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Noise Exposures Of Recreational Snowmobilers

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NOISE EXPOSURES OF RECREATIONAL SNOWMOBILERS

A Capstone Research Project Submitted in Partial Fulfillment
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Doctorate of Audiology

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ABSTRACT

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Noise exposure measurements, snowmobiler riding habits, and surveys addressing the knowledge, attitudes and beliefs about noise induced hearing loss (NIHL) were collected on 10 recreational snowmobilers. Participants included two females and eight males with the mean age of 53.9 (±14.07) years old, and ages ranging from 28-70 years. Noise exposure measurements were collected on a typical riding day with QuietDose™ noise dosimetry microphones placed under the helmet of the snowmobiler (Howard Leigh [QuietDose™], 2011). The snowmobilers traveled an average of 51.34 miles (± 10.62 miles) per day during data collection. Riding times ranged from 3 hours and 38 minutes to 8 hours and 50 minutes per day, including breaks. Seventy percent of participants (n = 7) exceeded the Occupational Safety and Health Administration (OSHA) action level (AL) of 85 dBA time weighted average (TWA) (50% dose). The OSHA permissible exposure level (PEL) protocol samples reveal a mean noise dose of 63.6% (±.2%) with a TWA of 86.17 (±3.1) dBA. One participant (10%) exceeded 100% dose (90 dBA TWA) for the OSHA PEL protocol. The mean noise dose for the National Institute for Occupational Safety and Health (NIOSH) protocol was 472.3% (±2.2%) and a mean TWA of 91.17 (±2.3) dBA. All participants were over-exposed when referencing the NIOSH REL. The health communication survey results suggest that 50% of the riders felt a helmet was protective from hazardous noise and that hearing protectors may be underutilized due to the cost, communication and comfort barriers. Results suggest a need

for more educational information on hearing loss from hazardous noise levels and how participants can protect themselves from the risk of NIHL. It is recommended that recreational snowmobilers be enrolled in a HLPP that provides for noise exposure measurement, audiometric monitoring, hearing protection device selection, fitting and verification as well as educational content specific to the sport.

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ABBREVIATIONS

dB - Decibel

dBA - Decibel A-Weighted

OSHA - Occupational Safety and Health Administration

NIOSH - National Institute for Occupational Safety and Health

NIHL - Noise Induced Hearing Loss

HBM - Health Belief Model

TWA - Time Weighted Average

HPD - Hearing Protection Device

SLM - Sound Level Meter

ANSI - American Standard Specification for Sound Level Meters

PEL - Permissible Exposure Level

REL - Recommended Exposure Level

AL - Action Level

CHAPTER I

STATEMENT OF THE PROBLEM

Noise induced hearing loss (NIHL) is a preventable health risk that affects many individuals on a daily basis. Of the 28 million Americans who have some degree of hearing loss, as many as 10 million individuals in America suffer from hearing loss caused from hazardous noise exposure in the workplace or recreational activities (Rabinowitz, 2000). Hazardous sound levels damage fragile structures of the inner ear and can cause permanent hearing loss over time. Temporary auditory damage can occur but repeated exposure to dangerous levels of sound can cause cell death which leads to irreversible permanent hearing threshold shifts, also known as noise induced permanent threshold shifts. Due to the increasing number of individuals with NIHL, more research must be done to evaluate the noise exposure levels of recreational activities that are contributing to this health issue. This study will investigate the recreational activity of snowmobiling to assess the noise exposure levels of participants in this sport. This will be accomplished by measuring the noise exposure levels with a noise dosimeter, which will calculate the amount of sound that a recreational snowmobiler is exposed to on a typical day while actively engaged in the sport. The knowledge, attitudes, and behaviors of the snowmobilers should be researched in order to better understand and ultimately reduce the risk of NIHL in this population. By means of a health communication survey, which was designed using the Health Belief Model (HBM), the knowledge, attitudes, and

beliefs of snowmobilers related to the risk of NIHL can be measured. The HBM is based upon factors that were developed by attempting to explain behaviors based on psychological and behavioral theories (Rosenstock, Strecher, & Becker, 1988). The research survey will reflect the personal risks associated with snowmobile noise exposure levels to be evaluated. Noise exposure standards have been developed for the occupational industry to prevent hearing damage from noise exposure. The Occupational Safety and Health Administration (OSHA) and the National Institute for Occupational Safety and Health (NIOSH) are two U.S. government agencies that create the standards or guidelines for occupational hearing safety (OSHA, 2006; NIOSH, 1998). The OSHA 29 CFR 191.95 standard states that when the time weighted average (TWA) measured with a 5 decibel (dB) exchange rate reaches or exceeds the permissible exposure limit (PEL) of 90 decibels A-weighted (dBA), noise control, hearing loss prevention program (HLPP) inclusion, hearing testing, training, and the wearing of hearing protection must be implemented. The NIOSH criteria are more conservative, where the recommended exposure limit (REL) is set or equal to 85 dBA TWA and calculated with a 3 dB exchange rate.

These standards and guidelines for industry do not take into account the additional noise that individuals are exposed to during recreational activities outside of work. However, the noise exposure measurement strategies and permissible limits can be used to determine if the noise exposures of recreational snowmobilers are loud enough to exceed permissible or recommended occupational limits and whether there is a need to implement hearing protection while riding. Snowmobiles have been measured at 86 decibels (dB) at an idle, to 113 dB at full throttle using a sound level meter (Bess &

Poynor, 1974). Sound level measurements have not been made underneath the helmet in snowmobile riders and there are no published dosimetry studies of rider noise exposures. Recreational snowmobiler noise exposure levels need to be researched further in order to improve our understanding of whether a helmet provides adequate protection from the hazardous sound levels or if additional hearing protection should be worn. This will be accomplished in this research effort by measuring the sound levels using new technology under the helmet and comparing those to levels measured outside the helmet.

If snowmobilers are educated regarding what activities are loud enough to cause hearing loss and how to best protect themselves from hazardous sounds, the risk of hearing damage may decrease. The following research questions were created to investigate the noise exposure levels of snowmobile riders and describe the knowledge, attitudes, and beliefs of these individuals:

Q1 What is the noise exposure of a recreational snowmobile rider when measured according to the Occupational Safety and Health Administration (OSHA) 29 CFR 1910.95 exposure standard?

H1 The noise exposure of a recreational snowmobile rider will exceed the daily OSHA exposure standard.

Q2 What is the noise exposure of a recreational snowmobile rider when measured according to the National Institute for Occupational Safety and Health (NIOSH, 1998) exposure criteria?

H1 The noise exposure of a recreational snowmobile rider will exceed the daily NIOSH noise dose limits.

Q3 What are the knowledge, attitudes, and beliefs of snowmobilers related to the risk of NIHL?

CHAPTER II

REVIEW OF LITERATURE

Introduction

This review of literature will cover the aspects of noise exposure as related to recreational snowmobiling by looking at the demographics and risk of NIHL from recreational motorsports. The HBM as applied to NIHL and the use of hearing protection devices will be included. The various types and methods of noise measurement will be discussed, along with the factors that affect these measurements.

Demographics of Snowmobiling

Since the 1950's recreational snowmobiling has been used worldwide as either a means of transportation or as a leisure time activity. Individuals who ride snowmobiles as a leisure time activity range from beginners to advanced riders. Advanced riders are more likely to ride more hours and days during the snow season compared to beginners. International Snowmobile Manufactures Association (2009) showed that the average rider in North America rides 1,402 miles a year. According to the International Snowmobile Manufactures Association (ISMA) there were over 50,000 snowmobiles sold in the United States in 2011, with over 140,000 being sold worldwide (ISMA, 2009). Snowmobiling is a growing recreational activity for both younger and older individuals. With 1,550,158 registered snowmobiles in the United States for 2011, the risk of noise exposure in this population must be addressed (ISMA, 2009).

Snowmobile Clubs

Recreational snowmobiling not only involves individuals but groups of individuals that are part of a collective club. There are over 3000 snowmobile clubs worldwide that are involved in trail grooming, charity events and family activities (ISMA, 2009). Recreational snowmobile clubs are organizations that ride together as a collective group, many of them meeting weekly. Active clubs will ride anywhere from two to eight hours a day, covering 40 or more miles during each ride. Snowmobile clubs put great emphasis on the importance of safety when it comes to avalanches, what to do if an individual gets lost or stranded and accident prevention and management. Safety measures to prevent hearing damage from hazardous noise exposure levels are not commonly involved in the safety topics due to the lack of knowledge about noise exposure levels of snowmobilers. Clubs are great for community involvement, although a greater risk of hazardous noise exposure may be present. With increased numbers of snowmobilers, a higher risk of damage to one's hearing from excess noise exposure may be present due to multiple noise sources being present.

Noise Induced Hearing Loss and Tinnitus

Hearing is often taken for granted until an individual loses the ability to communicate with the world. Noise induced hearing loss is caused by hazardous sound levels that damage the fragile structures of the inner ear. Decreased hearing sensitivity in the frequency range of 3,000 to 6,000 Hz is commonly seen in noise exposed individuals. These hearing changes can be temporary or permanent. A decrease in hearing sensitivity that returns to the previous level is known as a temporary threshold shift. A temporary

threshold shift may last several minutes to several days. A permanent threshold shift is an irreversible decrease in hearing sensitivity due to repeated exposures to hazardous noise.

Noise induced hearing loss is typically caused by exposure to loud sounds over time. Although less common, a one-time impulse exposure to extremely loud sounds, such as gunshots or explosives, can also cause NIHL. Hazardous sounds in work environments and recreational activities such as hunting and motorsports can cause NIHL over time. Hazardous noise in the workplace is a major concern for NIHL; therefore governing agencies have noise standards or regulations that may be enforced. The Occupational Safety and Health Administration (OSHA) have noise exposure standards preventing workers from NIHL are commonly enforced in many work environments (OSHA, 1983). The National Institute for Occupational Safety and Health (NIOSH) has recommended guidelines for noise exposure levels (NIOSH, 1998).

Tinnitus is one of the major side effects shown to occur in individuals who have NIHL. It is often described as a ringing, buzzing, roaring, or any other sound that an individual hears which is not existent in the external world. The exact area in the cochlea or nerves that cause tinnitus has yet to be located, making it difficult to treat. Tinnitus usually occurs after recent noise exposure, with the effects lasting several hours to several days (Ward, Royster, & Royster, 2000). The effects of tinnitus from NIHL may also last a lifetime and the impact of tinnitus varies from person to person. Tinnitus can range from a mild irritation to an unbearable problem that may affect an individual's daily life. Individuals with debilitating tinnitus may have loss of sleep, irritability, and lack of concentration. Tinnitus from NIHL can be prevented if the proper steps are taken to protect ones hearing from dangerous noise exposures.

Recreational noise exposure levels are often loud enough to cause damage to the cochlea, as well as cause tinnitus, an often permanent consequence of hazardous noise exposure. Tinnitus was reported by motorcycle riders after only an hour of high speed riding (McCombe, Binnington, Davis, & Spencer, 1995). Tinnitus can occur after short or long durations, depending on the level of the hazardous sound. Motorsport riders that are exposed to hazardous sounds for multiple hours are at risk for NIHL. Along with NIHL, tinnitus is not uncommon in individuals who participate in motorsports.

Temporary threshold shifts and permanent threshold shifts from dangerous noise exposure levels have been measured in recreational and professional motorsports. Larger, faster engines that produce more power and consequently greater hazardous noise exposure are seen in professional racing motor vehicles. Bess & Poynor (1974) reported temporary threshold shift and noise levels emitted by typical racing snowmobiles as high as 130 dBA when measured by a sound level meter at ear level. Noise exposure levels for both recreational and professional snowmobilers have not been researched in detail. Technological advances have been made in the manufacturing of motorsport engines to increase power; advances in noise control have not.

Noise exposures leading to NIHL have been recorded in multiple motorsports. McCombe and Binnington (1994) were the first to study NIHL among professional Grand Prix motorcycle racers. Due to turbulent wind sound, as well as dangerous sounds from the exhaust and engine, motorcyclists are shown to be at risk for NIHL. Audiograms were performed on 44 riders, with their average racing experience of ten years. It was reported that out of the 44 riders studied, 27 riders were shown to have high frequency NIHL. Bess and Poynor (1974) reported hearing loss in snowmobile racers and their pit

mechanics. A total of 26 riders were all shown to have NIHL with the largest decreases in threshold between 4,000 and 8,000 Hz, the range where threshold shifts from noise are commonly observed (Bess & Poynor, 1974). Although professional motorcycle and snowmobile racers drive at much faster speeds than recreational motorsports, the noise that is present from the wind, engine and exhaust still can be potentially dangerous even at lower speeds.

Health Communication Theories

Health Belief Model

The HBM is based upon factors that were developed by attempting to explain behaviors based on psychological and behavioral theories (Rosenstock et al, 1988). The key components of the HBM are the individual's perception of susceptibility, seriousness of the risk, benefits of the prevention measures, barriers to the desirable behavior, cues to action and self efficacy. Each component of the HBM can be related to the risk, prevention and actions in regards to NIHL.

The first component of the HBM is that the existence of a health concern must be present in order to make the health issue relevant. The individual must be aware that they are susceptible to the presented risk. Noise induced hearing loss is the presented risk; therefore individuals must understand what sound levels can be hazardous to their hearing. Seriousness of the risk depends on if the individual believes that there will be consequences. Many people are unaware of the physical and social effects that NIHL has on an individual's life. If the consequence of NIHL is tinnitus, the individual must be aware of the risk and how serious the consequences may be, including withdrawal from social activities and difficulty in conversation. The benefit of preventing the health risk is

the next component of the HBM. The benefit of preventing NIHL must be clear to the individual. The benefit of preventing NIHL, beginning with the most obvious, is maintaining normal hearing sensitivity. The decrease of financial burden for habilitation services during a lifetime is also a benefit. The desired behavior in regards to noise induced hearing loss is the actual prevention of hearing loss. The benefits of preventing NIHL must outweigh the action of wearing hearing protection. Cue to action is the fifth component of the HBM; the person must be willing to take recommendations to reduce the current health risk. When exposed to hazardous noise, the individual must be ready and willing to take action to prevent NIHL by wearing hearing protection devices. Finally, individuals must have the self-confidence that it would be beneficial to reduce the perceived threat. In order to reduce the risk of NIHL, the individual must believe that they can reduce the risk by performing preventive measures.

Use of Hearing Protection

If used correctly, hearing protection devices (HPD) prevent damage from hazardous noise exposure levels. Hearing protection devices reduce the amount of sound that reaches the cochlea. A wide variety of hearing protection devices exist within three main categories, ear plugs that fit in the ear canals, earmuffs which fit over the entire ear, and ear canal caps (NIOSH, 1998). Helmets are not routinely considered a type of hearing protector; however they may afford some sound attenuation. Hearing protection should be worn when noise exposure levels exceed a time-weighted average (TWA) of 85 dBA and above. Dual hearing protection (earplugs and earmuffs) is recommended when the TWA exceeds 100 dBA (NIOSH, 1998). Sokol (2005) suggests that in order for more individuals to utilize HPD regularly, four factors should be considered: 1) Comfort-

the HPD must be comfortable to wear, 2) Convenience- the HPD must be easy and ready to use when needed, 3) Communication- the HPD must not interfere with communication that is important, and 4) Caring- people must realize that the use of hearing protection is needed. If these four factors are met, individuals may wear hearing protection more frequently.

Noise Measurements

Instrumentation

Sound level meters (SLM) and noise dosimeters are two types of equipment commonly used to measure the noise levels/exposures of an environment. Noise dosimetry allows for a sample of varying noise levels to be averaged over time in multiple locations when worn on the body, whereas a SLM takes a static area measurement of the noise level in a specific location. Noise dosimetry is therefore the favorable choice when noise exposure levels are being compared to the criteria provided by OSHA and NIOSH for mobile individuals.

Sound level meters. Sound level meters are often used to measure area noise measurements in industry. This is done by measuring the noise levels of a particular machine, or work area. Sound level meters are also used to measure the sound levels an employee might be experiencing during a work day or week, by taking single measurements within two foot radius of their head. Noise exposures would then have to be extrapolated by measuring the amount of time that employees spent in specific locations and integrating it with sound level data.

There are two main types of sound level meters used in industry; general purpose (Type 1) and precision (Type2). Most sound level meters have a dynamic range that is

selectable for low or high settings, as well as the option to choose what type of weighting scale is appropriate for the measurement that will be made. Sound level meters also have SLOW and FAST response settings that refer to the time the meter will reach its final reading. A SLOW response setting is commonly 1 second, with the FAST response setting at .125 seconds (Earshen, 2003). The SLOW response setting is used to establish the average or changing average of the sound being measured and the FAST response is used where the sound level is variable (Earshen, 2003). The meter SPL fluctuates less when measuring with a SLOW response as compared to a FAST response (NIOSH, 1998). Sound level meters are set to certain allowable tolerances by the American Standard Specification for Sound Level Meters (ANSI S1.4), which only permits a $\pm$ of 1.5dB error for Type 2 meters. A Type 1 meter has much stricter standards due to the fact that they are primarily used in research settings (Suter, 2002). Type 2 SLM's are used for regulatory compliance with noise exposure standards. Sound level meters are ideal for measuring equipment in an individual's work environment that has a constant sound level that does not fluctuate. If the noise source fluctuates or the worker is actively moving from place to place, a noise dosimeter will perform the most accurate exposure measurements.

Noise dosimeter. Noise dosimeters are more commonly used to measure variable sound levels over time. A noise dosimeter is a small, portable device that can be connected to an individual's belt or shirt and worn for extended periods of time in order to collect noise exposure measurements. A microphone is clipped to a shirt or jacket and attached to a small box by a cord that is usually run down the back of the wearer. The electronic box collects noise level measurements obtained by the microphone and stores

data based on preprogrammed parameters. Noise dosimetry measurements are often used to determine if noise exposure levels are high enough to cause NIHL.

Noise dosimetry continuously measures sound levels in an environment. An accumulated noise dose and TWA is recorded from the sample period. Allowable noise dose depends on the regulation or standard that is being referenced. An exposure dose of 90 dBA TWA for 8 hours is defined as a 100% dose for the OSHA regulations (OSHA, 1983). The National Institute for Occupational Safety and Health specifies a 100% dose as 85 dBA TWA for an 8 hour time period (NIOSH, 1998). Dose refers to the amount of noise that a person is allowed in an 8 hour period. There is an exchange rate on most dosimeters can be changed depending on what standard is being used; 5 dB for OSHA and 3 dB for NIOSH.

Measurement Metrics

As previously mentioned a variety of acoustic metrics are measured and stored by noise dosimeters and sound level meters. Noise dosimetry devices have the ability to simultaneously collect multiple measurement parameters and protocols. The primary metrics that will be focused on in this research study are; Dose, Time weighted average and Run-time measurements. Dose refers to the amount of noise exposure relative to the allowable exposure (e.g. 90 dBA for 8 hours per OSHA PEL). When the noise dose is above 100% it is representative of exposure levels that are dangerous to the individuals hearing when exposed over extended periods of time. The averaging of different noise exposure levels during an 8 hour period is reported as the TWA and reported in dBA. An A-weighted scale is utilized during noise measurements because it closely mimics the loudness perception of the human ear. A run-time measurement will be performed in

order to determine the length of the measured sample. The metrics described are important when measuring the amount of noise an individual is exposed to and determining if the noise measurements are hazardous to one's hearing.

Free-field vs. in-the-ear measurement. Free-field measurement exists when there is nothing to impede the sound energy that is radiated from a source into open space. Free-field noise measurements are performed in most states to determine the allowable sound level of a snowmobile to determine if they meet the state environmental noise level guidelines. When above a reflecting plane, such as the floor, a free-field may also occur. In-the-ear measurement is taking the noise level as measured in the ear canal, which in turn will cause an increase in sound pressure level due to the size of the cavity, with an enhancement possible at certain frequencies.

"Real Ear" exposure measurement. The QuietDose™ (QD) is the first noise dosimeter that measures sound that reaches the user's ear by using in-ear noise dosimetry (Howard Leigh [QuietDose™], 2011). The unique feature of this device is that it is designed using small microphones that permit the measurement of sound levels under the hearing protector that is being used. This provides information for quantifying the actual field attenuated noise exposure of the worker. This technology has allowed for safety managers to determine the appropriate and correct fit of hearing protection devices while continuously monitoring the worker during the workday.

Noise Exposure Standards and Guidelines

Noise exposure standards have been developed for the occupational industry to prevent NIHL. The standards state when inclusion in a hearing conservation program is required and when engineering controls and/or hearing protection devices must be worn.

The Occupational Safety and Health Administrations (OSHA) is a mandatory regulatory agency that creates standards required by the federal government. The National Institute for Occupational Safety and Health (NIOSH) is an agency with best practice guidelines that the federal government does not enforce. The Occupational Safety and Health Administration's permissible exposure limits are based on a 40 hour work week with an 8 hour work day. The National Institute for Occupational Safety and Health's recommended exposure limits are also based on a 40 hour work week with an 8 hour a day work day. The noise exposures for industry do not take into account the extra noise that individuals are exposed to once they leave the workplace. Neitzel, Seixas, Olson, Daniell, & Goldman (2004) found that non-occupational activities such as doing yard work, going to the movies, dining at restaurants or bars, and many other common non-occupational activities could damage one's hearing. Out of the workers studied, it was shown that one in every five individuals reached exposures that exceeded 85dBA NIOSH REL, which placed them at risk for NIHL before their work noise exposure was factored in. It is important to take all noise exposure areas into account when assessing the risk of NIHL to realize it commonly occurs from a mix of occupational and non-occupational noise exposures.

Occupational Safety and Health Administration (OSHA) regulation. Occupational Safety and Health Administration (OSHA) is an occupational regulatory agency, mandated by federal law, with standards that protect employees from hazardous noise exposures. The OSHA 29 CFR 191.95 states that protection is required by the employer when the TWA exceeds an Action Level (AL). The action level is reached when the TWA is at or above 85 dBA. Inclusion of an employee into a HLPP is

warranted when the TWA equals or exceeds the AL. An 80 decibels A-weighted to 130 decibels A-weighted range is called the “low threshold” measurement and is used to determine compliance with the AL.

Occupational Safety and Health Administration 29 CFR 1910.95 stipulates that when the time weighted average (TWA) reaches or exceeds 90 dBA for an eight hour day, the permissible noise exposure limit (PEL) has been reached. The Occupational Safety and Health Administration uses a 5 decibel exchange rate which means that when the noise increases 5 dB, the PEL is cut in half. For example at 95dBA the PEL would be 4 hours, at 100dBA, a 2 hour PEL and so on for every 5 decibel increase in sound level. The ceiling limit for OSHA is 115 decibels A-weighted which means that an individual’s noise exposure should never exceed this limit (OSHA, 1989). A 90 dBA to 140 dBA range is called the “high threshold” measurement and is used to determine compliance with the PEL. When the PEL is reached, the use of hearing protection must be implemented, with engineering controls being required at 90 dBA.

National Institute for Occupational Safety and Health (NIOSH) guidelines. National Institute for Occupational Safety and Health (NIOSH) is a best practices scientific organization which establishes guidelines for occupational noise exposure, among many other areas. These guidelines are more conservative than OSHA and not mandated by federal law. National Institute for Occupational Safety and Health recommended exposure limit (REL) in place of the OSHA AL and PEL. The REL for NIOSH is set or equal to 85 decibels A-weighted TWA and any amount of noise exposure past this limit is considered hazardous. Hearing protection is required when the TWA exceeds 85 dBA and double protection must be worn when the TWA is greater

than 100dBA. An exchange rate of 3 dBA is recommended by NIOSH. Therefore a 100% dose would be set at 85 dBA, for an 8 hour day. Using the 3 decibel exchange rate, the equivalent noise exposure duration for 88dBA TWA would be 4 hours and no more than 2 hours for a 91dBA TWA exposure, with a decrease in time for the 3dB increase (NIOSH, 1998).

Sound Exposure Levels of Recreational Motorsports

Research in the area of snowmobiler noise exposure levels is not well developed in the literature, although motorcycle noise exposure has been reviewed in detail. The exact mechanism of recreational motorsports that causes high levels of noise has not been established. Wind turbulence, engine noise, and the speed that an individual is traveling all have affects on the noise exposure levels of recreational motorsports.

Variables Influencing Noise Exposure Measurements In Motorsports

Sound Level

The sound levels of many recreational activities have been measured in numerous studies. Firecrackers, sporting events, and concerts all have levels that are loud enough to cause hearing damage depending on the amount of time exposed. The higher the sound level, the more hazardous the noise exposure to an individual. Jordan, Hetherington, Woodside, and Harvey (2004) measured daily noise levels of occupational motorcyclists with miniature microphones placed underneath the helmet. Noise levels ranging from 76.1 dBA to 110.6 dBA were recorded at speeds ranging from 50 km/h (30 mph) to 120 km/h (75 mph). Motorsports that included motorcycles and snowmobiles have both been shown to have hazardous noise levels exceeding 100 dBA in many instances (Bess & Poynor, 1974; McCombe & Binnington, 1994; Ross, 1989).

Duration

Duration of noise exposure influences the degree of damage that can occur from noise exposure. Depending on how long an individual is exposed to a hazardous sound, hearing damage may occur. One hundred percent dose for both OSHA and NIOSH can be reached within a short riding period depending on how loud the noise levels are. Bess and Poynor (1974) reported snowmobile noise levels loud enough to cause temporary hearing damage after only 120 minutes of riding. The noise levels in this study ranged from 86 dBA to 113 dBA, putting these snowmobilers at risk for permanent hearing damage. Motorsports enthusiasts riding without hearing protection are potentially putting themselves at risk even within a short duration of riding time.

Spectral Characteristics

Spectral characteristics of noise depend on the type of noise, either broad band or pure-tone, and the exposure to each type. Ward et al, (2000) reported steady state noise to be most damaging between the frequencies of 1000 and 4000 Hz, with the very high and very low frequencies being less damaging. According to these authors, impulse noise can cause permanent acoustic trauma at high levels during a short amount of time. Noise with a pure-tone component is not shown to produce greater amounts of hearing damage when compared to octave-wide band noise, although pure-tone noise is often more annoying to the individual (Ward et al, 2000). Snowmobile spectral characteristics are within the frequency range that is most damaging to the hearing mechanism. Bess & Poynor (1974) reviewed the spectral characteristics of snowmobile sound levels of snow machines that were ridden by professional snowmobilers. The greatest amount of energy found was between 200 and 2000 Hz, a range that includes many of the speech frequencies. The

spectral characteristics in this study were attributed to the wind and engine noise. Although some low frequency noise is reported from snowmobiles, the frequencies of 1000 and 2000 Hz lie within the frequency range where the greatest amounts of hearing damage are shown to occur.

Environmental Conditions

Wind. Wind has been shown to be a leading factor contributing to the hazardous noise exposures of recreational motorsport participants. Kennedy, Adetifa, Carley, Holt, & Walker (2011) studied the helmet design as a contributing factor for higher noise exposures by measuring flow field, surface pressure and at ear acoustics. At ear acoustics were obtained by placing a ¼ inch, Piezotronics microphones in an expanded polystyrene mannequin head. Three potential areas of motorcycle helmets that generate at ear noise exposures from wind noise were investigated. These were the helmet wake, several locations around the helmet surface, and the cavity under the helmet, near the chin. At ear noise level from wind turbulence was most influenced by the cavity under the helmet at the chin. The chin cavity noise source was further investigated in a wind tunnel with wind speed measurements corresponding to speeds of 40 km/h, 60 km/h, and 80 km/h at a fully upright riding condition. Wind noise observed in this region was reported at low frequencies between 0 to 1000 Hz. The production of at-ear noise from the chin cavity region was variable and dependent upon helmet angle and flow speed. These authors noted that their finding support anecdotal reports of noise reduction from riders who use a neck shield to close off the chin cavity.

Temperature and altitude. Temperature and altitude can both influence the accuracy of sound level measurements. As altitude increases, temperature commonly

decreases. The characteristics of a sound wave actually change as the temperate and altitude change. Noise measurement equipment such as dosimeters and SLM's are unable to operate at colder temperatures. The batteries of the devices are unable to perform once temperature is below about 20 degrees Fahrenheit. The sensitivity of the microphone may also be impacted at decreased temperatures. Snowmobiling is done at higher altitudes because snow usually falls in these environments with lower temperatures. Noise measurements done at higher altitudes and cooler temperatures can affect the performance and sensitivity of the device, therefore special care must be taken to protect measurement devices from temperatures at increased altitudes.

Vehicle Conditions

Snowmobile manufactures are always trying to make the fastest, lightest, and most powerful snowmobiles possible. Currently, snowmobile manufactures are using two general types of engines, two-stroke and four-stroke. The speed of the snow machines will vary as a function of custom modifications that owner's may make. Owners may modify their snow machines by adding additional fuel injectors, upgrading their engines for more horsepower (hp), and adding non-original equipment such as manufactured pipes or exhaust systems to enhance performance. Through these modifications, noise exposures may also increase.

Engine types. Snowmobile engines come in two types, two-stroke and four-stroke. A stroke is the movement of a piston in an engine. A two-stroke engine has a single piston stroke in each direction. A four-stroke engine has one exhaust stroke and one compression stroke followed by returning strokes. Two-stroke engines give the snowmobile significant power, less weight, and cost less, however four-stroke engines

produce less air and noise pollution. Krause (2003) reported that four-stroke engines had shown lower sound levels at a distance than two-stroke engines. Since four-stroke engines have to exert less energy for the same revolutions per minute (RPM), which is how many times the piston goes up and down in one minute, the noise exposures from four-stroke engines is often less. The majority of recreational snowmobilers ride two-stroke engines, although every main snowmobile manufacture produces four-stroke engines.

Snowmobile horsepower (hp) must be taken into consideration, along with engine type, when assessing noise exposure levels. Snowmobiles with 36, 40, and 45 hp were measured at 86 dBA at an idle to 113 dBA at full throttle (Bess & Poynor, 1974). The average hp of a modern snowmobile is greater than 120 hp. Research on snowmobiles was performed starting in the 1970's, since then the technology and materials used to manufacture snowmobiles have improved. Increased hp allows for the snowmobiles to travel at much faster speeds than previously seen in the 1970's, which may increase the risk for more wind and engine noise.

Speed. Speed has been shown to be a major contributing factor to the noise levels of recreational motor vehicles. Noise can come from a number of different elements including engines, wind, tracks or tires, and road noise. Motorcycles noise levels have been found to depend greatly on the speed. With increasing speed, noise levels of motorcycles have been shown to range from 78-90 dBA at 30 miles per hour (mph) to 116 dBA at 120 mph, depending on the type of motorcycles and the road conditions (Liu, Kuo & Raghuathan, 2010). Carley, Holt, & Walker (2010) reported motorcycle noise levels at the ear which were shown to exceed 90 dBA at 30 miles per hour and were

measured as high as 105 dBA at 70 mph. Measurements were made using a sound level meter and a GPS unit to reference motorcycle speed. The microphones were mounted underneath the helmet in the ear, allowing for data collection to be recorded at ear level. The influence of speed on sound levels for snowmobilers has not been reported in the literature.

Riding Conditions

Snowmobiles and other recreational motorsports have multiple factors that contribute to noise exposure levels beyond the motorized vehicle itself. The numbers of snowmobiles, geographical location, and operator characteristics each have their own unique characteristics that contribute to different aspects of noise exposure.

Number of snowmobiles and riders. The amount of snowmobile machines present in an area at one time will increase the amount of noise that is present. Krause (2003) measured the different noise levels of passing snowmobile groups from 50 feet away at 35 MPH. As the number of snowmobiles in a group increase from one rider to more than six, the noise levels increased from 80 dBA to 92 dBA. Noise levels measured at a distance does not indicate the noise exposures that recreational snowmobilers were exposed to while riding their snow machines. It can be assumed that the noise exposure levels of snowmobilers will increase when multiple riders are within a close proximity. The measurement for decibel is log based, therefore a doubling of sound level results in a 3 dB increase.

Geographical location. The use of snowmobiles in National Parks is regulated by Federal Law Enforcement, rule 42 USC 4901 (Noise Control Act, 1972). The majority of snowmobiling occurs on roads groomed and marked for snowmobiling, the same

roadways used by other recreational vehicles, cars, trucks and busses. Snowmobiles are not used as off-road vehicles in National Parks, such as Yellowstone, Rocky Mountain and Grand Teton. On U.S. National Forest Land, most of the trails used by snowmobiles are on groomed roads used by summer recreationists. There are also secondary and seasonal roads within the forests used by snowmobilers. These roads are groomed and marked by volunteers who work closely with the local U.S. Forest Service staff in maintaining and managing those areas (ISMA, 2009). Krause (2003) reviewed criteria and standards for the allowable snowmobile noise in Yellowstone National Park, as set by the National Park Service, that were measured using an A-weighted SPL scale. The snowmobile noise measured at a distance of 50 feet must not exceed 78dBA at full throttle (Krause, 2003). At a distance of 50 feet, the allowable level of 78 dBA, according to the standards, is not at a level loud enough to cause hearing damage to a bystander. If the sound level is measured closer than 50 feet away, the allowable level will increase and risk of hearing damage will be present depending on the duration (Krause, 2003). Even though standards are set to protect individuals and wildlife from the annoyance of excess noise levels, individuals who ride snowmobiles will still be exposed to hazardous levels.

Community noise requirements. Multiple states have community noise level requirements that snowmobiles must not exceed. These are based upon the distance from the snowmobile and the operating rpm of the snow machine. In Colorado, the stationary sound level limit for snowmobiles is 88 dBA at 4000 RPM (Snowmobile technical committee, 2009). This measurement is taken 157.5 inches from the exhaust system of the snowmobile. These noise measurements are made in order to determine whether

modifications have been made to the muffler or exhaust system which would generate noise levels above 88dBA. Since the exhaust system cannot be visually evaluated, the noise levels must be measured. These exhaust sound level measurements are recorded on one snowmobile at a time, and with ambient noise levels no greater than 10 dB below the source being measured. Other states have stationary sound level tests, which vary slightly with regard to the permitted sound level. It must be noted that the community noise levels from snowmobiling are likely to be greater when more individuals are riding and environmental factors are taken into account.

Groomed vs. non-groomed trails. Depending on the level and experience of a snowmobile rider, the type of trail that is commonly ridden in a day will vary. Experienced riders will spend much of their day on back country trails, winding through trees, up and down the mountain. Beginning snowmobilers will usually ride on groomed trails, which take much less skill to navigate. The speeds on groomed trails will often be faster due to the availability of an open road. Although riders commonly decrease speed when in the trees, this may not always true. Extremely skilled riders are able to navigate through the trees almost as quickly as riders on groomed trails. The trees also create a much more reverberant environment, therefore even at lower speeds, the noise levels may still be hazardous to hearing.

Operator Factors

Gender. The recreational snowmobile population is male dominated, with approximately 88% of all active snowmobilers being male and around 12% female (ISMA, 2009). The amount of males compared to females is likely due to the physical demands of the sport, as well as the weather and elements that a winter sport entails.

Helmets. The debate is still out on whether helmets provide any attenuation for noise. Helmets used for recreational snowmobiling consist of three common types/styles, which are open face, full face, and the newest modular style (Figure 1A-C). An open face helmet has a clear face shield in the front that can be fully raised and lowered to expose or cover the whole face (Figure 1A). A full face helmet only has an area around the eyes just above the nose that is open to the external environment with the helmet extending to cover the mouth and nose (Figure 1B).The modular style is a combination of the full face and open face helmet. The helmet can either be worn as a full face where only the area around the eyes is open or converted into an open face by lifting the whole front up so the whole face is revealed (Figure 1C).

Figure 1. Full face snowmobile helmet (A). Open face snowmobile helmet (B). Modular snowmobile helmet(C).

Open face helmets have been shown to block more noise that full face helmets due to the material and helmet design (Carley et al, 2010; Van Moorhem, Shepherd, Magleby, & Torian, 1981). Helmets, whether they are full or open face, are worn not only to protect the rider from head injury if an accident were to occur, but a slight amount of noise protection is provided when compared to when a helmet is not worn. A one-half inch General Radio microphone connected to a General Radio model 1933 SLM was

used by Van Moorhem and colleagues to measure under the helmet ear-level noise (Van Moorhem et al, 1981). Sound levels were 100 dBA when the study participant was riding at medium speed levels. Open face helmets were shown to be associated with the lower noise levels, while the full face helmets had higher noise levels. The attenuation of helmets has not been extensively studied; however in general, attenuation has been shown to be very poor at low frequencies and offered a slight resonance at 250 Hz (McCombe, 2003). Most recreational snowmobilers wear helmets on a regular basis, for safety, as well as keeping warm.

Hearing protectors. Hearing protection has not been shown to be widely used in recreational sports, even though hazardous noise levels have been measured during these activities. HPD's have been endorsed and encouraged due to the hazardous noise levels that can cause hearing damage to the rider. Professional racers, such as grand prix racers are required to wear hearing protection in order to race, which was shown to only occur in nine out of the 44 riders (McCombe & Binnington, 1994). These authors state that even though hearing protection is required in grand prix racing, the number of racers who fail to wear HPD is alarming. From occupational to recreational motorsports, the education and enforcement for hearing protection devices is not present.

Custom hearing protection is available for motorsport riders. One manufacturer, Westone, has a plug recommended for motorcyclists with a noise reduction rating (NRR) of 21 decibels. Other custom plugs recommended for snowmobiling are available through Westone and the hearing aid company Starkey, but no published NRR data is available. Formable and preformed hearing protection devices may also be used to protect snowmobile riders from hazardous noise levels when riding.

Communication radios. Many recreational snowmobile riders now use radios as a form of communication while on the trails. There are two main types of radios that are used, underneath and outside of the helmet. The underneath the helmet radios are actually embedded into the helmet itself, the receiver is connected to the inside of the helmet near the ear, and the microphone positioned near mouth at the front of the helmet. Outside of the helmet radios are positioned underneath the jacket or clipped to the collar or zipper region. These radios are commonly general use radios and not specific for snowmobiling. The receiver is a box that sits inside a pocket of the snowmobiler's jacket and the microphone is connected to a cord where the rider has to push a button in order to communicate.

Ross (1989) measured the amount of radio volume as compared to the speed that the motorcycle was traveling. Two miniature microphones were taped inside the helmet connecting to an amplifier and two-channel cassette recorder, then analyzed in a noise laboratory. One microphone was taped near the ear and the other near the motorcyclist's mouth. When radio intercoms were used, the equivalent-continuous sound levels (Leqs) were increased by 2 dBA during open road driving. High peak levels existed during in town driving, showing that the intercom volume had to be raised as the speed increased. Motorcyclists driving in towns were shown to have noise levels of 63-90 dBA with their intercoms being measured louder than 90 dBA. With levels exceeding 90 dBA, NIHL is possible with extended riding exposure (Carley et al, 2010). The risk for increased intercom volume with increasing vocal output will potentially contribute to the noise exposure levels, when individuals are riding with excess levels of noise.

CHAPTER III

METHODOLOGY

Introduction

The purpose of this study was to investigate the noise exposure levels of snowmobilers. Snowmobiler's knowledge, attitudes and beliefs with regards to risk of NIHL were also assessed. Experimental methods and analysis are described in this chapter. The research was conducted under an approved University of Northern Colorado Institutional Review Board (IRB) protocol (Appendix A).

Participants

Participants selected for this study were adult male and female recreational snowmobilers, 18 years of age or older, who wore a helmet while snowmobile riding. The participants in this study were recruited from a convenience sample of the Northwest Colorado Snowmobile Club (NOWECOS). Participants were required to regularly participate in recreational snowmobiling at least five times a season in order to be eligible for inclusion in the study. Each participant had the ability to read and write English at a high school level (as evidenced by the receipt of a high school diploma or equivalent) in order to complete the written survey. Riders of all types of snowmobiles and helmets were eligible to participate.

If a participant had any known skin allergies to health-grade skin tapes, they were unable to partake in this study because tape was needed to hold the noise dosimeter

microphones in place underneath the helmet and would be in direct contact with their skin. Participants were required to indicate their availability to ride at least four hours on the day of data collection in order to have an opportunity to obtain longer noise exposure samples. If participants typically utilized HPD's, such as earplugs while riding, they were encouraged to continue the use of them while participating in this study. In rare cases, the placement of the noise dosimeter microphones may have been compromised by the wearing of hearing protectors and if so, then the subject was excluded from participation as it would be unethical to advise them to ride without hearing protection when that is their usual practice.

Research Environment

The snowmobile study location was based upon the NOWECOS organized club riding events. Data collection was completed outdoors in Northwest, Colorado on the public lands of Route National Forest. Characteristics of the terrain of Route National Forest consist of open meadows, pine and aspen trees, and trails. The pine and aspen trees are very dense in some areas. The trails that the participants were riding on were either groomed or non-groomed. Trails that are not groomed usually wind up and down large hills through trees.

Noise Measurement Procedure

For the purpose of this study each participant was involved in the completion of one noise dosimetry sample obtained on a typical day of snowmobile riding for recreational enjoyment. The noise dosimeter that was utilized in this study was the QuietDose™ manufactured by Honeywell International Inc. (Howard Leigh [QuietDose™] (2011).

QuietDose™. The QD noise dosimeter is a type 2 sound measurement instrument and complies with the guidelines described in ANSI S1.25-1991(R2002). The QD dosimeter was used to measure the under the helmet noise exposures of the rider. The microphones are connected by small cables to a small box which was worn underneath the jacket. Each microphone was positioned in front of the individual's ear, just in front of the ear canal opening. The microphones were held in place by medical grade tape appropriate for skin use. The device is illustrated in Figure 2. Note that it was used without the blue hearing protector flange tips pictured.

Figure 2. Howard Leigh QuietDose noise dosimeter. From Honeywell International Inc., San Diego, CA. Retrieved May 01, 2013 from: https://www.howardleight.com/quietdose. Reprinted with permission

The QD performs continuous monitoring of noise exposure using three measurement protocols. Dose was simultaneously calculated for OSHA PEL using a 90 dBA criterion level and a 5 dB exchange rate and the NIOSH REL using an 85 dBA criterion level and a 3 dB exchange rate. An 80 decibel threshold setting was used for both OSHA AL and NIOSH REL sampling protocols. Simultaneous dose was also calculated for OSHA AL using an 85 dB criterion level, a 5 dB exchange rate, and an 80 dB threshold setting. Since the QD has two microphones feeding into the noise exposure calculation (one for the right ear and one for the left ear), the sound level is sampled from each microphone 10 times per second and the dosimeter uses the higher of the two measurements for calculation. Therefore, separate individual ear measurements are not feasible using this device.

The noise dosimeter batteries were replaced with fresh batteries on the sample day. The QD dosimeter was calibrated according to manufacturer guidelines on the day of each noise sample. The instrument LEDs were taped over to avoid influencing the rider's noise exposure due to sound level feedback provided by the LEDs during the riding period. The dosimeter was turned off as soon as the riders reached the trail head in order to decrease any unwanted quiet periods from being averaged into the noise measurement data. Data from the noise dosimeter was downloaded to the researcher's computer after each riding day.

Rider Instructions

Each snowmobile rider was instructed to ride as they normally would and try to ignore the presence of the dosimeter and microphones. The noise dosimeter was placed on the participant by the researcher at the beginning of the day. The rider was verbally

instructed on their ability to personally relocate the main QD dosimeter processing unit that was worn in their jacket for comfort and how to remove their helmet without compromising the placement of the ear level microphones if necessary during riding breaks. Riders were encouraged to keep the helmets on if possible and not remove unnecessarily. The rider was also advised to wear the dosimeter until the end of the riding activity when the researcher personally removed the dosimeters. In order to further quantify the noise exposure levels, the participants were asked to record the time of day they stopped to eat lunch or rest and the time of day they resumed riding on a note card provided by the researcher. They were also instructed to indicate if the snowmobile engine was idling or operating while resting or eating.

Survey Instrumentation

Snowmobiler data form. The researcher completed a snowmobiler data form at the time the noise dosimeters were activated for the participant in order to record the specifics of the snowmobile, helmet and rider habits. See Appendix B for an example of the snowmobiler data form. Post-ride questions were also be recorded in order to determine other specifics of the ride such as the length of ride, the number of individuals riding, and atypical events that may have occurred during the sample period (e.g. engine malfunction). This was accomplished by verbal interview of the participant before and after the ride.

Health communication survey and analysis. Each participant was asked to fill out a 58 question survey pertaining to their knowledge, attitudes and beliefs about NIHL. Key components of the HBM were integrated into the survey. The survey was

administered in paper form and was filled out by the participant before they began riding on the noise measurement day. The survey is provided in Appendix C.

The HBM survey was adapted from Gill (2008). The survey used a five-point Likert scale measuring either a positive or negative response to the question presented (Allen & Seaman, 2007). The format of the Likert scale is as follows: (1) strongly disagree, (2) disagree, (3) neither agree or disagree, (4) agree, and (5) strongly agree. Questions from the survey were grouped into eight factors which consisted of; perceived benefits and cues to action, perceived severity and susceptibility, reported behaviors, barriers, hearing loss, self-efficacy and individual responsibility, common knowledge, and other. The survey questions and associated subscales are provided in Appendix D.

Noise Data Analysis Procedure

A descriptive analysis was done on noise dosimetry measurements and snowmobile/rider characteristics. The noise dosimeter used was originally designed as an in-the-ear measurement system where the microphones are positioned underneath a hearing protection device (ear plug or ear muff) and noise levels are measured to see how well the hearing protection device is working to block out sound. In this study, the microphones were placed under the helmet rather than under a hearing protector. The manufacturer does not utilize an ear canal transform function for the data collected in their standard application (under an earplug or earmuff); therefore no transformation to free-field noise values was required for comparison to auditory damage risk criteria. The noise dose, time weighted average and run-time measurements were quantified and compared to OSHA 29 CFR 1910.95 permissible exposure level and NIOSH (1998) recommended exposure levels using descriptive techniques for the QD outcomes

CHAPTER IV

RESULTS

Participants

Participants for this study were intermediate or advanced recreational snowmobilers selected from a convenience sample of the Northwest Colorado Snowmobile Club (NOWECOS). A total of ten snowmobilers participated in this study; none of whom reported the use of hearing protection devices. Participants included two females and eight males with the mean age of 53.9 ($\pm$14.07) years old, and ages ranging from 28-70 years. A noise dosimetry sampling and snowmobile data form was collected from each participant after completion of informed consent. Data collection took place during the winter months of December, January, and February in Northwest Colorado. Snowmobilers commonly ride in a group, each with their own snow machine. Primarily snowmobilers will go with at least one other person for safety reasons. Half of the participants reported riding in groups of three to five snowmobilers on average and the remaining reported riding in groups with an average of six to nine people. During data collection the number of snowmobilers that rode together ranged from two to eight, with a mean of five riders on the day of noise sampling. Subjects in this study were experienced riders, six (60%) had been riding snowmobiles for more than ten years. The remaining 40% (n=4) had been riding for between 5-9 years.

Snowmobile Characteristics and Rider Habits

In order to record the specifics of the snowmobile, helmet and rider habits during data collection, a snowmobile data form was collected from participants. Snowmobile characteristics ranged from person to person with variations in the equipment used.

Sixty percent of snowmobilers in this study consider themselves advanced riders, and the remaining (40%) classified themselves as intermediately skilled. More advanced riders would commonly ride at higher speeds and keep their snow machine at a higher throttle throughout the day. Snowmobiling occurs in a variety of different locations, consisting of woods, forests and open plains. Depending on the skill level of the rider and the area of the country, the terrain may vary. In this study, participants reported riding in terrain that consisted of woods and forests, with one report of riding in open plains.

All riders wore helmets, with 70% (n = 7) having full face snowmobile helmets (Fig. 1A), 20% (n=2) having modular helmets, and one having an open face helmet (Fig. 1B). Five participants utilized communication radios while riding. Out of the 50% who utilized radios, one radio had speakers integrated into the lining of the helmet and positioned opposite the opening to the left ear canal (subject #4). The remaining four had radios that were external to the helmet, which were worn either inside their jacket pocket or clipped to the outside.

The make and model of snowmobiles in the study varied. Data was collected on four major snowmobile makes and seven different models. The snowmobile type, engine, and year are summarized in Table 1. Nine out of ten snowmobile engines were two-stroke (90%), with one four-stroke (10%) driven by subject #9. All snowmobile machines were manufactured within the previous eight years, although the majority (70%) were

manufactured within the last four years. Snow machines have changed throughout the years with lighter parts being used in the more contemporary models, leading to increased speeds and increased riding possibilities in more challenging terrain. In more challenging terrain, the snow is often deeper, the hills are at a greater incline, and more energy must be exerted from the engine in order to plow through several feet of snow while trying to reach the top of a large hill.

Table 1

Snowmobile Characteristics

Subject #	**Make**	**Model**	**Engine**	**Year**
1	Polaris	800 Dragon	2-Stroke	2009
2	Polaris	800 Dragon	2-Stroke	2009
3	Polaris	800 RMK	2-Stroke	2005
4	Arctic Cat	M 800	2-Stroke	2012
5	Ski Doo	Summit 800	2-Stroke	2012
6	Polaris	800 Dragon	2-Stroke	2009
7	Arctic Cat	M 800	2-Stroke	2010
8	Arctic Cat	King Cat	2-Stroke	2004
9	Yamaha	Nytro Mtr	4-Stroke	2008
10	Polaris	800 Dragon	2-Stroke	2009

Riding Time

Results from the survey data forms indicate that the participants reported snowmobiling for an average of four to seven hours per day when participating in the sport. Four (40%) reported riding five to nine days per year and 60% (n=6) rode more than ten days per year. In this study, the snowmobiles traveled an average of 51.34 miles (± 10.62 miles) per day during noise exposure data collection. The daily mileage ranged from 33.3 to 64 miles.

Noise dosimetry data was continuous during riding and break times. Each participant was asked to write down how long their breaks were and the amount of time the snow machine was either idling or off. Most participants were inconsistent with filling out this log while riding; therefore approximate break times with the snow machine idling and off were obtained via verbal interview by the researcher at the end of the riding day when removing the noise dosimeter.

Along with the many miles covered, riders spent anywhere from 3 hours and 38 minutes to 8 hours and 50 minutes snowmobiling per day, including breaks. The average actual snowmobile riding time during data collection was 6.23 ± 1.32 hours. Breaks consisted of time in which the snow machine was idling or off. Break times vary depending on the length of time spent riding and other unforeseen factors. These factors may include snow machine problems or becoming immovable in deep snow that could cause the snowmobiles to be turned off or idling for longer periods of time. Table 2 provides a summary of the total mileage traveled, amount of riding time and break time during noise exposure data collection.

Table 2

Snowmobiler mileage, total riding time, and breaks while engine idling and off

Subject #	**Mileage**	**Total riding time (Minutes)**	**Break at idle (Minutes)**	**Break at off (Minutes)**
1	51	361	15	30
2	52	404	0	35
3	48	213	0	5
4	33.3	232	10	140
5	57	420	0	30
6	64	377	15	30
7	41.6	328	5	30
8	40.5	308	0	35
9	62	397	10	40
10	64	455	15	60
Mean	**51.34**	**349.5**	**7**	**43.5**
SD	**10.62**	**79.47**	**6.75**	**36.44**

Under Helmet Noise Exposures

Ten total noise samples were collected on different days throughout the winter season. There were no problems with the noise dosimetry equipment and all data was recovered from the QuietDose™ (QD) at the end of each sampling day.

Noise Exposures

The noise dosimeter utilized throughout data collection was set to simultaneously collect dose for each of three exposure standards (OSHA AL, OSHA PEL, and NIOSH). A TWA for each participant was calculated from the dose reported from the QD using reference tables contained within OSHA 29 CFR 1910.95 or the NIOSH (1998) criteria document. Dose refers to the amount of noise that a person is allowed in an 8 hour period. When dose is equal to or exceeds 100%, hazardous noise exposure has been reached and a risk of NIHL exists for repeated exposures over time. The averaging of

different sound pressure levels during an 8 hour period is reported as the TWA. The noise dose and TWA were calculated differently depending on the sampling protocol being used. Table 3 summarizes the measured doses and calculated TWAs for each participant and sampling protocol.

Table 3

Individual Subject Noise Dose and TWA

Subject #	**OSHA AL Dose %**	**OSHA AL TWA (dBA)**	**OSHA PEL Dose %**	**OSHA PEL TWA (dBA)**	**NIOSH Dose %**	**NIOSH TWA (dBA)**
1	46	84.4	27	80.6	207	88.1
2	71	97.5	61	86.4	395	90.94
3	92	89.4	90	89.2	747	93.7
4*	46	84.4	41	83.6	228	88.23
5	65	86.9	52	85.3	365	90.58
6	84	88.7	82	88.6	516	92.1
7	75	87.9	71	87.5	650	93.1
8	78	88.2	73	87.7	574	92.6
9	47	84.6	37	82.7	226	88.2
10	113	90.9	102	90.1	815	94.1
Mean	**71.7**	**88.29**	**63.6**	**86.17**	**472.3**	**91.17**
SD	**.2**	**3.9**	**.2**	**3.1**	**2.2**	**2.3**

* Under the helmet radio
Note. Subjects that exceed the recommended noise exposures for an eight hour work day according to OSHA PEL, OSHA AL, or NIOSH REL are highlighted in red

The results presented in Table 3 vary between the three sampling protocols as expected. Results obtained with the OSHA AL protocol reveal a mean noise dose of 71.7 (±0.2%) and a mean TWA of 88.29 (±3.9) dBA. Seventy percent of participants (n = 7) exceeded the OSHA AL of 85 dBA TWA (50% dose). The 3 riders that did not exceed the OSHA AL were borderline over-exposed within 3-4% noise dose (0.4 to 0.6 dBA TWA). Consequently, all the riders should be enrolled in a hearing conservation program

according to OSHA occupational standards, especially when taking into consideration the ± 2 dB measurement error for Type 2 noise dosimeters. It is worth noting that subject number four with the in-helmet radio, was one of the lower noise exposures measured.

The OSHA PEL protocol samples reveal a mean noise dose of 63.6% (±.2%) with a TWA of 86.17 (±3.1) dBA. One participant (10%) exceeded 100% dose (90 dBA TWA) for the OSHA PEL protocol. This particular subject (#10) also logged the longest ride time of the study participants (7.92 hours).

The mean noise dose for the NIOSH protocol was 472.3% (±2.2%) and a mean TWA of 91.17 (±2.3) dBA. Since the NIOSH protocol incorporates a 3 dB exchange rate it is not uncommon to see NIOSH dose and TWA higher than the OSHA AL and PEL. All participants exceeded the NIOSH REL of 85 dBA TWA, and exceeded a dose of 100%. Half of the participants in the study (n = 5) had sufficient noise exposure in one ride to be equivalent to an entire 40-hour work week of allowable exposure in an occupational setting. The remaining 50% had sufficient noise exposure to exceed the equivalent of two workdays (at 85 dBA TWA) of allowable exposure. All participants in this study are at risk for NIHL when referencing either the OSHA AL or NIOSH REL for repeated exposures while wearing helmets.

Health Belief Model Survey

Each individual filled out a 58 question survey pertaining to their knowledge, attitudes and beliefs about NIHL. All subjects completed all questions on the survey, there were no incomplete surveys. The key components of the HBM are the individual's perception of susceptibility, seriousness of the risk, benefits of the prevention measures, barriers to the desirable behavior, cues to action and self-efficacy. The survey was

administered in paper form and filled out by each participant before they began riding on their noise measurement day. Due to the limited number of subjects, all questions were collapsed into either “correct” or “incorrect” response based on the context of hearing health promotion. “Correct” responses were chosen based on which answers promoted hearing health, with “incorrect” answers not promoting hearing health in participants. The answers that were neither agree or disagree were grouped into the incorrect category. If the individual was unaware of the correct response to the question posed, then that was an “uninformed” or categorized as an incorrect answer. Cumulative response percentages for each survey question are provided in Appendix E.

Health Belief Model Constructs

Common Knowledge. The HBM construct of “common knowledge” is factor one. This construct was used to evaluate whether participants have the general knowledge about anatomy of the hearing mechanism, hearing loss, and the factors that lead to a higher risk of NIHL. Participants answered questions pertaining to the anatomy of the ear and how hearing loss occurs. Participant “common knowledge” responses are summarized in Table 4. It appears that all of the participants (100%) know how NIHL occurs and most (90%) understand that some leisure activities are loud enough to cause temporary hearing loss.

Table 4

Factor One: Common Knowledge Constructs

#	Survey Question	Incorrect Responses	Correct Responses
1	Repeated exposure to loud sound can cause hearing loss over time	0%	100%
3	There are some leisure activities that are loud enough to cause temporary hearing loss	10%	90%
33	Loud sounds can cause damage to hair cells in the ear	40%	60%
47	Turning down the volume of the loud sound is an effective way to avoid hearing loss due to loud sounds	0%	100%
55	Exposure to loud sounds can cause damage to small bones in the middle ear	80%	20%

Self-efficacy and individual responsibility. The next subscale was used to evaluate “self-efficacy and individual responsibility”. The subscale consisted of four questions which addressed the participant’s personal knowledge about hearing and the risk of hearing damage from hazardous noise exposure. Questions and responses are summarized in Table 5. Sixty percent of participants reported an understanding of how the ear works, with 80% having learned about how the ear works in their schooling. Ninety percent of participants report that they are personally aware of the risk of hearing loss due to loud noise. The participants also reported that they know when things are too loud, although 30% need more information and guidance recognizing when a sound level is hazardous to their hearing.

Table 5

Factor Two: Self-efficacy and Individual Responsibility Constructs

#	Survey Question	Incorrect Responses	Correct Responses
5	I have learned about how the ear works in my schooling	20%	80%
6	I know when things are too loud	30%	70%
23	I am aware of the risk of hearing loss due to exposure to loud noise	10%	90%
43	I understand how ears work	40%	60%

Hearing loss. Familiarity with hearing loss was addressed as a separate factor based on the Gill (2008) study. A set of seven questions determined whether subjects have hearing loss themselves or know someone who suffers from hearing loss (Table 6). The questions in this subscale also addressed whether participants partake in activities that are hazardous or if loud sound is a problem. Participants reported that they were either unsure or believe that there is medical treatment for NIHL. Eighty percent of participants reported that they have hearing loss and 100% have a friend with hearing loss. All but one participant knew someone with hearing loss due to loud noise exposure and two of them reported that person to be their spouse. A majority (70%) reported that noise exposure is not a serious problem, although every subject reported that they participate in activities that could be hazardous to their hearing. These results indicate that all of the participants in this study know either a friend, a spouse, or they themselves have hearing loss. Participants acknowledge that NIHL is present in their lives, yet it does not seem to influence their protective behaviors.

Table 6

Factor Three: Hearing Loss Constructs

#	Survey Question	Incorrect Responses	Correct Responses
8	Exposure to loud sound is **not** a serious problem for me	30%	70%
13	I know someone with a hearing loss due to loud sound exposure	100%	0%
21	I participate in activities that could be hazardous to my hearing	100%	0%
25	I have a hearing loss	80%	20%
46	Hearing loss caused by loud sounds can be medically corrected.	40%	60%
50	My spouse has a hearing loss from exposure to loud sounds	40%	60%
51	I know a friend with a hearing loss	0%	100%

Benefits and cues to action. The fourth subscale consisted of questions that addressed the HBM construct of "perceived benefit and cues of action". Named "benefits and cues to action", this factor included 12 questions (Table 7). These questions addressed the health concern of NIHL. A number of the 12 questions addressed the importance of the sense of hearing and the need to use hearing protection devices when exposed to loud sound. Questions also addressed if the individual were aware that they may be susceptible to the noise risk. A majority (90%) of participants have high regards when it comes to their concern of NIHL from loud sounds. Only one participant reported that even if they had an abnormal hearing test, they would not be encouraged to wear earplugs/earmuffs in loud noise. Participants in this study expressed an awareness

regarding when they were exposed to loud sounds and the symptoms associated with noise induced hearing loss, such as tinnitus. One individual reported that muffled speech after noise exposure is not a warning sign that the sound is too loud. With regards to most of the questions, participants seem to acknowledge the benefits of good hearing and the appropriate cues to action, yet they do not indicate that they implement these cues in their own behaviors, supported by responses in Cues to Action.

Table 7

Factor Four: Benefits and Cues to Action Constructs

#	Survey Question	Incorrect Responses	Correct Responses
2	Being able to hear is very important to quality of life	0%	100%
12	I have learned about the risks of exposure to loud sounds on the internet	90%	10%
17	It is important to understand the potential to damage my hearing from loud sounds	0%	100%
28	It is important to protect my hearing from loud sound	0%	100%
31	It is important for me to wear hearing protection when exposed to loud noise.	0%	60%
35	Using earplugs when exposed to loud sound is an effective way to reduce the risks of noise exposure	0%	100%
37	An abnormal hearing test for myself would encourage me the use of earplugs/earmuffs in loud noise	10%	90%
38	Free earplugs available at a public event implies the sound is potentially too loud	0%	100%
39	Ringing in my ear after exposure to loud sound is a warning sign that the sound is too loud	0%	100%
41	If speech sounding muffled after exposure to loud sound is a warning sign that the sound is too loud	10%	90%
45	I should move away from loud sounds	0%	100%
52	Having to shout to be heard at arm's length means that the sound in the area is too loud	0%	100%

Perceived severity and susceptibility. The fifth subscale is "perceived severity and susceptibility". This construct is used to pinpoint whether individuals perceive the seriousness of the risk and the potential consequences that are present. This subscale consisted of 14 questions (Table 8). Several questions were used to determine if the participants believed that being exposed to loud sounds warranted hearing protection use. Other questions addressed if individuals recognize when they are exposed to loud sounds that may cause NIHL. In general, participants are aware of the risk of NIHL and that hearing loss may have negative effects on their auditory/verbal communication and quality of life. Eighty percent of participants reported that having a hearing loss would make them feel isolated and 100% reported that noise induced hearing loss would negatively affect their quality of life. Even though participants were aware of the severity of hearing loss from loud sounds, thirty percent reported they would still participate in a loud activity, even if hearing protection was unavailable. Participants perceived the severity of hearing loss and tinnitus, and acknowledged they are susceptible to incurring NIHL, although not all would remove themselves from situations where they were at risk for NIHL.

Table 8

Factor Five: Perceived Severity and Susceptibility

#	Survey Question	Incorrect Responses	Correct Responses
4.	I may be at risk of hearing loss from exposure to loud sound	10%	90%
7	I should stop participating in a loud activity just because I do not have earplugs or earmuffs available	30%	70%
9	Hair cells in the inner ear aid in transmission of sound	40%	60%
10	It is my responsibility to ensure that I understand the risks of hearing loss due to loud noise	0%	100%
11	Listening to loud music can contribute to hearing loss	0%	60%
14	A hearing loss from exposure to loud sound would negatively affect my ability to understand conversational speech easily	0%	100%
15	There are some leisure activities that are loud enough to cause permanent hearing loss over time	0%	100%
18	Hearing damage from loud sounds when an individual is younger can contribute to worse hearing as an adult	0%	100%
20	My hearing does **not** need to be protected from loud sounds	0%	100%
26	A hearing loss would make me feel isolated	20%	80%
29	Moving away from loud sound is an effective way to prevent hearing loss caused by loud sound	10%	90%
49	I understand that loud sound can hurt my ears	0%	100%
53	Hearing loss from loud sound would negatively affect my quality of life	0%	100%
54	Only workers who are around loud sound every day need to wear hearing protection	20%	80%

Reported behaviors. A sixth construct of the HBM addressed the "reported behaviors" through seven questions, which included the various techniques that are used to prevent hearing loss attributed to hazardous noise exposure (Table 9). All participants have worn hearing protection at least once when exposed to loud sound, with 50% reported that they regularly wear hearing protection when exposed to loud sound. Fifty percent also reported that they carry earplugs with them and 70% report that they encourage others to wear hearing protection when exposed to loud noise. Participants may be aware of the risk of hearing loss from hazardous noise levels but the techniques to prevent hearing loss are not employed regularly. This behavior was also evident when asking if the snowmobilers used hearing protection while riding their snowmobiles, since 100% indicated that they do not utilize hearing protection while engaging in this sport. Roughly 30% to 50% of participants need to implement behavior change, particularly related to the use of hearing protection when in noise hazardous situations.

Table 9

Factor Six: Reported Behaviors

#	Survey Question	Incorrect Responses	Correct Responses
16	I have worn earplugs/earmuffs when exposed to loud sound at least once	0%	100%
24	I have worn ear plugs at least once when exposed to loud sound	0%	100%
32	I carry earplugs with me	50%	50%
36	I wear earplugs regularly when exposed to loud sound	50%	50%
42	I routinely wear earplugs/earmuffs when exposed to loud sounds	30%	70%
48	I wear earplugs/earmuffs during loud activities	20%	80%
56	I encourage others to wear hearing protection when exposed to loud noise	30%	70%

Barriers. The next component of the HBM consisted of seven questions that evaluated the “barriers” that prevent the desired hearing health behaviors from occurring (Table 10). With regards to wearing hearing protection, many barriers are present. Twenty percent of participants believe that hearing protection is expensive, which makes cost a barrier with regards to the use of hearing protection. Two participants were unaware that hearing protection is sized to fit individual ears correctly. Twenty percent also reported that earplugs or earmuffs made their ears sore, which may be caused by a poor fit. Eighty percent of participants (80%) were aware that hearing protection devices are made to fit properly. Half of participants either didn’t know or had the misconception that using cotton in the ears is an effective way to reduce the risk of NIHL. Fifty percent

of individuals reported that they would not be able to communicate effectively while wearing earplugs or earmuffs. Since half of the participants believed that they will have diminished communication with hearing protection, communication is a major barrier to overcome when protecting the hearing of a snowmobiler. In summary, cost, comfort and impaired communication were all identified as barriers to the routine use of HPDs.

Table 10

Factor Seven: Barriers

#	Survey Question	Incorrect Responses	Correct Responses
22	I will be embarrassed if I wear earplugs or earmuffs when around loud sound	0%	100%
27	I will not be able to communicate effectively while wearing earplugs/earmuffs	50%	50%
30	Hearing protection is expensive	20%	80%
34	Ear plugs or earmuffs will make my ears sore	20%	80%
40	Earplugs and earmuffs are sized to fit properly	20%	80%
44	Using cotton in the ears when exposed to loud sounds, is an effective way to reduce the risks of noise exposure	50%	50%
57	Earplugs or earmuffs will **not** protect my hearing	10%	90%

Other. Lastly, one additional question was included in the survey to determine how many individuals believed helmets provided hearing protection during exposure to loud motorized vehicle activities. Fifty percent of participants reported that helmets worn during loud activities would provide protection to their hearing, while the other half (50%) do not believe that helmets provide hearing protection.

Summary

All snowmobile riders were over-exposed to noise while riding with helmets in this study. Under the helmet noise exposure levels did not demonstrate adequate protection from hazardous snowmobile sounds while participants were engaged in recreational snowmobiling. The HBM survey results suggest that 50% of the riders felt a helmet was protective from hazardous noise and that hearing protectors may be underutilized due to the cost, communication and comfort barriers.

CHAPTER V

DISCUSSION AND CONCLUSIONS

Noise hazards exist for all snowmobilers in this study, regardless of the many variables that are present between riders. Some riders had lower noise dose than others, which can be attributed to differences between riders, equipment, and time spent riding. The actual time snowmobilers spend riding, along with the high snowmobile noise levels and non-use of hearing protection devices, contribute to the risk of NIHL.

Factors Related to Recreational Snowmobile Rider Noise Exposures

Speed

Previous research in the recreational motorsports has also found hazardous sound exposures. While noise levels in this study ranged from 80.6 – 90.1 dBA TWA (OSHA PEL) and 88.1 – 94.1 dBA TWA (NIOSH REL), other studies have reported higher sound levels. Noise levels measured from a typical racing snowmobile ranged from 86 dBA to 113 dBA when measured with a sound level meter at ear level, outside of the helmet (Bess & Poynor, 1974). Jordan et al, (2004) measured noise levels of occupational motorcyclists in the United Kingdom underneath the helmet with miniature microphones. Noise levels ranging from 76.1 dBA to 110.6 dBA TWA sampled with an 85 dBA criterion and a three dB European regulation were measured at speeds ranging from 30 mph to 75 mph. These levels may be higher due to the higher speeds of the motorcyclists. The sound source and riding environment differences between motorcycles and

snowmobiles may also contribute to higher noise exposures for motorcyclists. Motorsports that included motorcycles and snowmobiles have both been shown to have hazardous noise levels exceeding 100 dBA in many instances (Bess & Poynor, 1974; McCombe & Binnington, 1994; Ross, 1989). The varying noise levels are in part due to the advances in snowmobile technology over the years and the differences in speeds while racing versus riding recreationally. One thing is clear; snowmobilers continue to be at risk for NIHL from dangerous noise levels.

Engine Type

Noise exposures did not appear to be influenced by snow machine model; however engine type did appear to generally relate. Previous research reported that four-stroke engines had lower sound levels at a distance when compared to two-stroke engines (Krause, 2003). Krause's (2003) findings are similar to the current study, in that the noise dosimetry data shows that the four-stroke snowmobile had one of the lowest noise exposures sampled. This may be due to the location of the exhaust on a four stroke snow machine, whereby noise is exiting the rear of the snowmobile rather than the front side of the machine. Although only one four stroke was measured, noise dose was significantly lower than 70% of the other snow machines in this study for comparable or shorter riding times.

Helmet Type

Previous research on helmets reported that open face helmets have been shown to block more noise than full face helmets due to the material and helmet design (Carley et al, 2010; Van Moorhem et al, 1981). Noise levels between the different types of helmets varied between all participants in this study, although snowmobile engine type confounds

this comparison. Subject number nine was the only participant with an open face helmet and a four-stroke snow machine. This participant did have a noise exposure lower than 70% of participants, but it cannot be determined that the open face helmet alone contributed to the lower dose. The combination of riding a four stroke snowmobile and having an open face helmet may have both contributed to the lower measurements for this participant.

Communication Radio

One might expect sound levels to be higher when a radio speaker is located under the helmet. However, the rider with the under helmet radio did not have higher noise doses than the riders whose radios were outside of the helmet, with riding times comparable to all other participants. Since radios are used for short amounts of time, there does not seem to be an impact on recreational snowmobiler's noise dose in this case.

Age and Gender

Rider characteristics related to the noise dose of participants were the ages and gender of the participants. The recreational snowmobile population is male dominated, with approximately 88% of all active snowmobilers being male and around 12% female (ISMA, 2009). Similar to previous research, the ratio of females to males in the current study was 1:5. Gender may play a role, since the females in this study had the two lowest noise doses when compared to all eight males in the study, regardless of the engine type. Not only were the males more likely to ride on a regular basis, they also had higher noise doses when compared to the female snowmobilers. Males tend to have higher muscle mass which allows them to maneuver a snowmobile in ways that women may not be able

to do. The two youngest participants, both males, had the two highest recorded noise doses. Perhaps the higher noise doses are due to greater athleticism and the ability to aggressively maneuver a snowmobile in more difficult terrain. Individuals who are capable of maneuvering their snow machine often have their snowmobile at higher RPM throughout the day. When individuals are more athletic, they have greater control over their snow machine and are able to ride at higher speeds, even in more difficult terrain. Therefore, it was not unusual to have the highest noise doses from the youngest male participants. The data in this study suggests that females are still at risk for NIHL, although males, especially those that are younger, may be at a higher risk.

Riding Time

Depending on the speed of the snowmobile and the amount of terrain covered, noise levels can vary from rider to rider. The snowmobiler with the shortest riding time (203 minutes) had the second highest noise dose (92% OSHA AL, 90% OSHA PEL, & 747% NIOSH REL) of all participants, whereas the rider with an average riding time (406 minutes) had one of the lowest noise doses (46% OSHA AL, 27% OSHA PEL, & 207% NIOSH REL). Participants who rode for longer durations were at higher risk for NIHL, but a shorter ride time can also be hazardous to hearing.

Duration of riding time impacts how much noise exposure snowmobilers accumulate. Bess and Poynor (1974) reported snowmobile noise levels loud enough to cause temporary hearing damage after only 120 minutes of riding. The amount of time a snowmobiler can ride before hearing damage may occur depends on the noise standards being referenced. Because of the political motivation and damage risk compromises behind the OSHA PEL criterion, noise exposures are under estimated and the number of

individuals at risk for NIHL is greater than when using the NIOSH REL criterion. For the OSHA PEL, the risk of developing occupational noise induced hearing loss is 25%, whereas the risk of NIHL using NIOSH REL is reduced to 8% (NIOSH, 1998). When referencing the average TWAs of 86.17$\pm$3.1 (OSHA PEL) and 91.17$\pm$2.3 (NIOSH REL) in this study, participants are at a higher risk when noise sampled with reference to the NIOSH REL. Riders in this study rode for an average of 5 hours. Rider breaks were less than 1 hour and were not sufficient to reduce the overall noise exposures for the day. Snowmobilers who wear a helmet can ride no more than two hours according to the National Institute for Occupational Safety and Health sampling protocol and sixteen hours per day according to the OSHA sampling protocol, assuming no other hazardous noise exposure on the day of riding. In order to decrease the risk of NIHL, riders should not ride any longer than two hours without proper hearing protection, even if a helmet is worn.

Implications for Other Motorsport Riders

The current research study has supported what previous research from 40 years agoreported in terms of hazardous noise exposures for recreational snowmobilers (Bess & Poynor, 1974). The findings for the current study have implications for other motorsports riders besides recreational snowmobilers. All-terrain vehicles such as four wheelers, dirt bikes, and dune buggies travel at speeds comparable to snowmobiles in different terrain, but on dirt rather than snow. Since there is limited research on noise exposures of other motorized vehicles, research from snowmobilers and motorcyclists can be generally related to other motorsport riders that may be at risk of NIHL until such time that specific data becomes available. Individuals who ride recreational motorsport

vehicles may be at risk for NIHL if the noise levels are comparable to snowmobiles, regardless of helmet use or not. Occupational workers such as forest rangers, ski patrol, or rescue teams that utilize snowmobiles or comparable motorized vehicles for extended periods of time each day are likely to be exposed to hazardous noise levels if not wearing hearing protection. More studies need to be performed in order to provide the information needed to support whether other motorsport riders are at risk for NIHL and what steps can be taken to prevent NIHL.

Health Belief Model: Implications for Hearing Health Promotion for Snowmobilers

The HBM provides a context for understanding the knowledge, attitudes, and beliefs of snowmobilers related to the risk of noise induced hearing loss. Many areas of health communication need to be improved for recreational snowmobilers in order to ultimately prevent NIHL in this population.

Attitudes and Behaviors

The use of HPD’s have been endorsed and encouraged due to exposure to hazardous noise levels. Previous research by McCombe and Binnington (1994) reported that only nine out of 44 grand prix motorcycle racers wore hearing protection, even though they were required to wear hearing protection in order to race. There were no snowmobilers in the current study that reported that they wore HPDs during snowmobiling. This may be attributed to the fact that half of the participants believed that their helmets would provide protection to their hearing. There is also a need for snowmobilers to understand that although their helmets may dampen the noise slightly, snowmobiles are still loud enough to cause NIHL while wearing a helmet.

A barrier to HPD use in the motorsport population may relate to communication challenges. The snowmobilers in this study reported that they believed they would have decreased communication if they used HPDs. Snowmobilers need to be provided with hearing protection that will still allow for communication and provide a comfortable fit under the helmet. Since communication is vital in terms of safety and enjoyment while snowmobiling, the barrier of communication must be overcome before riders will likely protect themselves from the hazardous noise levels of snowmobiles. A comfortable commercial or custom earplug that dampens hazardous noise levels while allowing speech to be heard clearly is imperative.

Hearing Loss Prevention Plan for Snowmobilers

The results of this study indicate that all recreational snowmobilers should be enrolled in a HLPP. Riders that were not included in this study should be a part of a noise dosimetry sampling to determine what hazardous noise levels they are exposed to. All snowmobilers whether in this study or not should also have a noise sample to determine their noise exposure levels. Depending on how often the snowmobiler rides and how much noise exposure they have other than snowmobiling, appropriate steps can be taken to provide education, audiometric monitoring, and HPD selection, fitting and verification.

Audiometric monitoring should be performed in order to establish a baseline, monitor thresholds annually, and identify changes that may occur over time. In this population it is extremely important to establish baseline testing due to the fact that 80% of snowmobilers in this study reported that they have hearing loss. Baseline testing will give snowmobilers an accurate description of their current hearing levels. Through education, proper counseling and snowmobiling relevant information can be provided

about the risk to their hearing and the affects that may occur over time. Because all participants are exposed to hazardous noise levels, monitoring hearing annually is important to track any changes that may occur. Annual monitoring will also allow for snowmobilers to address any hearing concerns that are present, while allowing for annual education and HPD fit checks.

HPD selection for recreational snowmobilers must be customized due to the fact that communication must be maintained when choosing appropriate HPDs for snowmobilers. Custom earplugs with a radio connection are available for communication underneath an earplug while also providing hearing protection from hazardous noise levels. If this type of communication device were utilized, all riders would need to have the same in-the-ear device for communication. A reduction in hazardous noise levels while maintaining the passive communication needs of snowmobilers may be obtained by use of commercially available flat attenuation custom earplugs. These custom earplugs are small enough for use underneath a helmet and have different filter attenuation levels depending on the noise exposure of the snowmobiler.

Verification must be performed once the appropriate HPD is chosen to determine if the fit is correct for each individual. Performing verification will determine if a proper fit was established and if not, then the custom HPD can be remade. All individuals fit with hearing protection devices should have verification performed once a year in order to maintain proper HPD fit.

Educational Implications for Snowmobilers

Common knowledge in the participants of this study is weak, especially in terms of their ability to recognize hazardous noise levels. There is a need for more information

about the anatomy of the ear and what noise levels are actually hazardous. Educational resources should be developed and distributed through websites, club meetings, shops or mailers that snowmobilers will have access to on a regular basis. This would allow for not only participants of this study to be reached, but for their families and friends who may participate in noise hazardous activities to be reached as well. Information can be provided about how our ears work and what physical damage can occur from hazardous noises. Resources can also be provided to guide them in the recognition of when a sound level is potentially hazardous to their hearing. Since all of the participants knew either a friend or family member with hearing loss, helping snowmobilers understand that hearing loss is irreversible and avoidable is important. There is misunderstanding that NIHL can be medically treated and by educating this population, the proper information can be provided.

During annual audiometric monitoring, a short educational workshop can be held in order to address hazardous noise levels measured in snowmobilers Information about what noises are hazardous, how to protect themselves, and the importance of hearing and the gradual progression of NIHL. Roughly half of participants need to implement behavior change, particularly related to the use of hearing protection when in noise hazardous situations. As professionals, providing snowmobilers with educational materials, audiometric monitoring, and HPDs that allow for communication will provide snowmobilers with materials to make choices about their own hearing health. By providing snowmobilers will all the information to make informed decisions; they will have education on the implications that can occur if they do not make appropriate choices to protect their hearing health.

Strengths and Limitations of the Study

Limitations

The ability to collect noise dosimetry data was impacted by the weather during the winter season. Noise dosimetry data was collected on fewer snowmobilers than planned due to a shorter winter riding season and the lack of snow. A larger sample size with equal enrollment of engine types, helmet styles, and genders would have provided more representation results across the general population of snowmobilers. Due to a smaller sample size, it was impossible to determine which rider characteristics lead specifically to the increased noise levels and which did not.

This study also was focused on a field-data collection when riding in mountainous terrain. The findings of this study may not be directly transferable to riding in more open/flat terrain environments. Another limitation of the study related to the QuietDose™ noise dosimeter instrumentation used in this study, did not allow for measurement of right and left ear noise dose independently. Since noise dose could not be calculated independently for each ear, information about the risk for right versus left ears was not possible. The snowmobile exhaust is located on the side of two-stroke snow machines, therefore having individual noise levels from each ear may have provided additional information about the relative risk of NIHL between ears.

Strengths

The study collected data in the field using subjects who routinely ride snowmobiles for recreational enjoyment. The ability to recruit subjects and collect data in a familiar rural area allowed for a more personal approach to be taken. All participants were either personal acquaintances or family members of the researcher. Data was easily

collected, subjects were cooperative and all study-related information was completed, allowing for no missing information. Although the subjects were from a convenience sample, this researcher does not feel the population would differ from others who engage in recreational snowmobiling in the Colorado mountains. Data collection was also felt to be successful because the size of the QuietDose™ instrumentation was small making under the helmet noise dosimetry possible while maintaining participant comfort.

Future Research Directions

Further studies about noise levels in racing, occupational, and recreational snowmobilers are needed. This study provided information on the high noise levels adult recreational mountain snowmobilers are exposed to when wearing a helmet. A study focusing on youth under 18 years of age that snowmobile will allow for comparisons with adult noise exposure data. By determining noise exposure levels of youth, we would be able to address hearing loss prevention toward this population specifically. Audiometric data should be collected on all individuals who snowmobile whether recreationally or occupationally. By tracking hearing levels over time, the effectiveness of HLPPs in this population can be obtained. Collecting ear specific noise dosimetry may also provide information about different levels of noise exposure related to snowmobile design. Collecting noise dosimetry data on a variety of snowmobilers will also help to better understand the auditory risks associated with recreational snowmobiling.

Summary

ISMA (2009) reported that there were over 1,500,000 registered snowmobiles in the US in 2011. Many people go snowmobiling in the US and around the world every year, whether for recreational or occupational purposes. Recreational snowmobilers are at

risk for developing NIHL due to the high noise levels they are exposed to while riding. Snowmobilers rode for an average of six hours per day, with an average under the helmet noise dose of 472% when measured according to the NIOSH (1998) sampling protocol and compared to the NIOSH RELs. Snowmobilers should be enrolled in a HLPP that includes measurements of snowmobiling noise exposures, audiometric monitoring, HPD selection, fitting and validation, and education. In terms of HPDs, snowmobilers need proper fitting of HPDs that can be worn underneath their helmets and afford communication. It is important to educate snowmobilers and other motorsport riders about hazardous noise levels and the risk of developing NIHL even while wearing a helmet. This research has supported that riders are exposed to hazardous noise levels when measured under the helmet.

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APPENDIX A

IRB APPROVAL

UNIVERSITY *of* NORTHERN COLORADO
Institutional Review Board (IRB)

September 26, 2011

TO: Carol Roehrs
Nursing

FROM: Megan Babkes Stellino, Co-Chair MS
UNC Institutional Review Board

RE: Expedited Review of Proposal, *Noise Exposures of Recreational Snowmobilers,* submitted by Kiera Moore (Research Advisor: Deanna Meinke)

First Consultant: The above proposal is being submitted to you for an expedited review. Please review the proposal in light of the Committee's charge and direct requests for changes directly to the researcher or researcher's advisor. If you have any unresolved concerns, please contact Megan Babkes Stellino, School of Sport and Exercise Science, Campus Box 39, (x1809). When you are ready to recommend approval, sign this form and return to me.

I recommend approval as ~~is~~ revised. Carol Roehrs 9-27-2011
Signature of First Consultant Date

The above referenced prospectus has been reviewed for compliance with HHS guidelines for ethical principles in human subjects research. The decision of the Institutional Review Board is that the project is approved as proposed for a period of one year: October 10, 2011 to October 10, 2012

Megan Babkes Stellino 10/10/11
Megan Babkes Stellino, Co-Chair Date

Comments:
email approval 10/10/11

APPENDIX B

SNOWMOBILER DATA FORM

Snowmobiler Data Form

Subject # ___________________________

Date mm/dd/yyyy ____________________

Pre questions

1. What is your age? ____________________

2. What is your gender?
   a. Male
   b. Female

3. What type of snowmobile do you ride?
   a. Ski doo
   b. Polaris
   c. Arctic Cat
   d. Yamaha
   e. Other ___________________________

4. What type of engine does your snowmobile have?
   a. 2-Stroke
   b. 4-Stoke
   c. Other ___________________________

5. What type of helmet do you wear?
   Make _____________________________ Model ____________________________________

6. Do you wear hearing protection while riding? Yes ______ No _______
   If yes, what type is used (ear plugs, ear muffs, ect)? _______________________________

7. How many people do you snowmobile with on average?
    a. Less than 2
    b. 3-5
    c. 6-9
    d. More than 10

8. How would you categorize your snowmobile riding skill level?
    a. Beginner
    b. Intermediate
    c. Advanced

9. How long is your average riding day (in hours)?
    a. Less than 3
    b. 4-5 hours
    c. 6-7 hours
    d. 8 hours or more

10. How many times a year, on average, do you snowmobile?
    a. Less than 5
    b. 5-9
    c. More than 10

11. Where do you regularly snowmobile?
    a. Woods and forests
    b. Open plains
    c. Both

12. Do you use a communication radio while snowmobiling? Yes _____ No _____
    a. If so what type?
        1. Under the helmet
        2. Outside of the helmet
        3. None

13. How often do you take your communication radio snowmobiling?
    a. Never
    b. Sometimes
    c. Always

14. How many years have you been snowmobiling?
    a. Less than 5
    b. 6-10
    c. More than 10

15. Are you exposed to workplace noise? Yes______ No ______
    If yes, what occupation? ____

16. Do you ever have to wear hearing protection (ear plugs, ear muffs, ect) at work?
    Yes ____ No _____ If Yes, what type? ____

APPENDIX C

SURVEY

Project Title: *Noise Exposures of Recreational Snowmobilers*

Subject # - ________________________Date mm/dd/yyyy _____________________

Participant Survey

In this survey we are interested in your knowledge, attitudes, and behaviors in regards to loud noises, hearing protection and noise induced hearing loss. There is no right or wrong answer; we are just interested in your opinion in these areas. All responses that you give will be kept completely confidential.

Please circle the one number for each statement that best describes your knowledge, attitude, and behaviors for each statement. **Please do not leave any of the statements blank.** The words "hearing protection" or "earplugs/earmuffs" DO NOT refer to helmets.

	Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree
1. Repeated exposure to loud sound can cause hearing loss over time	1	2	3	4	5
2. Being able to hear is very important to quality of life	1	2	3	4	5
3. There are some leisure activities that are loud enough to cause temporary hearing loss	1	2	3	4	5
4. I may be at risk of hearing loss from exposure to loud sound	1	2	3	4	5
5. I have learned about how the ear works in my schooling	1	2	3	4	5
6. I know when things are too loud	1	2	3	4	5
7. I should stop participating in a loud activity just because I do not have earplugs or earmuffs available	1	2	3	4	5
8. Exposure to loud sound is **not** a serious problem for me	1	2	3	4	5
9. Hair cells in the inner ear aid in transmission of sound	1	2	3	4	5
10. It is my responsibility to ensure that I understand the risks of hearing loss due to loud noise	1	2	3	4	5
11. Listening to loud music can contribute to hearing loss	1	2	3	4	5
12. I have learned about the risks of exposure to loud sounds on the internet	1	2	3	4	5
13. I know someone with a hearing loss due to loud sound exposure	1	2	3	4	5

	Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree
14. A hearing loss from exposure to loud sound would negatively affect my ability to understand conversational speech easily	1	2	3	4	5
15. There are some leisure activities that are loud enough to cause permanent hearing loss over time	1	2	3	4	5
16. I have worn earplugs/earmuffs when exposed to loud sound at least once	1	2	3	4	5
17. It is important to understand the potential to damage my hearing from loud sounds	1	2	3	4	5
18. Hearing damage from loud sounds when an individual is younger can contribute to worse hearing as an adult	1	2	3	4	5
19. Exposure to loud sound usually causes damage to an individual's ear drum	1	2	3	4	5
20. My hearing does **not** need to be protected from loud sounds	1	2	3	4	5
21. I participate in activities that could be hazardous to my hearing	1	2	3	4	5
22. I will be embarrassed if I wear earplugs or earmuffs when around loud sound	1	2	3	4	5
23. I am aware of the risk of hearing loss due to exposure to loud noise	1	2	3	4	5
24. I have worn ear plugs at least once when exposed to loud sound	1	2	3	4	5
25. I have a hearing loss	1	2	3	4	5
26. A hearing loss would make me feel isolated	1	2	3	4	5
27. I will not be able to communicate effectively while wearing earplugs/earmuffs	1	2	3	4	5
28. It is important to protect my hearing from loud sound	1	2	3	4	5
29. Moving away from loud sound is an effective way to prevent hearing loss caused by loud sound	1	2	3	4	5
30. Hearing protection is expensive	1	2	3	4	5

	Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree
31. It is important for me to wear hearing protection when exposed to loud noise.	1	2	3	4	5
32. I carry earplugs with me	1	2	3	4	5
33. Loud sounds can cause damage to hair cells in the ear	1	2	3	4	5
34 Ear plugs or earmuffs will make my ears sore	1	2	3	4	5
35. Using earplugs when exposed to loud sound is an effective way to reduce the risks of noise exposure	1	2	3	4	5
36. I wear earplugs regularly when exposed to loud sound	1	2	3	4	5
37. An abnormal hearing test for myself would encourage me the use of earplugs/earmuffs in loud noise	1	2	3	4	5
38. Free earplugs available at a public event implies the sound is potentially too loud	1	2	3	4	5
39. Ringing in my ear after exposure to loud sound is a warning sign that the sound is too loud	1	2	3	4	5
40. Earplugs and earmuffs are sized to fit properly	1	2	3	4	5
41. If speech sounding muffled after exposure to loud sound is a warning sign that the sound is too loud	1	2	3	4	5
42. I routinely wear earplugs/earmuffs when exposed to loud sounds	1	2	3	4	5
43. I understand how ears work	1	2	3	4	5
44. Using cotton in the ears when exposed to loud sounds, is an effective way to reduce the risks of noise exposure	1	2	3	4	5
45. I should move away from loud sounds	1	2	3	4	5
46. Hearing loss caused by loud sounds can be medically corrected.	1	2	3	4	5
47. Turning down the volume of the loud sound is an effective way to avoid hearing loss due to loud sounds	1	2	3	4	5
48. I wear earplugs/earmuffs during loud activities	1	2	3	4	5
49. I understand that loud sound can hurt my ears	1	2	3	4	5
50. My spouse has a hearing loss from exposure to loud sounds	1	2	3	4	5

	Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree
51. I know a friend with a hearing loss	1	2	3	4	5
52. Having to shout to be heard at arm's length means that the sound in the area is too loud	1	2	3	4	5
53. Hearing loss from loud sound would negatively affect my quality of life	1	2	3	4	5
54. Only workers who are around loud sound every day need to wear hearing protection	1	2	3	4	5
55. Exposure to loud sounds can cause damage to small bones in the middle ear	1	2	3	4	5
56. I encourage others to wear hearing protection when exposed to loud noise	1	2	3	4	5
57. Earplugs or earmuffs will **not** protect my hearing	1	2	3	4	5
58. Helmets worn during loud activities will protect my hearing	1	2	3	4	5

APPENDIX D

SUBSCALES

Subscales

Survey Questions per Construct Analysis

Common Knowledge

1. Repeated exposure to loud sound can cause hearing loss over time
3. There are some leisure activities that are loud enough to cause temporary hearing loss over time
19. Exposure to loud sound usually causes damage to an individual's ear drum
33. Loud sounds can cause damage to hair cells in the ear
47. Turning down the volume of the loud sound is an effective way to avoid hearing loss due to loud sounds
55. Exposure to loud sounds can cause damage to small bones in the middle ear

Self-Efficacy and Individual Responsibility

5. I have learned about how the ear works during my schooling
6. I know when things are too loud
23. I am aware of the risk of hearing loss due to exposure to loud noise
43. I understand how ears work

Hearing Loss

8. Exposure to loud sound is **not** a serious problem for me
13. I know someone with a hearing loss due to loud sound exposure
21. I participate in activities that could be hazardous to my hearing
25. I have a hearing loss
46. Hearing loss caused by loud sounds can be medically corrected.
50. My spouse has a hearing loss from exposure to loud sounds
51. I know a friend with a hearing loss

Benefit and Cues of Action

2. Being able to hear is very important to quality of life
12. I have learned about the risks of exposure to loud sounds on the internet
17. It is important to understand the potential to damage my hearing from loud sounds
28. It is important to protect my hearing from loud sound
31. It is important for me to wear hearing protection when exposed to loud noise.
35. Using earplugs when exposed to loud sound is an effective way to reduce the risks of noise exposure
37. An abnormal hearing test for myself would encourage me the use of earplugs/earmuffs in loud noise
38. Free earplugs at a public event implies the sound is potentially too loud
39. Ringing in my ear after exposure to loud sound is a warning sign that the sound is too loud
41. If speech sounding muffled after exposure to loud sound is a warning sign that the sound is too loud
45. I should move away from loud sounds
52. Having to shout to be heard at arm's length means that the sound in the area is too loud

Perceived Severity and Susceptibility

4. I may be at risk of hearing loss from exposure to loud sound
7. I should stop participating in a loud activity just because I do not have earplugs or earmuffs available
9. It is my responsibility to ensure that I understand the risks of hearing loss due to loud noise
10. Hair cells in the inner ear aid in transmission of sound
11. Listening to loud music can contribute to hearing loss
14. A hearing loss from exposure to loud sound would negatively affect my ability to understand conversational speech easily
15. There are some leisure activities that are loud enough to cause permanent hearing loss over time
18. Hearing damage from loud sounds when an individual is younger can contribute to worse hearing as an adult
20. My hearing does **not** need to be protected from loud sounds
26. A hearing loss would make me feel isolated
29. Moving away from loud sound is an effective way to prevent hearing loss caused by loud sound
49. I understand that loud sound can hurt my ears
53. Hearing loss from loud sound would negatively affect my quality of life
54. Only workers who are around loud sound every day need to wear hearing protection

Reported Behaviors

16. I have worn earplugs/earmuffs when exposed to loud sound
24. I have worn ear plugs at least once when exposed to loud sound
32. I carry earplugs with me
36. I wear earplugs regularly when exposed to loud sound
42. I routinely wear earplugs/earmuffs when exposed to loud sounds
48. I always wear earplugs/earmuffs during loud activities
56. I encourage others to wear hearing protection when exposed to loud noise

Barriers

22. I will be embarrassed if I wear earplugs or earmuffs when around loud sound
27. I will not be able to communicate effectively while wearing earplugs/earmuffs
30. Hearing protection is expensive
34. Ear plugs or earmuffs will make my ears sore
40. Earplugs and earmuffs are sized to fit properly
44. Using cotton in the ears when exposed to loud sounds, is an effective way to reduce the risks of noise exposure
57. Earplugs or earmuffs will **not** protect my hearing

OTHER

58. Helmets worn during loud activities will protect my hearing.

APPENDIX E

CUMMULATIVE RESPONSES TO QUESTIONAIRE

Project Title: *Noise Exposures of Recreational Snowmobilers*

Subject # - ________________________Date mm/dd/yyyy __________________**Participant Survey**

In this survey we are interested in your knowledge, attitudes, and behaviors in regards to loud noises, hearing protection and noise induced hearing loss. There is no right or wrong answer; we are just interested in your opinion in these areas. All responses that you give will be kept completely confidential.

Please circle the one number for each statement that best describes your knowledge, attitude, and behaviors for each statement. **Please do not leave any of the statements blank.** The words “hearing protection” or “earplugs/earmuffs” DO NOT refer to helmets.

	Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree
1. Repeated exposure to loud sound can cause hearing loss over time				*10%*	*90%*
2. Being able to hear is very important to quality of life					*100%*
3. There are some leisure activities that are loud enough to cause temporary hearing loss		10%		*10%*	*80%*
4. I may be at risk of hearing loss from exposure to loud sound			10%	30%	60%
5. I have learned about how the ear works in my schooling	10%	10%		*40%*	*40%*
6. I know when things are too loud	10%	10%	10%	*30%*	*40%*
7. I should stop participating in a loud activity just because I do not have earplugs or earmuffs available		10%	20%	*50%*	*20%*
8. Exposure to loud sound is **not** a serious problem for me	*30%*	*40%*		30%	
9. Hair cells in the inner ear aid in transmission of sound			40%	*40%*	*20%*
10. It is my responsibility to ensure that I understand the risks of hearing loss due to loud noise				*60%*	*40%*
11. Listening to loud music can contribute to hearing loss				*20%*	*80%*
12. I have learned about the risks of exposure to loud sounds on the internet	30%	40%	20%	*10%*	
13. I know someone with a hearing loss due to loud sound exposure			10%	40%	50%

	Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree
14. A hearing loss from exposure to loud sound would negatively affect my ability to understand conversational speech easily				40%	60%
15. There are some leisure activities that are loud enough to cause permanent hearing loss over time				30%	70%
16. I have worn earplugs/earmuffs when exposed to loud sound at least once				20%	80%
17. It is important to understand the potential to damage my hearing from loud sounds				30%	70%
18. Hearing damage from loud sounds when an individual is younger can contribute to worse hearing as an adult				30%	70%
19. Exposure to loud sound usually causes damage to an individual's ear drum		40%	50%	10%	
20. My hearing does **not** need to be protected from loud sounds	60%	40%			
21. I participate in activities that could be hazardous to my hearing				70%	30%
22. I will be embarrassed if I wear earplugs or earmuffs when around loud sound	70%	30%			
23. I am aware of the risk of hearing loss due to exposure to loud noise			10%	20%	70%
24. I have worn ear plugs at least once when exposed to loud sound				30%	70%
25. I have a hearing loss		20%		40%	40%
26. A hearing loss would make me feel isolated	10%		10%	60%	20%
27. I will not be able to communicate effectively while wearing earplugs/earmuffs		50%	20%	30%	
28. It is important to protect my hearing from loud sound				40%	60%
29. Moving away from loud sound is an effective way to prevent hearing loss caused by loud sound			10%	50%	40%
30. Hearing protection is expensive	50%	30%		10%	10%

	Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree
31. It is important for me to wear hearing protection when exposed to loud noise.				30%	70%
32. I carry earplugs with me	10%	20%	20%		50%
33. Loud sounds can cause damage to hair cells in the ear		10%	30%	30%	30%
34 Ear plugs or earmuffs will make my ears sore	20%	60%	10%	10%	
35. Using earplugs when exposed to loud sound is an effective way to reduce the risks of noise exposure				30%	70%
36. I wear earplugs regularly when exposed to loud sound		20%	30%	20%	30%
37. An abnormal hearing test for myself would encourage the use of earplugs/earmuffs in loud noise			10%	70%	20%
38. Free earplugs available at a public event implies the sound is potentially too loud				40%	60%
39. Ringing in my ear after exposure to loud sound is a warning sign that the sound is too loud				40%	60%
40. Earplugs and earmuffs are sized to fit properly			20%	80%	
41. If speech sounding muffled after exposure to loud sound is a warning sign that the sound is too loud			10%	60%	30%
42. I routinely wear earplugs/earmuffs when exposed to loud sounds		20%	10%	40%	30%
43. I understand how ears work		20%	20%	40%	20%
44. Using cotton in the ears when exposed to loud sounds, is an effective way to reduce the risks of noise exposure	10%	40%	30%	10%	10%
45. I should move away from loud sounds				40%	60%
46. Hearing loss caused by loud sounds can be medically corrected.	20%	40%	30%	10%	
47. Turning down the volume of the loud sound is an effective way to avoid hearing loss due to loud sounds				60%	40%
48. I wear earplugs/earmuffs during loud activities		10%	10%	60%	20%
49. I understand that loud sound can hurt my ears				20%	80%
50. My spouse has a hearing loss from exposure to loud sounds	20%	40%	20%	20%	

	Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree
51. I know a friend with a hearing loss				40%	60%
52. Having to shout to be heard at arm's length means that the sound in the area is too loud				*40%*	*60%*
53. Hearing loss from loud sound would negatively affect my quality of life				*50%*	*50%*
54. Only workers who are around loud sound every day need to wear hearing protection	50%	30%	10%	*10%*	
55. Exposure to loud sounds can cause damage to small bones in the middle ear		*20%*	60%	20%	
56. I encourage others to wear hearing protection when exposed to loud noise	10%	20%		*40%*	*30%*
57. Earplugs or earmuffs will **not** protect my hearing	*60%*	*30%*			10%
58. Helmets worn during loud activities will protect my hearing	*30%*	*20%*	30%	20%	

Note. Italicized items are the "correct" responses chosen based on which answers promoted hearing health.