dBA or greater when subjects listened to music at their preferred volume. The high-risk study group was estimated to be 604 (13%) out of a total 4,559 ears. Results indicated that subjects placed in the high-risk group have lower OAE levels than low-risk subjects. High-risk subjects had significantly reduced emissions at 4000 Hz, suggesting that noise exposure caused a reduction of the OAEs. It appears that 13% of the population that uses personal music players may be at-risk for over-exposure to sound and inner ear, outer hair cell damage (Chong Lee et al., 2014).

Live Concerts

Some individuals attend concerts frequently, and, during those activities, they are exposed to hazardous sound levels. Bogoch et al. (2005) examined the perception of noise and hearing protection in a population of listeners. His study included 204 participants at four rock concerts. His data revealed that, for 40% of the subjects, rock-concert sounds-intensity levels could damage hearing, and 80% of the sample reported that they never used hearing protection at concerts. Tinnitus was present in 85% of participants and other hearing problems were reported by 38% of the group. Hearing protection devices that may be used included ear plugs and ear muffs; however, only 42% of respondents indicated they would utilize ear plugs even if they were available for free before the concert. Clearly, concertgoers recognize that sound in live-music venues is capable of reaching hazardous levels, but they still choose not to address the issue with use of hearing protection.

Barlow (2010) recorded attendance and sound levels at various music activities frequented by young adults. For 100 participants, 94% reported attending at least one live music concert per month, each lasting approximately 2 hours. Forty-six percent reported attending more than 3 concerts per month. The average noise level over a four-and-a-half-hour period was 99 dBA, which suggests that these listeners were at-risk from over-exposure to noise because, presumably, hearing protection was not worn. Concertgoers should be aware of the damaging effects of attending loud music performances in advance of these activities. Level of risk may actually be higher when additional factors such as poor health, smoking, medications, vibration, and heat are present.

Nightclubs/Discotheques

Young adults commonly attend nightclubs and discotheques, which can introduce risk for auditory system damage. A study that included 780 college students investigated exposure to loud music (Budimcic et al., 2014). The authors used a self-reporting questionnaire to examine auditory risks and associated hearing problems related to hazardous noise levels in recreational activities such as concerts, disco clubs, and personal music devices. At least once each week, the majority of students (80%) went to disco clubs and similar environments with loud music. Approximately half (47%) of these students experienced two to three-hour exposure durations. Additionally, 25% of the students in this study spent in excess of 3 hours in a variety of noisy environments. Post-exposure results revealed that 66% of subjects experienced tinnitus and 10% reported subjective hearing loss. It is believed that repeated exposure to intense sound is cumulative and may increase complaints of tinnitus and hearing loss as continuous unprotected exposure occurs.

Nightclubs are a frequent form of entertainment for college students. Barlow (2010) found that 94% of their participants attended a nightclub at least once per week. The reported duration of time spent at nightclubs exceeded 3 hours for 43% of their population and measured noise levels produced an average of 100 dBA. Serra et al. (2005) discovered that the equivalent sound levels in discos ranged from 104-112 dBA. With very few exceptions, a single visit to a dance club is unlikely to result in permanent hearing loss, but repeated exposure is more likely to cause temporary threshold shift. Even for young people, mean exposures of 100 dBA may result in auditory damage when appropriate precautions are not taken.

When estimating adolescent risk for hearing loss, few studies have measured the cumulative exposure effects of high-intensity music. Vogel et al. (2010) used self-report questionnaires to identify the listening habits and auditory symptoms of young people. Safety standards were developed from a more lenient version of the European Union Noise Exposure standards, indicating that 80 dBA for 56 hours per week, would be effectively classified as hazardous. A sampling of 1512 adolescents indicated in a survey that 40% exceeded federal occupational safety standards after attending discotheques or pop concerts. Further, 54% exceeded the revised safety threshold when exposed to MP3 players, stereo headphones, pop concerts, and discotheques. Of these participants, 30-61% reported temporary auditory symptoms following excessive sound exposure. This study identified that adolescents often exceeded current occupational safety standards for hazardous noise exposure, which suggested a need for preventive community health guidelines to address recreational noise exposures.

Sporting events

Time spent at sports-entertainment events may produce hazardous exposures due to the high-intensity sound generated by spectators, bands, and public-address systems. Morris et al.

(2013) measured sound levels in National Collegiate Athletic Association (NCAA) basketball arenas. Personal noise-exposure monitoring dosimetry of 15 subjects who attended three home basketball games revealed a peak-noise level of 138 dB. Five subjects exceeded the 85 dBA OSHA Action Level, which would mandate enrollment in an HCP for occupational populations. These data indicated that spectators, competitors, and employees at arena athletic events might have an increased risk of auditory injury, especially when subjected to long-term exposure.

England and Larsen (2014) measured sound levels using noise dosimetry at 10 intercollegiate basketball games. Hearing thresholds and Distortion Product Otoacoustic Emissions (DPOAEs) were measured for 20 participants before and after exposure at these events. Temporary threshold shift calculations showed a mean difference of 4 dB, and DPOAEs demonstrated a mean change of 2 dB for test frequencies 2000, 3000, and 4000 Hz. These data were measured at one of the basketball games. The sound level measurement at one of the basketball games was 90 dBA 8-hour time-weighted average (TWA), which exceeded the NIOSH (1998) recommended exposure criterion (i.e., 85 dBA) and matched the OSHA (1983) permissible exposure limit (PEL; i.e., 90 dBA). For 60% of the games, measured sound levels exceeded the damage-risk criteria published in the OSHA (1983) noise exposure standard. These results suggested that public awareness and personal hearing protection should be strongly considered to prevent hearing loss from sporting events.

Rabinowitz et al. (2016) examined the noise levels of National Collegiate Athletic Association (NCAA) Division I basketball arenas. Eight locations were measured using a Type II sound level meter. The mean measurement was 92 dB, which exceeded the OSHA PEL. In addition, 40% of the games were above the OSHA (1983) PEL. The NCAA should be encouraged to educate spectators about the excessive sound levels that are likely to be experienced at sporting events. They should also make hearing protection accessible for use by attendees.

Professional automobile racing has been found to generate high intensity levels, especially in seating areas close to the racetrack. A sound level survey was administered by Rose et al. (2008) at a National Association for Stock Car Auto Racing (NASCAR) event, which indicated that noise levels were 97 to 104 dBA at approximately 150 feet from the race track. Noise measurements were 99 to 109 dBA when taken 20 feet from the track. This indicates that both fans and employees in close proximity to the track should be wearing effective hearing protection to avoid overexposure to hazardous levels of noise. The author reported individuals who have occasional exposure to NASCAR (approximately once per year) would unlikely develop a permanent NIHL. Nevertheless, audiologists should encourage a healthy-hearing lifestyle and discourage exposure to loud sports without use of protection.

Fitness Classes, Firearms, Video gaming, and Movie Theatres

Young individuals have a variety of activities to occupy free time, including firearms, video gaming, fitness classes, as well as movie theatres. According to Fligor (2010), discharging a round from most firearms will likely exceed 132 dB, so, over time, use of weapons without hearing protection could produce persistent hearing shift. Young adults should be educated about the importance of using hearing protection devices in order to preserve good hearing ability. To that end, Chen and Brueck (2016) captured personal noise measurements at a basic outdoor firing range. They reported measurement data from 14 participants over the course of 5 hours using 3 firearms: (1) a 12-Gauge Shotgun, (2) a .45-70 rifle, and (3) a .30-.06 rifle. Peak noise measurements were 155-163 dB for the shotgun, 155–160 dB for the .45-70 rifle, and 159–163 dB for the .30-.06 rifle. The TWA 8-hour sound levels ranged from 78-89 dBA when measured by personal dosimetry, although common dosimeters are generally incapable of measuring sound peaks that exceed 142 dB, due to the physical limitations of the microphone. For example, Chen and Brueck (2016) reported that noise exposure measurements from gunfire noise that are collected with dosimeters may underrepresent exposure and subsequent risk estimates because the dosimeter ceiling cutoff limits the intensity of noise that can be recorded. Due to excessive noise levels in firing ranges, the authors recommended double hearing protection to ensure adequate sound attenuation.

Over the past 10 to 15 years, video gaming has become extremely popular with children as well as adults. Spankovich et al. (2014) observed subjects while they played a video game that involved the sound of gunfire through headphones. The purpose of this investigation was to measure changes in hearing sensitivity and track recovery of function when a temporary threshold shift (TTS) was indicated. Outcome measures included pure-tone air conduction audiometric thresholds and DPOAEs. The sound intensity level and number of impulse sounds were sequentially increased throughout the study. Their data revealed that a subset of participants demonstrated threshold shifts under specific conditions, but overall there was significant individual variability. Video games may not accurately represent sound levels and the realistic effects of gunfire (Spankovich et al., 2014).

Clark (1991) conducted a review of exposure to recreational noise activities, including live music, personal listening devices, noise around the home, and hunting and target shooting. Hunting and target shooting, using firearms, appeared to present the largest risk for hearing loss according to the literature. Furthermore, research about these activities suggested that human hearing is at significant injury risk if exposure is accumulated from a repeated number of events.

Fitness classes are a popular daily activity for health-conscious adults. Sound levels produced by the music in these classes may cause a reduction in hearing acuity. Torre and Howell (2008) measured sound levels in an aerobics program. Participants included 50 attendees who wore a personal dosimeter for a 50-minute class. The majority of the participants (75%) attended aerobics activities 1-3 times per week and 74% reported that the music was at a comfortable level. DPOAEs were measured before and after the aerobics class. Sound levels ranged from 83 to 91 dBA, with a mean of 87 dBA. Average post-exposure DPOAEs decreased for 6000 Hz. Overall, the combination of frequent aerobic classes and high levels of sound exposure should be avoided, or limited, whenever possible.

Huth et al. (2014) measured sound levels in movie theatres using a smart phone application. Participants used a sound pressure level meter application to determine whether sound in movie theatres exceeded permissible occupational limits. Two types of movies were measured using the application. Slightly higher sound levels were found in the action movie (74 dB SPL) as compared to the movie made for children (72 dB SPL). Overall, the data indicated that sound levels in movie theatres generally do not exceed occupational damage-risk criteria. The study suggested that sound levels in movie theatres were unlikely to cause damage to the auditory system.

Effects of recreational noise exposure

The effects of recreational noise exposure can lead to a sequela of auditory and non-auditory symptoms. Prolonged exposure exceeding 85 dBA can produce outer hair cell damage, that may lead to complaints of hearing loss and tinnitus. Non-auditory effects include loss of sleep, elevated blood pressure, changes in brain chemistry and increased heart rate (Daniel, 2007). Gupta et al. (2014) sought to examine the preparedness of young adults regarding the harmful effects of recreational sound. A semi open-ended questionnaire was used to obtain data from 940 young adults. The majority of participants reportedly listened to loud music on their phones and experienced headache (58%), inability to concentrate (48%), and tinnitus (41.8%). Overall, 84% of the subjects acknowledged that loud sounds were harmful to hearing, but only 3% were users of hearing protection devices. The effects of loud sound levels can vary between listeners, but excessive exposure is capable of causing irreversible damage to the auditory system.

Tinnitus

Loud noise exposure is a common cause of tinnitus, which has been described as a ringing, buzzing, or roaring sound in the ears or head. This sensation may occur abruptly and subside over time, but may become constant and disabling (NIDCD, 2015). A study by Gilles et al. (2013) examined the prevalence of permanent noise-induced tinnitus and temporary tinnitus for young adults exposed to noise. A total of 3,892 high school students completed the *Youth Attitudes to Noise Scale*, and the *Beliefs about Hearing Protection and Hearing Loss* questionnaire for the study. These tools were used to assess their attitudes and beliefs about noise and hearing protection. Data revealed that the incidence of temporary noise-induced tinnitus (NIT) and permanent NIT was 75% and 18%, respectively. There was an increasing occurrence of temporary tinnitus with age. Most students had a neutral attitude towards loud music and only 5% of students used hearing protection. Despite the high prevalence of tinnitus, young adults lacked knowledge about the risks of loud music. Overall, hearing loss prevention and education should focus on recognizing the warning signs preceding noise-induced damage for this population.

Temporary threshold shift (TTS) and Hearing loss

Following noise exposure, auditory effects may promptly become recognized. Holmes et al. (2007) conducted a study to identify the prevalence of perceived hearing loss, tinnitus, and TTS in young adults, including their attitudes about noise. The study included 245 students who completed the *Hearing Symptom Description*, *the Youth Attitude to Noise Scale*, and *Adolescents Habits and Hearing Protection Use* questionnaire. Only subjective measures were collected, and no audiologic test data were obtained. Holmes et al. (2007) revealed that approximately 6% of participants reported that they perceived a hearing loss, 14% reported prolonged tinnitus, and they generally had neutral attitudes toward noise. More than 20% of participants reported otalgia, tinnitus, or TTS after noise exposure at least *sometimes*, and very few reported hearing protection use. It appears that further research is needed to compare attitudes toward noise exposure and the damaging effects on the auditory system in young populations.

Potentially hazardous intensity levels are apparent in entertainment-related excessive sound exposure (ERESE) such as concerts, disco clubs, and personal music devices. Budimcic et al. (2014) administered self-report measures that examined the auditory risks and associated hearing problems for 780 college students that were exposed to hazardous sound levels at these leisure activities. Their data identified that 82% of students made a habit of listening to loud music, 66% experienced tinnitus, and 10% had a subjective feeling of hearing loss after exposure. The study suggested that the majority of adolescent college students who experienced ERESE during typical recreational activities and experienced various auditory problems, likely the result of the intensity and duration of the exposure.

Preventive Measures

Given the literature review discussed above, it is reasonable to conclude that people who consistently listen to loud music, or attend live concerts, sporting events, and other popular activities must embrace preventive measures and limit their unprotected exposure to hazardous sound levels. Auditory damage may not be discernible at first, but long-term exposure may cause permanent identifiable hearing damage. Prevention does not necessarily consist of avoiding all forms of recreational noise; instead, listeners should seek to permit brief ERESE only. Further, listeners should take auditory rest breaks between periods of ERESE. It is important that listeners utilize hearing protection devices (HPDs) when indicated (Fligor, 2010). The best type of HPD may be determined during a visit with the audiologist. A protective device should be selected based upon the type of ERESE and its duration. Protectors may be passive, active, non-linear, electronic, one-size-fits-most or custom molded.

Personal hearing conservation attitude depends on a person's beliefs about excessive sound and the preventive measures they might choose. Keppler et al. (2015) evaluated the effects of attitudes and beliefs toward noise, hearing loss, and hearing protection with young adults. The study included 163 subjects ranging from age 18-30 years. Each subject completed a questionnaire and audiological test battery. Individuals with problematic beliefs about hazardous sound had poorer hearing than those with health-oriented attitudes, including beliefs about hearing loss and HPDs. For example, individuals with a more positive opinion about hearing health were found to use HPDs more often. Information about health-oriented behavior is necessary to effectively improve hearing conservation awareness in young adults, especially those who frequently participate in loud entertainment activities.

Recreational and occupational noise

Hazardous sound levels have been associated with a number of occupational work settings. Some individuals in noisy occupations may be exposed to levels of sound that require enrollment in an HCP. In order to protect hearing properly, HCPs should include annual education and access to hearing protective devices; however, it is important to understand that use of hearing protection should not be exclusive to the workplace. Some occupational noise-exposed workers have personal activities that include ERESE. They should be identified, counseled, and provided HPDs for use when off duty. Le Prell (2016) indicated that many recreational sound exposures may not occur at a high level or for a long enough duration. In other words, these sounds may not be considered hazardous according to occupational standards but are cumulative for total daily and weekly exposure. A combination of both occupational and recreational sources may cause persistent loss of hearing sensitivity.

When making a comparison between recreational and occupational noise dose, the auditory-risk criterion may be alarming. In a literature review, Davis (1986) suggested that individuals who are typically exposed to recreational noise during a 7-year period would accumulate the equivalent of 40 years of occupational noise at 85-90 dBA. Clearly, recreational sound exposure should not be taken lightly due to its apparent cumulative effect over a lifespan. Hence, young adults who are active in ERESE events should be educated about intensity, duration, and periodicity of exposure for prevention of auditory injury.

CHAPTER 2

Methodology

Table 1 is a summary of discussed publications, including reported sound-measurement data and other information. From the summary table (1), peak-noise exposures ranged from 158-163 dB, TWAs were approximately 90 dBA, and average noise levels were between 71 and 132 dB. This single-case investigation was administered to determine if the common recreational habits of a college-student were similar to the literature review data in Table 1.

Subjects

For this investigation, the case was a 23-year-old female graduate student (MW) with generally-quiet daily routine activities. Over a six-month period, select recreational activities were measured and reported. Activities that were selected were those expected to be in the ERESE classification.

Instrumentation/Equipment

A Quest Technologies NoisePro Series personal dosimeter (SN: NPF010012) was used to obtain the first three sound measurements. The Extech Model SL355 noise dosimeter (SN: 150107737) was used to obtain the remaining five measurements. The dosimeter was calibrated before and after each field measurement. Batteries were replaced if indicated. Instruments were worn on the body with microphone placed near the ear but pinned to clothing in the shoulder area. The device was turned on upon entering the measurement area and remained on for the entire sampling. Devices were stored in a protective carrying case in the field and kept in the laboratory when measurements were not scheduled.

Environment

Music was playing for the duration of each pub measurement. There were at least 20 people present during the pub measurements. Pubs contained wall hangings throughout the spaces. Floor coverings included carpet, wood, and tile. One sampling was conducted outdoors, which was a reverberant concrete setting.

Procedures

Sample duration was recorded in minutes. The sampling peak-noise level, 8-hour TWA-8 hours, dose estimate in percent, and statistical noise range were recorded for each environment. Data were extracted from the dosimeter and entered manually into a spreadsheet after each measurement. Outcome data will be analyzed in the next section.

CHAPTER 3

Results

Eight noise measurement samples, that included run time, peak-noise, TWA, and dose will be discussed. The run time of samples ranged from 50 minutes (e.g., recreation center) to 107 minutes (e.g., party), with a total of 643 dosimetry minutes or 10.7 hours (Table 2). The peak noise level ranged from 114 dB SPL (e.g., recreation center) to 138 dB SPL (e.g., downtown pub). The mean peak noise level was 130 dB SPL across the eight samples.

The TWA ranged from 63 dBA (e.g., recreation center) to 96 dBA (e.g., crowded pub). Taken together, the samples produced an average a TWA of 78 dBA. As seen in Figure 1, the graphical form displays the damage-risk criterion (DRC) line at 85 dBA. Only two conditions produced dosimetry samples that exceeded the DRC line: the crowded pub and the downtown pub produced sound levels of 96 dBA and 88 dBA, respectively. The campus pub generated an exposure level of 83 dBA; however, per NIOSH (1998), this would not pose a significant risk. The scatterplot in Figure 2 demonstrates the relationship between peak output and time. This figure includes recordings that had similar run times and peak outputs; however, a short sample contained a high peak output value. Two samples with similar run times had different peak outputs. Each exposure condition presented a unique set of measurement characteristics.

Table 3 displays the three venues that posed the most risk. The crowded pub, downtown pub, and campus pub all revealed significant means for peak noise level, TWA, and dose. The peak noise of the three louder pubs ranged from 129-138 dB SPL, with an average of 135 dB SPL. These pubs also created a TWA of 66-96 dBA, with a mean of 89 dBA. Noise dose varied from 4-230% with an average of 123%. When an additional low-noise pub was added, the averages decreased to 133 dB SPL peak noise, 83 dB TWA, and 93% noise dose. A scatterplot of the samples and their time-weighted averages is shown in Figure 3. Generally, longer samples have higher TWAs, but as previously mentioned, only two samples exceeded the 85 dBA DRC line.

The noise dose statistic was calculated and compared to a risk line of 50%. Noise dose ranged from 3% (e.g., recreation center) to 230% (e.g., crowded pub). Noise dose data are similar to TWA data (see Figure 3) as TWA is used to calculate dose. From those data, a variability can be seen between the sound conditions. The crowded pub and downtown pub generated the highest noise dose within the samplings, contributing 230% and 73%, respectively (data not shown). While the crowded pub delivered a noise dose of 48%, the sports pub generated a lower dose of 4%. The relationship between TWA and peak was also calculated and it became evident that as the peak increased, the TWA also increased (data not shown). The two samples with the highest TWA contained the highest peaks, while the sample with the lowest TWA contained the lowest-measured peak intensity.

CHAPTER 4

Discussion

To compare common ERESE activities from a single case to data discovered in a review of the literature, the acoustical characteristics of eight conditions were documented at the time each sample was collected. These data were analyzed and described. Each of the eight conditions presented a slightly different setting.

Music was played through speakers throughout each of the measurements in the pubs. At least 20 people were present at each pub during the measurement. The *crowded pub* consisted of a disk jockey, bar area, and wooden dance floor and large crowd. This pub was visited on a busy night, during a peak attendance. The *crowded pub* had few windows and approximately 10-foot ceiling height. The *downtown pub* was also visited on a busy night. Music was played through large speakers within a rectangular, open space. This pub had wood flooring with tile ceiling.

Speakers played loud music, as sports were being televised in the *campus pub*. At this location, the bar stretched along the wall across from the televisions, with occupied tables and chairs between them. The *campus pub* was crowded with a number of people socializing. This space contained wood flooring and high ceilings. By comparison, the *sports pub* was visited on an evening when the business was not crowded. This location included a bar and slot machines that were occupied by just a few people. Music was playing, and sports were being shown on television while patrons were socializing. The *sports pub* had tile floors and its ceiling height was about 10 feet.

One of the sound conditions was a residence near the university campus where a *party* was taking place. There was loud music being played through large speakers and approximately 20 people attended this party. The residence was fully furnished. There were paintings on the walls, including window coverings. The home was carpeted, and its ceiling height was eight to nine feet. The *outdoor concert* was located on the university campus as well. This setting was outdoors with a small stage and surrounding speakers. The measurement was taken in the center of the audience facing the stage and speakers. The concert occurred on an evening during the week and was attended by several hundred students.

Two *fitness classes* were sampled in the same location with similar environmental conditions, but at different times. The class was a Zumba dance-fitness lesson, which was comprised of an instructor and about 25 female participants. The instructor wore a microphone headset. She guided participants through class routines while dance music was playing in the background. Exercises were conducted on wood flooring with high ceilings and speakers surrounding the fitness space. There were no window coverings or decorations on the walls in this setting.

Impressions

Recreational activities classified as ERESEs were sampled using a personal dosimeter on a university student. These activities generated acoustical measures that were lower than the ERESE data reported in the literature. Two sound conditions exceeded the DRC when TWAs were calculated. However, three conditions were classified as risk environments when noise dose was calculated. For settings that posed a risk (*crowded pub* and *downtown pub*), the conditions consisted of a live disk jockey, bar area, and a crowd of patrons gathered on a peak night of weekend business. Although the *campus pub* did not exceed the 85-dBA DRC, it produced a noise peak of 130 dB for a run time of 95 minutes. The *crowded pub* produced the highest TWA of 96 dBA, and a substantial noise dose of 230%. These samples were representative campus environments of student recreational activities. Although the environments were similar, the acoustical sound measures were different.

The *sports pub* did not produce a hazardous noise level and had a low noise dose (4%). This setting did not include a disk jockey or dance floor, and measurements were made on a week night with low attendance. These factors may have contributed to the notably low noise measurements and may explain why the *sports pub* did not present as an ERESE.

The remaining four venues (*party, outdoor concert, and fitness classes*) did not demonstrate a significant risk according to the measurement data. The conditions for each venue varied. The *party* event occurred in a furnished home with a small group of people. The *fitness classes* occurred in a large reverberant space. The *concert* was outdoors and included several hundred people, large speakers, and live music. Each of these factors should be taken into consideration for interpretation of the measurement data.

Figure 2 is a display of the peak sound measurement of each observation as a function of duration. From these data, it is clear that sampling duration does not appear to influence the measurement of peak noise level. The highest peak measurements emerged from the highest TWA observations, but the other peaks, with the exception of the lowest peak measure, are 128-133 dB regardless of sample duration.

Figure 3 is an illustration of the sample average intensity level as a function of sample duration, including the 85-dB DRC line. The data indicated that longer sampling time resulted in the three highest TWAs, so sampling duration does appear to influence outcome (see Figure 3). Samples that are longer in duration captured higher average sound-level outcomes. Two conditions exceeded the damage-risk line of 85 dBA. To determine if peak-intensity levels and TWAs for each sample were associated, they were plotted together. It appears that as peak-noise measurement increases, the average level of sound exposure increases (data not shown). This suggests that peak output levels contributed to the average sound level measures. So, students and employees should be mindful of the apparent ERESEs at pubs during peak times. And, although the other venues did not produce ERESE, individuals who frequently participate in these activities should be aware of potential risks.

Finally, Table 1 is a summary of sound data reported in the literature review. From the review, the highest peak exposures ranged from 158-163 dB, average sound levels were approximately 90 dBA, and average noise levels were 71 to 132 dB. From the data collected from the case study, peak exposures ranged from 114-138 dB, TWAs were approximately 77 dBA, and average noise dose was 3-230%. Overall, when comparing data from the literature to the case-study measurements, the mean case study data are lower, which suggest less risk.

CHAPTER 5

Conclusion

Despite the high prevalence of tinnitus, young adults lacked knowledge about the risks of loud music. In addition, Gilles et al. (2013) and Holmes et al. (2007) reported that young adults generally do not use hearing protection when indicated. So, to avoid hearing shift and hearing loss, secondary to ERESE, awareness should be raised for this population of students and other young people who experience these recreational environments. Workers in these settings should be monitored and educated as well.

The damage-risk exposure level is defined as 85 dBA for a maximum of 8 hours (WHO, 2015; NIOSH, 1998), and exposures above 85 dBA should be known by patrons, workers, and owners of entertainment venues. Pubs can be sources of hazardous sound exposure for university students as demonstrated in this single-case investigation. Other dosimetry measurements alerted that additional sound sampling may be warranted. Overall, it is profoundly important to educate young adults about ERESE activities. To assess individual ERESE status, a risk assessment checklist was created from observations in the case investigation (Appendix A). This checklist may be administered to university students as a screening that determines whether leisure behaviors warrant an audiology visit for evaluation, education, and monitoring, based on responses to items in the tool. Additional studies could be done to assess the effectiveness of the tool.

Awareness of potential harm from ERESE may be the first step for hearing loss prevention. Avoidance of ERESE may be the simplest way to prevent damage. Realistically, this is not achievable or practical. Individuals usually seek ERESE activities for pleasure, so practical strategies, besides avoidance, must be considered (WHO, 2015). Alternative preventive actions include:

(1) monitoring the ERESE activity sound level

(2) surveilling the frequency of ERESE activities

(3) using proper hearing protection during exposure

(4) practicing safe listening outside of ERESE activities

Results of the literature review and case study suggested that public awareness and personal hearing protection should be initiated by community health leaders to prevent hearing loss. Generally, it may be prudent for family practitioners and other providers to refer their patients for hearing tests at least every five years.

Limitations

A limitation of this investigation is sample size (n = 1), although the subject did collect eight dosimetry samples from common university-student leisure environments (each sound environment was measured once). To improve the sample size of the study, it may have been more effective to include several subjects (e.g., n = 5) and collect data more than once (e.g., several days during the week to capture mean performance for the week). The gold standard for noise-dosimetry measurement is to sample each condition different three times to establish mean exposure levels.

Equipment and time presented additional study limitations. For example, the dosimeters used for sampling these conditions had a measurement floor of 65 dB and ceiling of 142 dB, so measurement were limited to those floor-ceiling parameters. Also, sample duration was not the same for each measurement; however, the actual sample durations were a more realistic representation of typical student exposures for each condition.

Future Research

Future research is needed to determine how recreational noise exposure and occupational noise exposure interact and impact auditory health. The cumulative effect of ERESE should be studied further to properly educate the exposed population about hearing loss prevention. Future research might provide more specified preventive measures. The Risk Assessment Checklist (Appendix A) could be validated so that exact criteria could be used for interpretation of the tool when used for screening or clinical purposed. Finally, audiologists should examine exposure risks incurred by young college students when they present to the clinic, and when encountered in the screening environment.

TABLES AND FIGURES

Table 1. Recreational noise exposure conditions and sound levels reported in the literature.

VENUE	AUTHOR	PEAK NOISE	TWA-8	AVERAGE NOISE LEVEL (dB)
Concerts	Barlow (2010)			98.9
	Davis (1986)			101-105
Pubs	Beach et al. (2013)			71-96
Nightclubs/Discos	Barlow (2010)			100
	Serra et al. (2005)			104.3-112.4
Basketball game	Morris et al. (2015)	138 dB		
	England and Larsen (2014)		90.1 dBA	
	Rabinowitz et al. (2016)			92.46
Racecar event (20 ft from track)	Rose et al. (2008)			96.5-104
Racecar event (150 ft from track)	Rose et al. (2008)			99-109
Firearms	Fligor (2010)			132+
	Chen and Brueck (2016)	154.6–162.7 dB (shotgun) 155.2–159.9 dB (.45-70 rifle) 158.7–163.1 dB (.30-.06 rifle)	78-89 dBA	
Aerobics class	Torre and Howell (2008)			83.4–90.7
Movie theatre (action movie)	Huth et al. (2014)			74.1
Movie theatre (children's movie)	Huth et al. (2014)			72

Table 2. ERESE conditions and acoustical data sampled from the case (MW)

Venue	**Run time (mins)**	**Peak (Lcpk)**	**TWA (Lavg)**	**Dose (%)**
Recreation Center	50	114.3	63.3	2.50
Party	107	128.7	72.8	9.32
Crowded Pub	98	135.5	96.1	230
Downtown Pub	92	138.2	87.6	72.60
Sports Pub	93	129.0	65.8	3.50
Outdoor concert	58	133.4	80.3	26.10
Recreation Center	50	129.0	71.3	7.55
Campus Pub	95	130.4	82.5	67.83

Table 3. Pub sound-measurements and acoustical data sampled from the case (MW)

	Run time	Peak noise	TWA	Noise dose
Pub 1	98	135.5	96.1	230
Pub 2	92	138.2	87.6	72.60
Pub 3	95	130.4	82.5	67.83
Mean	95.0	**134.7**	**88.7**	**123.4**
Pub 1	98	135.5	96.1	230
Pub 2	92	138.2	87.6	72.60
Pub 3	93	129.0	65.8	3.50
Pub 4	95	130.4	82.5	67.83
Mean	94.5	**133.3**	83.0	93.4

Figure 1. Average sound level (dBA) of each ERESE condition. Note: the dashed line is the 50% dose exposure level according to OSHA.

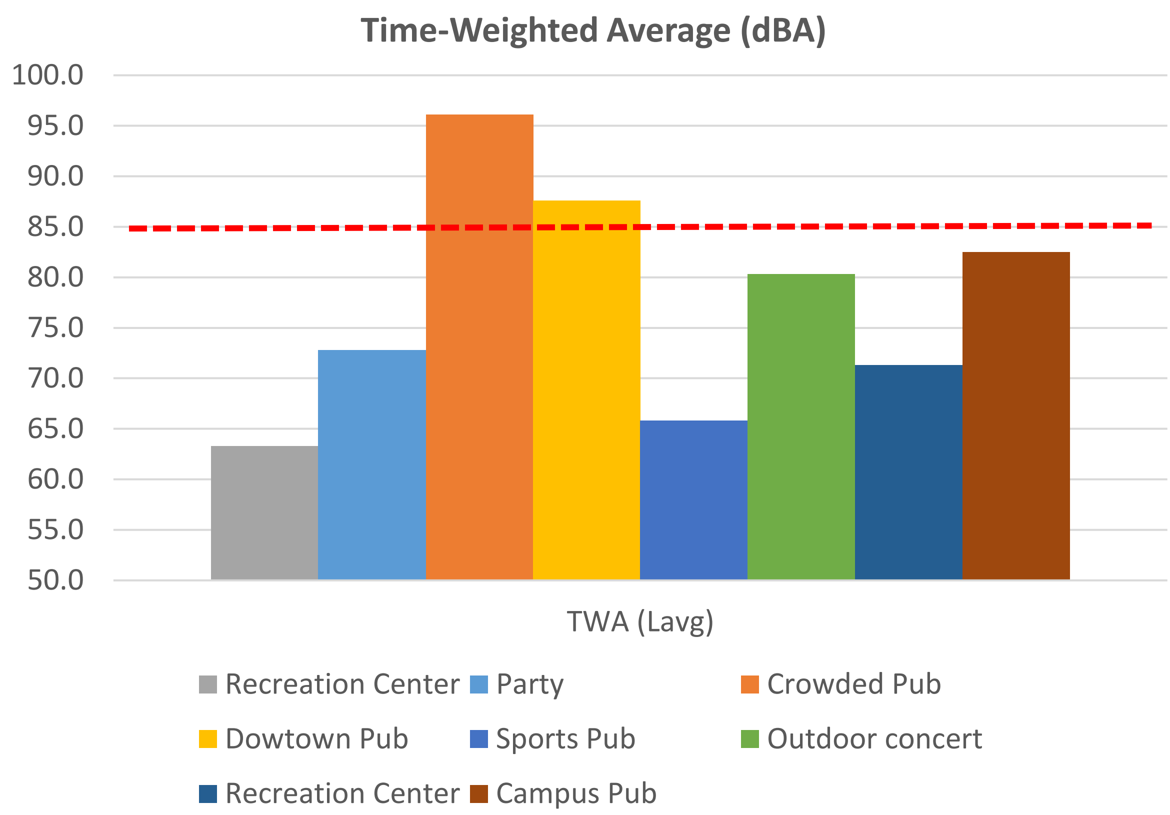


Figure 2. Peak-noise level (dB) of the ERESE condition by sample duration (in minutes)

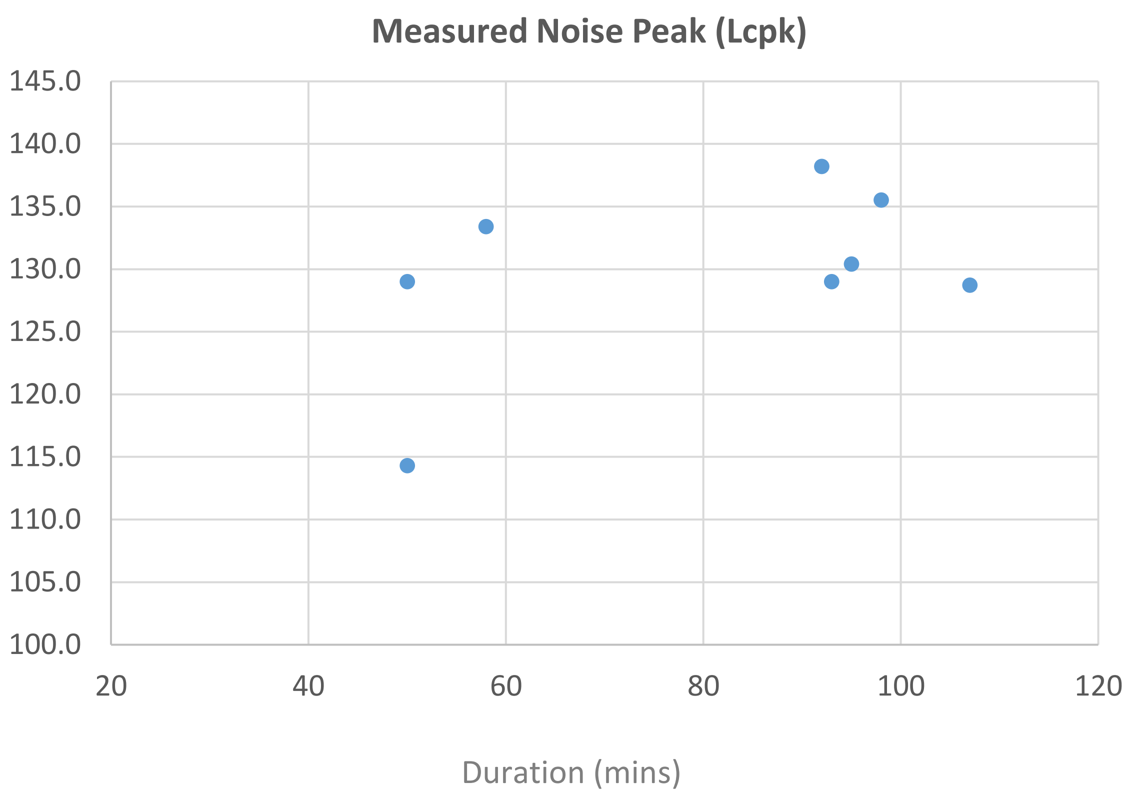
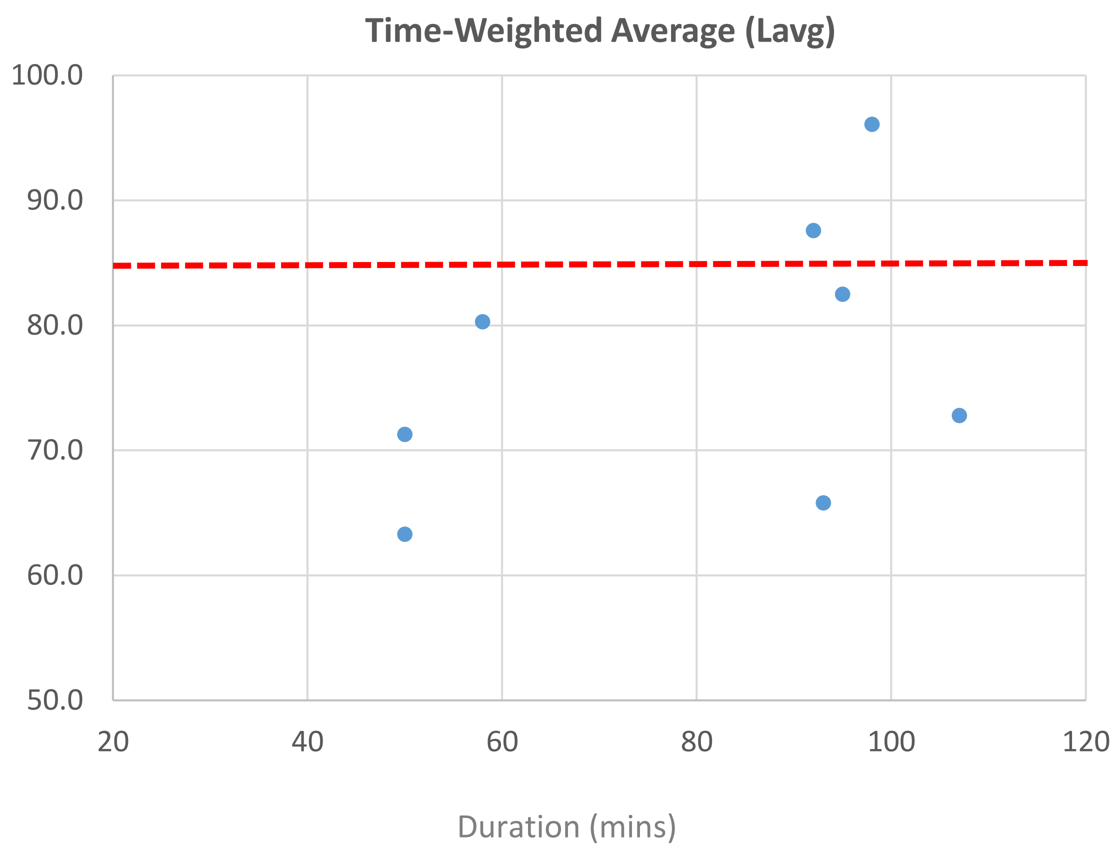


Figure 3. Recreational noise TWA by time collected from the case



REFERENCES

Barlow, C. (2010). Potential hazard of hearing damage to students in undergraduate popular music courses. *Medical Problems of Performing Artists,25*(4), 175-182.

Barlow, C. (2011). Evidence of noise-induced hearing loss in young people studying popular music. *Medical Problems of Performing Artists, 26*(2), 96-101.

Beach E, Williams W, Gilliver M (2013). Estimating young Australian adults' risk of hearing damage from selected leisure activities. *Ear Hear*. 34(1):75-82.

Bogoch, I. I., House, R. A., & Kudla, I. (2005). Perceptions about hearing protection and noise-induced hearing loss of attendees of rock concerts. *Canadian Journal of Public Health, 96*(1), 69-72.

Budimčić, M., Seke, K., Krsmanović, S., & Živić, L. (2014). Auditory risk behaviours and hearing problems among college students in Serbia. *Medicinski Glasnik, 11*(2), 264-269.

Chen, L., & Brueck, S. E. (2011). Noise and Lead Exposures at an Outdoor Firing Range ─ California. Health Hazard Evaluation Report. Retrieved from https://www.cdc.gov/niosh/hhe/reports/pdfs/2011-0069-3140.pdf

Chong Lee, Gary Jek; Lim, Ming Yan; Kuan, Angeline Yi Wei; Teo, Joshua Han Wei; Tan. Hui Guang; & Low, Wong Kein (2014) Relationship between leisure noise exposure and otoacoustic emissions in a young Asian population, International Journal of Audiology, 53:7, 462-468

Clark, W. W. (1991). Noise exposure from leisure activities: A review. *The Journal of the Acoustical Society of America, 90*(1), 175-181.

Daniel, E. (2007). Noise and hearing loss: A review. *The Journal of School Health,77*(5), 225-31.

Davis, A., & Coles, R. (1986, February). Turn It Down! *Occupational Health*, 52-58.

England, B., & Larsen, J. B. (2014). Noise Levels Among Spectators at an Intercollegiate Sporting Event. *American Journal Of Audiology*, *23*(1), 71-78.

Fligor B. (2010) Recreational noise and its potential risk to hearing. *Hearing Review*, 17(5), 48-55.

Gilles, A., Hal, G. V., Ridder, D. D., Wouters, K., & Heyning, P. V. (2013). Epidemiology of noise-induced tinnitus and the attitudes and beliefs towards noise and hearing protection in adolescents. *PLoS One, 8*(7)

Gupta, N., Sharma, A., Singh, P., Goyal, A., & Sao, R. (2014). Assessment of Knowledge of Harmful Effects and Exposure to Recreational Music in College Students of Delhi: A Cross Sectional Exploratory Study. *Indian Journal Of Otolaryngology & Head & Neck Surgery*, *66*(3), 254-259.

Holmes, A., Widén, S., Erlandsson, S., Carver, C., & White, L. (2007). Perceived hearing status and attitudes toward noise in young adults. *American Journal Of Audiology*, *16*(2), S182-9.

Huth, M., Popelka, G., & Blevins, N. (n.d). Comprehensive Measures of Sound Exposures in Cinemas Using Smart Phones. *Ear And Hearing*, *35*(6), 680-686.

Keppler, H., Dhooge, I., & Vinck, B. (2015). Hearing in young adults. Part I: The effects of attitudes and beliefs toward noise, hearing loss, and hearing protector devices. *Noise & Health*, *17*(78), 237-244.

Keppler, H., Dhooge, I., & Vinck, B. (2015). Hearing in young adults. Part II: The effects of recreational noise exposure. *Noise & Health*, *17*(78), 245-252.

Le Prell, C. G., Ph.D. (2016, March). Potential Contributions of Recreational Noise to Daily Noise Dose. *Council for Accreditation in Occupational Hearing Conservation*, 28(1), 1-3.

Lopez, E., & Morales, F. (n.d). Construction and validation of questionnaire to assess recreational noise exposure in university students. *Noise & Health*, *16*(72), 292-298.

Meyer-Bisch, C. (1996). Epidemiological evaluation of hearing damage related to strongly amplified music (personal cassette players, discotheques, rock concerts)—High-definition audiometric survey on 1364 subjects. *Audiology*, *35*(3), 121-142.

Miller, V. L., Stewart, M., & Lehman, M. (2007). Noise exposure levels for student musicians. *Medical Problems of Performing Artists*, *22*(4), 160-164.

Morris, G. A., Atieh, B. H., & Keller, R. J. (2013). Noise exposures: Assessing an NCAA basketball arena on game day. *Professional Safety*, *58*(8), 35-37.

Noise-Induced Hearing Loss | NIDCD. (2015, May 15). Retrieved from https://www.nidcd.nih.gov/health/noise-induced-hearing-loss

Ohlemiller KK. (2012) Current Issues in Noise-Induced Hearing Loss. *Translational Perspectives Auditory Neuroscience*. Plural Publishing, 1-34.

Rabinowitz, E., & Kernodle, M. (2016). Noise decibel levels during division I college basketball games. *Journal of Facility Planning, Design, and Management*, *4*(1).

Rose, A. S., Ebert, C. S., Prazma, J., & Pillsbury, H. C. (2008). Noise exposure levels in stock car auto racing. *Ear, Nose, & Throat Journal, 87*(12), 689-692.

Spankovich, C., Griffiths, S. K., Lobariñas, E., Morgenstein, K. E., de la Calle, S., Ledon, V., & Le Prell, C. G. (2014). Temporary threshold shift after impulse-noise during video game play: Laboratory data. *International Journal Of Audiology*, *53*S53-S65.

Torre, I. P., & Howell, J. C. (2008). Noise levels during aerobics and the potential effects on distortion product otoacoustic emissions. *Journal Of Communication Disorders*, *41*501-511.

Torre, P. (2008). Young adults' use and output level settings of personal music systems. *Ear and Hearing, 29*(5), 791-799.

Washnik, N. J., Phillips, S. L., & Teglas, S. (2016). Student's music exposure: Full-day personal dose measurements. *Noise & Health*,*18*(81), 98-103.

World Health Organization. (2015). Hearing loss due to recreational exposure to loud sounds: a review.

Vogel, I., PhD., Verschuure, H., PhD., Van der Ploeg, C.,P.B., Brug, J., PhD., & Raat, Hein,M.D., PhD. (2010). Estimating adolescent risk for hearing loss based on data from a large school-based survey. *American Journal of Public Health, 100*(6), 1095-100.

APPENDIX (A)

RISK ASSESSMENT CHECKLIST

Use the checklist below. If the response is “Yes” is for 3 or more environments, please schedule an appointment for a hearing evaluation with an audiologist. If the responses for “How Often?” totals 2 or more times per week, or “Duration” totals 4 or more hours per week, please schedule an appointment for a hearing evaluation with an audiologist. If “Protection” is not marked for marked exposures, please schedule an appointment for a hearing protection fitting with an audiologist.

Environment	***No***	***Yes***	***How Often?***	***Duration***	***Protection***
Firearms					
Nightclubs/Discos					
Concerts					
Racecar events					
Pubs					
Sporting events					
Exercise classes					
Other:					
TOTAL					

Notes: