THESIS

NOISE EXPOSURE AND EVALUATION AT TIRE CHANGING FACILITIES

Submitted by

Cory Willson-Kerns

Department of Environmental and Radiological Health Sciences

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Master's Committee:

Advisor: William Brazile

Karin Adams
Gwenith Fisher

ABSTRACT

NOISE EXPOSURE AND EVALUATION AT TIRE CHANGING FACILITIES

The purpose of this study was to (1) determine if workers in the tire changing industry are overexposed to hazardous noise that could result in occupational hearing loss; and (2) determine the maximum number of tire changes that could be performed without exceeding occupational exposure limits. Personal noise dosimetry data were compared to published occupational noise exposure limits to assess compliance. The noise dosimetry results were then extrapolated against the number of tire changes to determine if there was a relationship between the number of tire changes and employee noise exposures.

Thirty (30) full-shift noise-exposure samples were collected on tire technicians using Larson-Davis 703 audio dosimeters in three tire-changing facilities. The technicians recorded the number of tires changed during their shift. The eight-hour time weighted averages were recorded for each subject following the Occupational Safety and Health Adminsitration (OSHA) permissible exposure limit (PEL) and action level (AL); and the American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV). Each sample was evaluated against the number of tire changes performed in the shift. In addition, area noise samples of specific pieces of tire-changing equipment and processes were taken with a sound level meter.

It was determined from the 30-sample data set that only one of the 30 technicians was exposed at or above the OSHA noise action level of 85dBA (as an 8-hour TWA). Eighteen (18) of the 30 employees were exposed above the ACGIH noise TLV and no employees exceeded the OSHA

noise PEL. Based on the area noise samples, noise in the tire changing facilities appeared to be largely intermittent with peak noise levels exceeding 140dB.

The findings of this study are that tire technicians were not exposed above the OSHA PEL at least up to 40 tire changes per shift but may still be exposed to hazardous levels of noise. A 95% confidence interval for each of the three categories of noise analyses (i.e., PEL, AL, TLV) was calculated to determine the average noise exposure for each number of tire changes. In addition, a 95% prediction interval was calculated to determine the noise exposure level for an individual worker chosen randomly for a specific number of tire changes. Last, it was determined from the area noise sampling that the air ratchet, Cheetah, and tire-changing machine contributed the most to the overall noise exposure.

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CHAPTER 1: INTRODUCTION

Exposure to hazardous noise is one of the most common hazards found in workplaces around the world. In the United States (US), 22 million workers reported exposure to excessive noise in occupational settings and 34% of those workers reported not wearing hearing protection devices (Tak, Davis, & Calvert, 2009). Exposure to hazardous noise can lead to a number of negative outcomes including hearings loss (Alberti, 2006a), increase in incidents (Picard et al., 2008), and hypertension (Chen et al., 2017). These negative outcomes, in addition to regulatory requirements from the Occupational Safety and Health Administration (OSHA), require industry representatives to understand noise exposure sources in their workplaces and to control them as necessary.

The researchers of this study focused on noise exposure to workers in the tire changing industry, differentiating this study population from the more commonly studied automobile mechanics. Tire changers, or tire technicians, primarily work in smaller shops that have business models that rely on selling tires and the labor associated with changing out the tires. This industry employs roughly 114,000 employees in the US and has an injury/illness incident rate of 4.9 per 200,000 man-hours (Bureau of Labor Statistics, 2016).

The primary focus of this research was to determine if workers in the tire changing industry exceeded published noise exposure limits set by both the OSHA and the American Conference of Governmental Industrial Hygienists (ACGIH). In addition, the researchers aimed to determine if there was a correlation between the number of tires each worker changed during a shift and the associated noise exposure. To accomplish this, Larson Davis Spark® personal noise dosimeters were attached to 30 employees in three automobile shops in Northern Colorado. The sampled workers also tracked the number of tires they changed during their shifts and these data points were paired. One of the goals of this study was to determine the number of tire changes each employee could perform in a shift and not be exposed above the OSHA or ACGIH noise exposure limits.

The noise exposure assessment of workers in the tire changing industry provided a critical assessment to whether or not workers were exposed above OSHA and ACGIH noise exposure criteria. OSHA has two assessment methods, which include the Action Level (AL) and the Permissible Exposure Limit (PEL) for noise. The OSHA AL criteria include a criterion level (i.e., exposure limit) of 90dBA, threshold of 80dBA, and an exchange rate of 5dB. The threshold is the level at which a dosimeter starts recording noise during monitoring. Below the threshold, no noise is recorded and does not contribute to the exposure for that analysis. When an employee exceeds the action level of 85dBA as an 8-hour time-weighted average, it is required that he or she be enrolled in a hearing conservation program as defined by OSHA. The OSHA PEL criteria include a criterion level of 90dBA, threshold of 90dBA, and an exchange rate of 5dB. The OSHA PEL is the noise-exposure limit mandated by OSHA, which if exceeded, can render companies liable for monetary penalties from OSHA for not protecting their employees' hearing.

The ACGIH Threshold Limit Value (TLV) is not mandated by law, but is considered a best practice and is followed by many industries and industrial hygienists to better protect worker hearing. The ACGIH TLV criteria include a criterion level of 85dBA, threshold of 80dBA, and an exchange rate of 3dB. Compared to the OSHA AL and PEL, the TLV is a more protective standard in two ways. First, the ACGIH uses a criterion value of 85dBA making this the limit instead of 90dBA. Also, the exchange rate used for the TLV is 3dB instead of 5dB, meaning for every increase of 3dB the allowable exposure time is cut in half. For example, using this rule under ACGIH a worker is allowed to be exposed to 88dBA for four hours while OSHA allows the worker to be exposed to 95dBA for four hours. By definition, this would mean that exposures based on the TLV criteria of an 80dBA threshold, 85dBA criterion, and 3dB exchange rate will be much higher than those recorded by OSHA. Again, all three of these noise exposure limits are measured as 8-hour time weighted averages of the employee exposure throughout the entirety of their shifts.

CHAPTER 2: LITERATURE REVIEW

Human Ear Anatomy and Sound

The ear is the mechanism that allows humans and other species to turn physical vibrations in the environment into nerve impulses that our brain decodes as sounds. Humans use their ears for a number of things, from communicating to pleasure, which all depends on this organ functionality not being diminished. One ear can function on its own, but when working in tandem the ears are much more efficient and can localize from where a sound is propagating (Alberti, 2006a).

The human ear is comprised of three main sections: the outer ear, the middle ear, and the inner ear (see Figure 2.1). Each of these sections focus on transmitting sound waves from the environment to convert them to nerve impulses, much like a microphone. The main function of the outer ear is to transmit sound to the tympanic membrane, or ear drum, from the environment. The pinna is the section of the outer ear on the exterior of the skull that collects sound waves and directs them into the ear canal. Due to the angle of the pinna and the length of soundwaves, it is useful for localizing sounds at higher frequencies, but is less efficient at lower frequencies. The outer ear has several protective measures to prevent damage to the tympanic membrane such as thicker skin on the outermost areas, ear wax which serves as a disinfectant, and a slight bend in the ear canal to keep out foreign objects (Alberti, 2006a).

The middle ear is terminated on one end by the tympanic membrane and the oval window on the innermost side. This air-filled area of the ear is home to three tiny bones, or ossicles, known as the malleus, incus, and stapes. The ossicles of the middle ear convert soundwaves directed into the outer ear into physical vibrations transferred to the inner ear, or cochlea. The middle ear also includes a long, thin tube called the eustachian tube that connects the middle ear to the nasopharynx in the nose. This means that the middle ear is part of the respiratory space and nose and thus lined with the same respiratory membrane. Since the two spaces are connected and lined with the same type of membrane, the middle ear is susceptible to the same types of infections as the sinuses (Alberti, 2006a).

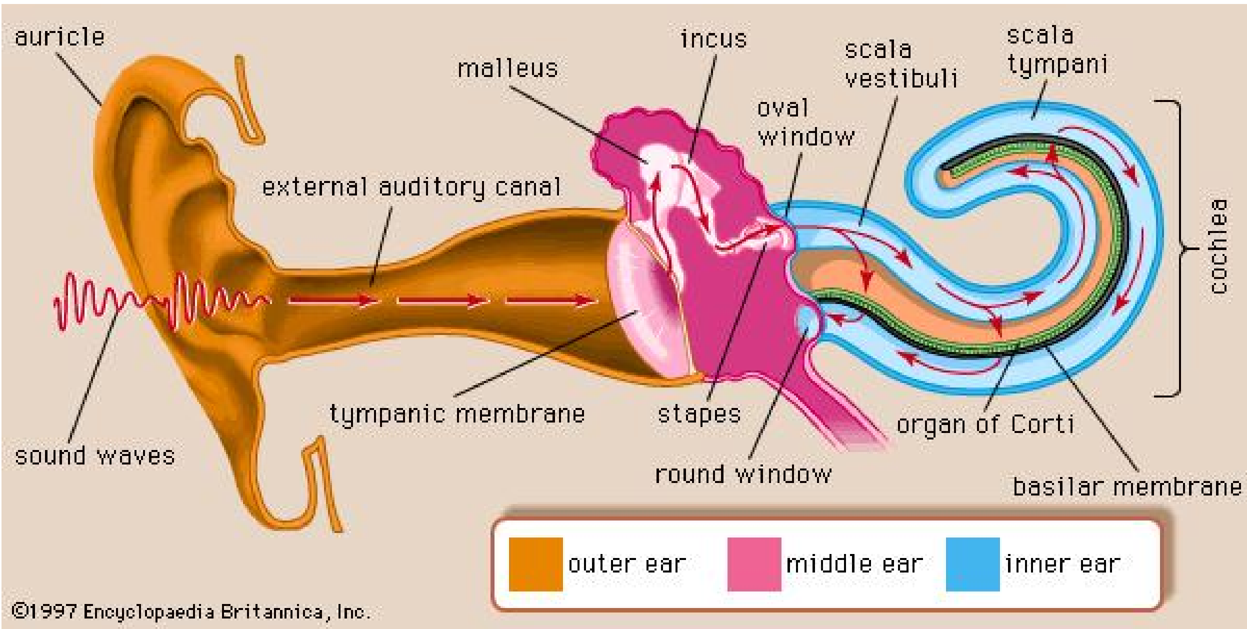

Figure 2.1 Anatomy of the Human Ear (Encyclopedia Britannica, 1997)

The inner ear consists primarily of the cochlea, which is a snail-shell shaped organ that contains the organ of hearing. The organ of hearing is called the membranous labyrinth, which contains a fluid known as the perilymph. The cochlea of the inner ear transduces vibration caused by movement of the footplate of the oval window into nerve impulses to the brain. These impulses are generated from approximately 30,000 hair cells, or stereocilia, contained in the cochlea and 19,000 nerve fibers to transmit the signal. These nerve fibers can send signals to the brain in just under 200 times per second, including changes in pitch and intensity. The inner ear is also the location where the majority of noise-induced hearing loss takes place. The stereocilia in the inner ear can become damaged due to prolonged exposure to noise in excess of 85dBA. This damage to the stereocilia is localized due to the fact that different areas of the cochlea only respond to specific frequencies. The frequency range that is permanently damaged first is the area that responds to 4kHz and also the areas associated with 3 and 6kHz (see Figure 2.2). Stereocilia are the most fragile in this region due to the fact that the ear canal amplifies sound in this range (Alberti, 2006b).

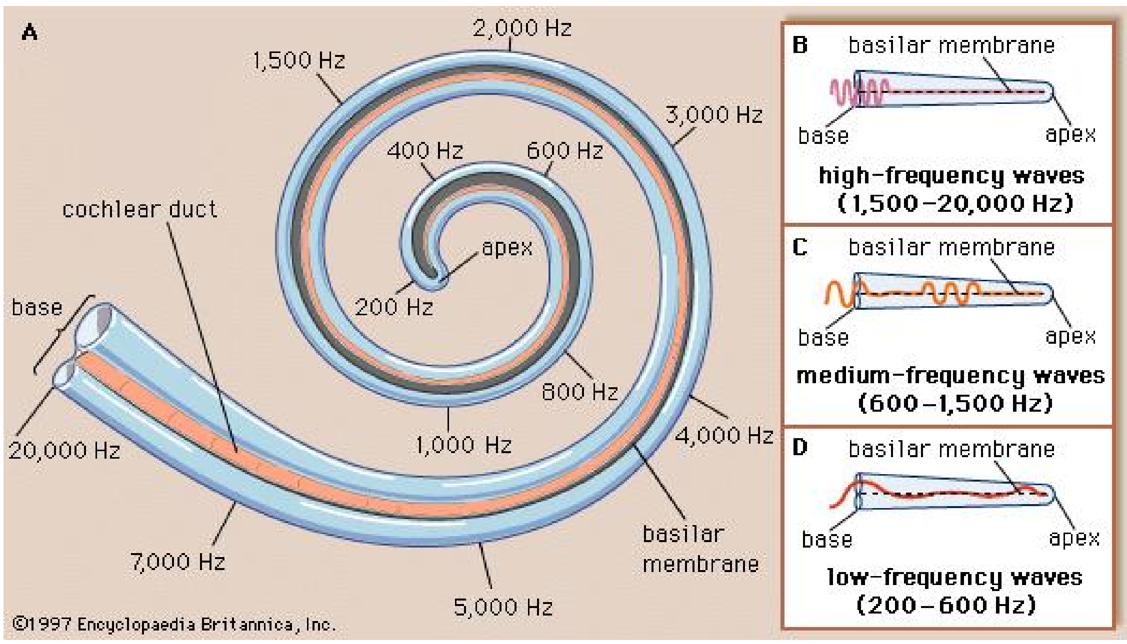

Figure 2.2 Anatomy of the Human Ear (Encyclopedia Britannica, 1997)

<u>Noise-Induced Hearing Loss (NIHL)</u>

Noise-induced hearing loss (NIHL) is a preventable condition caused by exposure to noise near or in excess of 85dBA. Hearing loss can manifest in many forms such as reversible, permanent, sudden, or chronically over time depending on the level of noise exposure. The Centers for Disease Control and Prevention (CDC) estimates that anywhere from 10 to 40 million adults, under 70 years old, in the US have symptoms of hearing loss from exposure to hazardous noise. Also, it is estimated that as many as 17 percent of teens aged 12 to 19 show signs of noise induced hearing loss ("Noise-Induced Hearing Loss," 2015).

The National Institute for Occupational Safety and Health (NIOSH) analyzed data collected from 1999 to 2004 in the National Health and Nutrition Examination Survey in order to determine the prevalence of noise exposure in the US. NIOSH researchers found that 22 million US workers self-reported exposure to hazardous noise in their workplaces and 34 percent of them reported not using hearing protection devices (Tak et al., 2009). This is especially concerning when considering that exposure to hazardous noise is associated with an increase in accidents in the workplace (Picard et al., 2008) as well as hypertension (Chen et al., 2017).

NIHL can be caused both by extremely loud sounds, prolonged exposure to noise near 85dBA, or by a combination of the two. Damage is caused when the stereocilia in the ear are exposed to excessive noise for an extended period of time or loud bursts of noise and causes what is known as a temporary threshold shift (TTS). A temporary threshold shift, for example, is what a person often experiences when leaving a concert and his or her hearing is muffled, due to the stereosilia becoming fatigued. The stereocilia experience metabolic stress after high noise exposures making hearing less acute, but is reversible with rest and recovery (Alberti, 2006b).

The concern with TTSs is that hearing loss can become permanent if TTSs occur frequently, day after day, such as in a factory setting. When the stereocilia are not given adequate rest and recovery time, a permanent threshold shift (PTS) can begin to manifest. A sensorineural PTS is identified on an audiogram as a notch between 3 and 6 kHz and usually maximal at 4 kHz, due to the amplification of noise that the ear canal provides at this frequency range. This damage is found in the outer hair cells of the basilar region of the cochlea. Once a PTS is present, continued exposure to hazardous noise can cause the hearing loss to extend to other adjacent frequencies and increase the intensity of TTSs (Alberti, 2006b).

Regulatory Requirements

Due to the fact that millions of workers across the country and world are exposed to noise that can be damaging to hearing, several governmental and non-governmental organizations have developed standards to help prevent noise-induced hearing loss. Three of the primary noise standard developers in the US are the ACGIH, NIOSH, and OSHA.

The ACGIH develops consensus standards for occupational safety and health as TLVs and biological exposure indices. These standards address workplace stressors such as chemical exposures, physical hazards, and biological determinants of exposure. While the TLVs are not enforceable by law, they are considered best practice in the scientific community and have been used in legal court proceedings. Many of the ACGIH TLVs were adopted by OSHA when the Occupational Safety and Health Act of 1970 (OSHAct) was passed. Currently, the TLV for noise recommends an exposure limit of 85dBA with a threshold of 80dBA and an exchange rate of 3-dB (Berger, Royster, Royster, Driscoll, & Layne, 2003). An exchange is the increase in sound pressure level at which the allowable exposure time is halved. For example, the allowable exposure time at 85dBA is eight hours whereas the allowable exposure time at 88dBA (an increase of three dB) is four hours. This TLV was established to "represent conditions under which it is believed that nearly all workers may be repeatedly exposed without adverse effect on their ability to hear and understand normal speech" (*TLVs and BEIs: Threshold limit values for chemical substances and physical agents biological exposure indices*, 2014).

NIOSH was created with OSHA by the OSHAct of 1970 but is housed in the Department of Health and Human Services instead of the Department of Labor where OSHA is located. NIOSH was created in order to conduct research and develop criteria to recommend to OSHA or other regulatory agencies for standard development. NIOSH does not have the authority to create laws, but its recommendations may be adopted by regulatory agencies and enacted into law. The Recommended Exposure Limit (REL) established by NIOSH is similar to the ACGIH TLV in that the exposure limit is 85dBA with a threshold at 80dBA and a 3-dB exchange rate. NIOSH, unlike OSHA, does not have an action level in its recommendation, but instead has a single REL where action needs to be taken to reduce employee noise exposure (Berger et al., 2003).

OSHA is the only one of the mentioned three organizations that has the authority to promulgate legal standards that are enforceable and punishable when not followed. OSHA has the most lenient noise standard with a PEL of 90dBA, a threshold of 90dBA, and a 5-db exchange rate. The OSHA standard also includes an action level, which if exceeded, requires employee enrollment into a hearing conservation program. This action level has a criterion of 90dBA with a threshold of 80dBA and a 5-dB exchange rate. However, if an employee's AL noise measurement exposure is at 85dBA, or a 50% dose, the employee must be enrolled in a hearing conservation program. Hearing conservation programs, as required by OSHA, include requirements for noise measurement, baseline and annual audiograms, use of hearing protection devices (HPDs), employee training, as well as recordkeeping (Berger et al., 2003). Due to the costs associated with implementing a hearing conservation program, it is in an employer's best interest to stay below the action level as defined by OSHA.

Table 2.1 is a comparison between the level of noise required for an employee using the NIOSH REL, ACGIH TLV, and the OSHA PEL to reach a 100% noise dose. A noise dose is reflective of how close an employee's noise exposure is to meeting an exposure limit. For example, if an employee is at a 100% noise dose then he or she are at their daily noise limit, for that analysis, and any exposure above the threshold will exceed the standard. This table helps demonstrate the difference in worker protection by using the NIOSH REL or ACGIH TLV as compared to the OSHA PEL. An example would be if an employee was in a room where the noise exposure was 100dBA, he or she would be overexposed after 15 minutes according to the TLV, but wouldn't be overexposed until after two hours according to the PEL.

Table 2.1 ("CDC - Noise and Hearing Loss Prevention - Reducing Noise Exposure, Guidance and Regulations - NIOSH Workplace Safety and Health Topic," 2018)

Time to Reach 100% Noise Dose	**Exposure level per NIOSH (REL) & ACGIH (TLV)**	**Exposure level per OSHA PEL**
8 Hours	85 dBA	90 dBA
4 Hours	88 dBA	95 dBA
2 Hours	91 dBA	100 dBA
1 Hour	94 dBA	105 dBA
30 Minutes	97 dBA	110 dBA
15 Minutes	100 dBA	115 dBA

Industry Background

The tire changing industry in the US consists primarily of small shops that are either corporately owned and franchised or privately owned and operated. The Bureau of Labor Statistics (BLS) has estimated that the industry employs approximately 114,690 people as of May 2017 with a mean hourly wage of $13.71. This industry is classified by the BLS occupation code 49-3093 'Tire Repairers and Changers' (Bureau of Labor Statistics, 2017). Injuries and illnesses are somewhat prevalent in the industry with an incidence rate of 4.9 with approximately 8,900 recordable injuries in 2016. A majority of these incidents occur due to overexertions, contact with objects, and falls on the same level. Injury and illness rates are categorized by the North American Industry Classification System (NAICS) and given a code. Tire changers are found under NAICS code 44132, 'Tire Dealers' (Bureau of Labor Statistics, 2016).

Relevant Studies

The researchers of this study found that there is a paucity of research focused strictly on dedicated tire technicians, but several studies were found that examined industry hazards for automobile mechanics as a study population. Mechanics are likely to have more variety in their daily tasks than a tire technician which may lead to more variability in their noise exposure. However, noise exposure to mechanics is assumed to be analogous to tire technicians as they perform similar duties on a day-to-day basis and use the same tools.

Health Hazards of Automotive Repair Mechanics: Thermal and Lighting Comfort, Particulate Matter and Noise

Researchers at Democritus University of Thrace, Xanthi, Greece conducted an environmental quality survey at a small private automotive repair shop in the summer of 2009 and winter of 2010. The researchers addressed several areas of investigation including two related to noise, which were to determine the ambient levels of noise in the shop and also to locate the sources of the noise. During this study, the sampling durations varied in order to capture the variability of the noise in the shop over a course of six days. No personal measurements were taken at the owner's request, but area samples were recorded as close as possible to the hearing zone of the employees to estimate personal noise exposure (Loupa, 2013).

Loupa (2013) estimated that the six employees in the automotive shop were exposed to a full-shift noise level of 69.3 dBA ± 3.4 dBA. This average, as well as all personal estimates, were all below the European exposure limit (87 dBA) as well as the noise action level (80 dBA). The researchers expected that if they had used personal audio dosimetry then the levels of noise would have been higher (Loupa, 2013). Task-specific and tool noise measurements recorded by the researchers are summarized in Table 2.2. The compressed air wrench, which is a tool of interest in tire changing facilities, was found to have an average sound pressure level of 83.1 dB with the 95th percentile above 89dB (Loupa, 2013).

Table 2.2 Noise Statistics in the Garage Due to Tools or Other Activities During the Hot Season (Loupa, 2013)

Source	Average (dB)	5th% (dB)	95th% (dB)	SD (dB)
Tools				
compressed air blow gun	78.3	72.0	81.0	2.7
hammer (manual)	90.7	75.0	94.0	10.0
compressed air wrench	83.1	74.3	89.3	5.2
compressed air drill	67.5	67.0	68.0	0.7
grinder	70.9	68.0	75.0	2.9
Activities				
closing the car hood	81.4	67.0	86.0	6.7
hitting a tool plate	71.1	60.1	77.6	5.5
revving up an engine (modified car)	83.3	71.1	88.1	5.5
horn noise	76.7	63.6	81.1	6.6
falling of a tool	69.8	57.0	78.0	7.1
people's talk	71.0	61.0	80.0	5.3
turn on a car's engine	76.6	63.5	83.6	7.5
closing a car's door	83.5	69.6	87.1	4.6

Exposure Assessment in Auto Collision Repair Shops

Researchers from the Park Nicollet Institute and the University of Minnesota School of Public Health, both of Minneapolis, Minnesota, conducted a study to evaluate chemical and physical hazards in auto collision shops. In this study, four representative auto collision repair shops were sampled, each with three to seven employees, for three consecutive days. The researchers investigated exposures to dust, solvents, and noise in shops. In regard to noise, full-shift noise dosimetry and tool-specific measurements were conducted (Bejan, Brosseau, & Parker, 2011)

Bejan, Brosseau, and Parker (2011) collected 17 personal noise samples on auto-body technicians from the four collision shops. The NoisePro DLX dosimeters used in the study were set to record three sampling criteria: (1) the OSHA PEL; (2) the OSHA action level; and (3) the ACGIH TLV. The researchers found that none of the employees' exposures exceeded the

OSHA PEL, but four of 17 subjects exceeded the ACGIH TLV of 85 dBA. In addition, the ACGIH noise doses were as much as 10 times higher than the measured OSHA noise doses (Bejan et al., 2011). Summary statistics of the personal noise dosimetry results are found in Table 2.3 below.

Table 2.3 Personal Noise Sampling Results Summary (Bejan et al., 2011)

Dosimeter Settings	N	Min (% dose)	Max (% dose)	MVUE[A] (% dose)	GM (% dose)	GSD	95th Percentile (% dose)	UTL(95th%, 95%)[B] (% dose)
OSHA PEL[C]	17	1.9	21.3	8	6.66	1.85	18.31	30.71
ACGIH	17	16.1	256.7	79.89	62.9	2.05	205.26	375.76

[A]MVUE = minimum variance unbiased estimate of the arithmetic mean of a lognormal distribution.
[B]UTL (95th%, 95%) = the upper confidence limit for the distribution of the 95th percentile.
[C]Minnesota OSHA PEL is identical to the federal OSHA PEL.

When measuring tool-specific noise levels, Bejan, Brosseau, and Parker (2011) found substantial variation between tools depending on their brand, maintenance, type of attachment, and other variables. Statistical analysis performed on the data confirmed a 99% certainty that less than 5% of the noise generated from the air gun, wrench, and cutoff wheels were below 90 dBA (Bejan et al., 2011). Many of these tools are routinely used in tire changing facilities.

Health Hazards in a Small Automotive Body Repair Shop

Researchers, Jayjock and Levin, at the Environmental Studies Institute of Drexel University in 1984 evaluated the health hazards to which workers in small, neighborhood automotive body repair shops were exposed. The researchers monitored a single owner-operated automotive body repair shop for a one-year period and found high exposures to hazardous chemicals as well as sporadically high noise (Jayjock, 1984).

In the Jayjock and Levin study (1984), the researchers conducted a 10-day noise dosimetry study of the two-person run shop. The researchers found noise doses up to 160% of based on the

OSHA PEL. In addition to the personal noise dosimetry noise measurements, the researchers measured the noise levels of the various tools that were used in the shop. The loudest tools used in the shop were pneumatic with exposures up to 115dBA (Jayjock, 1984).

Health Hazard Evaluation Report 95-0406-2609 Matrix Auto Body

The NIOSH, as a part of its health hazard evaluation program, conducted a study at Matrix Auto Body in Englewood, Colorado in 1995. The primary stressor of concern in the study was isocyanate exposure, but noise data were also collected. Personal noise exposures were recorded with a noise logging dosimeter to collect samples based on OSHA, ACGIH, and NIOSH criteria. The researchers only recorded a measurement for one employee in the shop and found that he or she had an average noise level of 94.4dBA using OSHA criteria. This average noise level resulted in a 185% dose of the OSHA PEL and also exceeded NIOSH and ACGIH criteria. NIOSH recommended that more noise measurements be taken and a hearing conservation program be implemented if results were found to be above 85dBA (McCammon & Sorensn, 1996).

CHAPTER 3: PURPOSE AND SCOPE

Purpose

The purpose of this study was to determine: (1) if workers in the tire changing industry were exposed to levels of hazardous noise as defined by OSHA and the ACGIH; and (2) if there is a relationship between the number of tires changed in a shift to the associated noise exposure level. Noise dosimeters were attached to 30 employees in three corporate tire shops for their entire shifts with an average recording time of 6:43. Measurements taken from these dosimeters were compared to the OSHA AL, the OSHA PEL, and the ACGIH TLV noise exposure criteria. Many employees in this industry are not educated about noise exposure and NIHL and are often provided access to only one type of foam earplugs in the shop area. The results of this research could potentially be used to create an administrative control to set a limit on the number of tires a worker can change in a shift to protect hearing and stay below published occupational noise exposure limits.

Hypothesis and Research Questions

The null hypothesis for this research was that workers in the tire changing industry are not exposed to levels of noise that are in excess of published occupational limits. It was hypothesized that workers in this industry would be exposed above the OSHA AL as well as the ACGIH TLV, but not above the PEL. Also, it was hypothesized that there is a direct correlation between the number of tires changed in a shift and the associated noise level.

The evaluation of personal noise dosimetry measurements was used to answer the following:

1. Are workers in the tire changing industry exposed to levels of noise that exceed the OSHA AL, OSHA PEL, and ACGIH TLV during their shifts?

2. What is the maximum number of tire changes that could be performed in a shift without exceeding occupational exposure limits?

Scope

This study was conducted during calendar year 2018, soliciting a total of 30 workers from three tire repair facilities in Northern Colorado. These shops employed two primary types of employees: automobile mechanics and tire technicians. Mechanics were specifically excluded from this study to narrow the study scope to tire technicians, as their work is more narrowly defined and has less variation in tasks. The study population was not limited to gender or race; however, all participants were above the age of 18.

CHAPTER 4: METHODS AND MATERIALS

Site Selection

The researchers from Colorado State University cooperated with the franchisee of several tire shops in Northern Colorado to perform this study. The three shops that were selected all employed similar equipment, but the shops varied in size. One shop had four working bays, the second had six working bays, and the third had seven working bays. Each of these shops had dedicated tire technicians as well as mechanics who varied on any given day. Permission was obtained by the owner of all three shops to collect all noise measurements and workers were given the opportunity to opt out of this voluntary study. All sampling performed at these shops occurred between November 2017 and July 2018.

Description of Tire Shops

Shop One

The first tire shop was located along a major city roadway. The shop consisted of six bays where work was performed and were arranged in a three-by-two pattern. This shop was similar to the size of Shop Two and both had cramped work areas. Generally, two bays on one side were used specifically for tire work including changing tires, rotations, and balancing. The other four bays on the other side of the shop were used by mechanics performing less routine work. On a normal day there were approximately six employees working on the shop floor.

Shop Two

The second shop, located off of a main road and in a shopping plaza, had a similar layout to Shop One. This shop consisted of four working bays that were arranged in a two-by-two pattern with one side being used for tire work and the other used by mechanics. This shop was the smallest of the three that were sampled and had a relatively small, cramped work area. During a normal shift, approximately six employees were working on the shop floor.

Shop Three

Shop Three was the largest and newest facility of the three shops that were sampled. The location for this facility was near a mildly trafficked road, but the bays faced away from it. There were seven working bays at this shop, but they were arranged in a row instead of a grid like the other two study sites. There was not as much consistency as to which bays were used by the mechanics or tire technicians at this shop, but rather work was performed in the bays that were available. Shop Three appeared to be the least busy of the three locations sampled and also offered the most room for employees to perform their duties. This location also had newer technology such as car lifts that were embedded in the concrete as opposed to bolted to the ground slab. The tools that the mechanics used in this shop were similar to those in the two other locations. On a normal day, there were approximately six employees working on the shop floor.

Tire Technician Recruitment

Employees who were asked to volunteer for this study were required to be 18 years of age, worked as a tire technician, and worked a shift of at least four hours. Mechanics were specifically excluded from this study if they did not consistently perform the tasks of a tire technician on a given day. Once selected, employee volunteers were read a script and asked to sign a consent form. All applicable phases of this study were conducted in compliance with a human subjects study protocol approved by the Institutional Review Board of Colorado State University.

Personal Noise Monitoring

Personal noise measurements were taken using the Larson Davis Spark® Models 706 and 703+ (Provo, UT) to determine each tire technician's noise exposure during a normal shift. Each dosimeter was pre- and post-calibrated to ensure the integrity of any measurements that were taken during the shift. The dosimeters were set to record three different criteria for analysis, which included the ACGIH threshold limit value, OSHA action level, and OSHA permissible exposure limit, all of which are described in Table 4.1. Noise sampling followed the parameters set by OSHA in the OSHA Technical Manual, TEDI-0.15A, Section III Chapter 5 and used the A-weighting scale.

Table 4.1 Audio Dosimeter Measurement Criteria.

Criterion	ACGIH TLV	OSHA AL	OSHA PEL
Weighting	A	A	A
Response	SLOW	SLOW	SLOW
Exchange Rate	3	5	5
Threshold	80	80	90
Criterion Level	85	90	90

At the beginning of their shift, each tire technician was equipped with a Larson Davis Model 703+ dosimeter with the microphone clipped to their uniform as close to the hearing zone as possible. Each dosimeter was controlled by the use of a singular Model 706 primary dosimeter that was used to ensure that each secondary dosimeter was on before the employees started working. During the setup, each group of technicians was instructed to continue their work as they would on any other day, but not to play with the microphone, cover it up, or yell directly into it. A log was kept during each sampling period of the employee name, date, dosimeter serial number, calibration information, and when the device was turned on and off. An example of this log is found in Appendix A.

At the beginning of their shift, each group of technicians was given a sheet of paper to record and tally every time they performed a tire change during the sampling period. The researcher explained to each technician individually, and in a group, the criteria that defined a tire change to help assure consistency. A tire change was defined as each time a tire was removed from the hub and then reattached, regardless of any work that was to be performed on it. This means that rotating four tires was the equivalent of putting four new tires on a vehicle. The importance of this was to isolate how many times each employee used an air wrench to loosen/tighten lug nuts. The air wrench was initially recognized, before the beginning of the study, to be one of the substantial contributors of noise exposure in each of the tire shops.

At the end of the shifts, the dosimeters were removed from the employees, shut off, and any relevant information was collected on the log. Dosimeters were then promptly post-calibrated to determine if the data collected were valid. A record of the sampling data was downloaded from each dosimeter using the Larson Davis Blaze® software and data points of interest were recorded on a Microsoft Excel spreadsheet.

Area Noise Sampling

Area noise samples were collected in a few equipment or process-specific locations in Shop Two and Shop Three to determine how loud specific pieces of equipment or processes were. A Larson Davis 831 hand-held sound-level meter / octave band analyzer was used to collect each of the samples ranging from five seconds up to 20 seconds in sampling time. Some of the samples that were collected included an air wrench under load (as used normally with a lug nut), air wrench not under load, a tire changing machine, filling a tire with compressed air, and using the Cheetah Tire Bead Seater. The Cheetah is a compressed air tank that is rarely used, which releases almost all of its pressure in an instant to seat a stubborn tire onto a rim. Generally, a tire machine is used to accomplish this process, but some tires are more difficult than others and the Cheetah is a tool used as a last-ditch effort to seat the bead on a tire.

Statistical Analysis

The data collected from the Larson Davis Blaze® software was first analyzed in Microsoft Excel to examine descriptive statistics such as how many employees were overexposed to the different occupational exposure limits. This Excel spreadsheet was then loaded into the open source R Studio software for additional analysis. R Studio was used to plot a graph for each noise exposure analysis (AL, PEL, and TLV) against the number of tire changes to determine a line of best fit. A 95% confidence interval was created using R Studio software to determine the average sound pressure level for every tire change from one to forty in a shift. Also, a 95% prediction interval was created using the same software to determine the range of noise exposure (dBA) values a single, random employee could encounter during his or her shift for each tire change, between one and forty.

CHAPTER 5: RESULTS

Personal Dosimetry

Throughout this study, a total of 30 personal noise dosimetry measurements were collected at three tire-changing shops in Northern Colorado. While employees were measured for the entirety of their shifts, tire technicians were often sent home early if the shop was not busy enough that day. Variability in the shift lengths lead to an average measurement time of six hours and forty-two minutes with any recordings less than four hours not included in the study. The scope of this study did not include the examination of the differences in noise exposures between the shops, and while there were differences in layout, all the shops were owned by the same company and used the same equipment.

When analyzing the 30 samples, it was found that one employee was exposed at the OSHA AL, no employees were exposed at or above the OSHA PEL, and 18 were exposed above the ACGIH TLV. Each of these analyses will be discussed in the following sections.

OSHA Action Level (AL)

The OSHA action level of 85dBA, when surpassed, prompts the employer to develop a hearing conservation program for any employee overexposed. Of the 30 measurements taken in this study, only one employee was at or above this level as an 8-hour TWA. This employee also changed the most tires of any employees at 37 changes in a shift. The distribution of measurements using OSHA AL criteria are summarized in Figure 5.1. The dotted, vertical line represents the action level exposure limit of 85dBA.

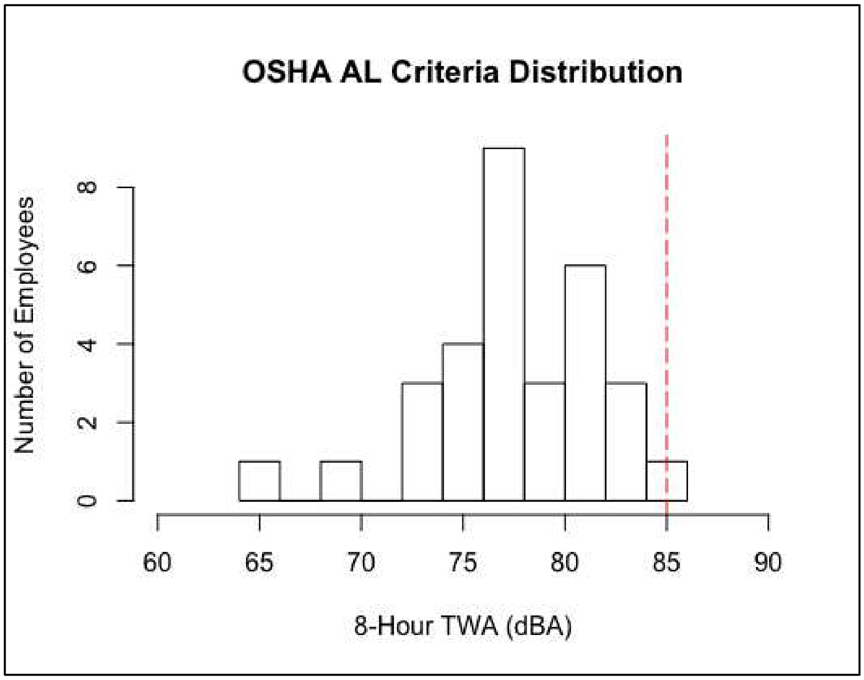

Figure 5.1 OSHA AL Criteria Distribution (n = 30)

In reference to the OSHA AL measurements, 27 of the 30 workers sampled were exposed to levels of noise between 75 and 82dBA throughout their shifts. A polynomial regression (R^2=0.81) was performed that compared the action level measurements to the number of tires changed during the shift, which is displayed in Figure 5.2. The 95% confidence interval for the average expected TWA at each number of tire changes is represented by the green, narrow dotted line. The 95% prediction interval that could be expected when randomly sampling one worker is represented by the orange, wider dotted line. The prediction interval is useful because it can help determine the maximum number of tire changes that can be performed without an employee exceeding the OSHA action level. For this data set, the upper limit on the prediction interval for 23 tire changes would be 84.9dBA, which is just below the action level. If one is more interested in the average noise exposure, the confidence interval can be used to ensure that the average exposure is lower than the action level, which would be 31 tire changes with an upper limit of 84.7dBA.

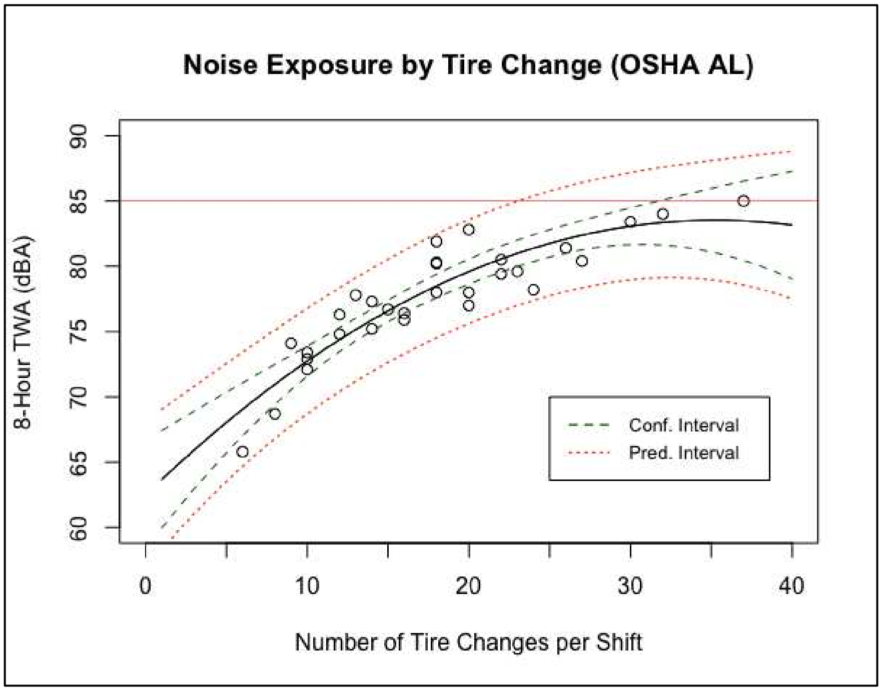

Figure 5.2 Noise Exposure by Tire Change (OSHA AL Criteria)

Table 5.1 below is a list of intervals of tire changes with the associated upper and lower limits for both the confidence and prediction intervals. These data can be used to estimate noise exposures based on how many tires a technician changes during a shift. For example, in examining Table 5.1, one can predict with 95% confidence that a randomly chosen worker changing 25 tires could be exposed to noise ranging from 77.7 to 85.8dBA. While this range can reasonably be expected when randomly selecting one employee to sample, the average exposure if all the employees were sampled would be between 80.7 and 82.8dBA. These average ranges are important to consider when simply examining the average noise exposure that was found in this study of 81.8dBA for 25 tire changes.

Table 5.1 OSHA AL Confidence and Prediction Limits

OSHA AL Confidence and Prediction Limits					
Tire Changes	Average	Lower Confidence	Upper Confidence	Lower Prediction	Upper Prediction
			TWA (8) dBA		
20	79.6	78.6	80.6	79.6	83.6
25	81.8	80.7	82.8	77.7	85.8
30	83.1	81.7	84.5	79.0	87.1
35	83.5	81.2	86.0	79.0	88.1
37	83.5	80.4	86.5	78.6	88.4

OSHA Permissible Exposure Limit (PEL)

In this study, no employees were exposed to noise at or above the OSHA PEL. The highest exposure recorded was the one employee who changed 37 tires and had an exposure of 82.6dBA. The relatively large gap between the highest noise exposure of 82.6dBA and the PEL of 90dBA suggests that it is unlikely that an employee will be exposed above this limit. The distribution of noise measurements collected using the PEL parameters can be found in Figure 5.3.

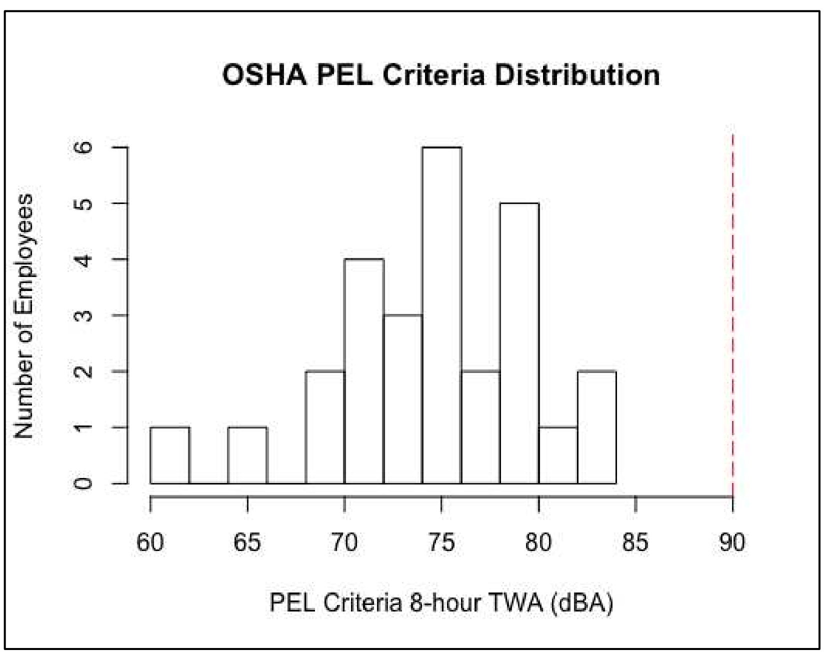

Figure 5.3 OSHA PEL Criteria Distribution (n = 30)

The largest grouping of noise exposures (15/30) were found to be between 73dBA and 80dBA, substantially below the OSHA PEL. A polynomial regression (R^2=0.80) was performed on this data set, comparing the PEL measurements to the number of tires changed during the shift. The results of this regression can be found in Figure 5.4 below. The narrow, green dotted line depicts the 95% confidence interval, which would be the average noise exposure expected at that number of tire changes. The wider, orange lines display the 95% prediction interval, which is the range of noise measurements expected when randomly sampling one worker at a specific number of tire changes.

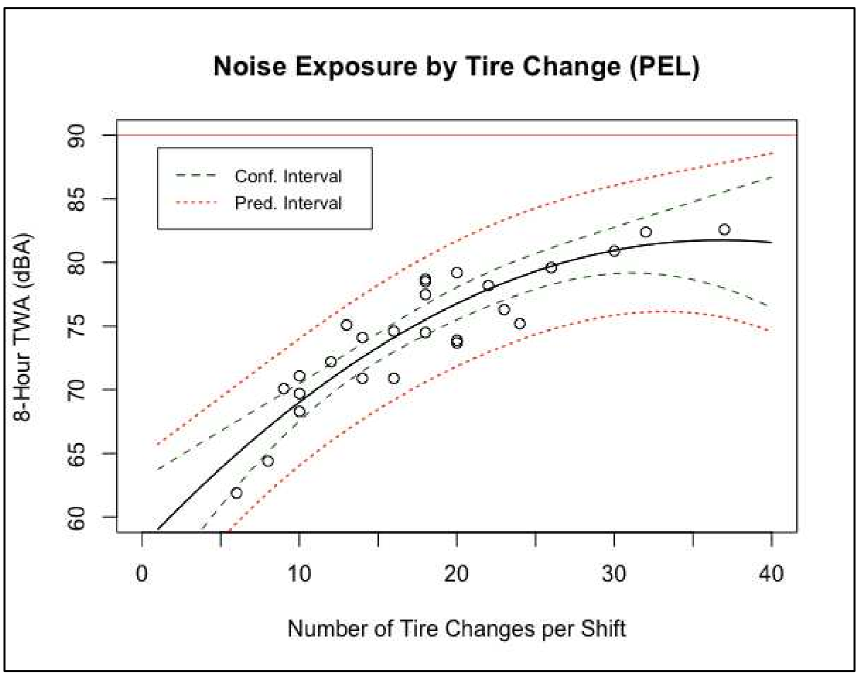

Figure 5.4 Noise Exposure by Tire Change (OSHA PEL Criteria)

Table 5.2 is a list of intervals of tire changes with the associated upper and lower limits for both the confidence and prediction intervals. This can be used to help estimate the noise exposure range based on the number of tires changed in a shift. For example, if a randomly selected employee was monitored using PEL criteria and changed 25 tires in a shift, the range of exposures may be between 74.3 and 84.3dBA. Additionally, the average exposure for these 25 tire changes would be 79.3dBA with a lower limit of 78.0dBA and upper limit of 80.7dBA.

Table 5.2 OSHA PEL Confidence and Prediction Limits

OSHA PEL Confidence and Prediction Limits					
Tire Changes	Average	Lower Confidence	Upper Confidence	Lower Prediction	Upper Prediction
			TWA (8) dBA		
20	76.8	75.5	78.1	71.8	81.7
25	79.3	78.0	80.7	74.3	84.3
30	81.0	79.1	82.8	75.9	86.0
35	81.7	78.7	84.8	76.1	87.4
37	81.8	78.0	85.6	75.7	87.9

ACGIH Threshold Limit Value (TLV)

The researchers of this study found that 18 of the 30 sampled employees were overexposed to the TLV with the highest exposure at 100.6dBA. The distribution of measured exposures in regard to the TLV can be found in Figure 5.5.

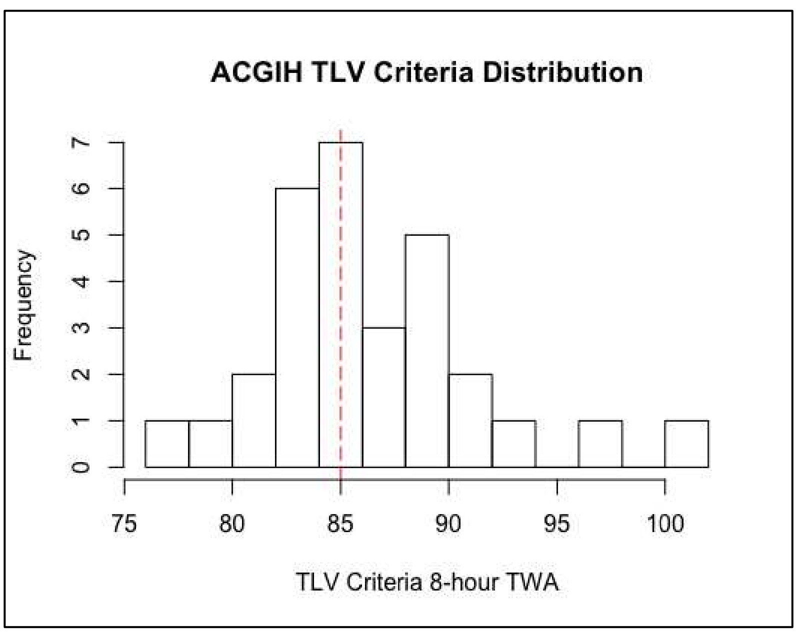

Figure 5.5 ACGIH TLV Criteria Distribution (n = 30)

A linear regression was performed comparing the TLV measurements to the number of tires changed during the shift, which can be found in Figure 5.6 below. Interestingly, the TLV data set was the only one of the three data sets to better fit a linear model as compared to a polynomial one. As with the previous two, the narrow, green dotted lines represent the 95% confidence interval displaying the average exposure expected at a certain number of tire changes. The wider, orange dotted lines represent the 95% prediction interval displaying the range of values that one could expect when randomly sampling one employee at a specific number of tire changes.

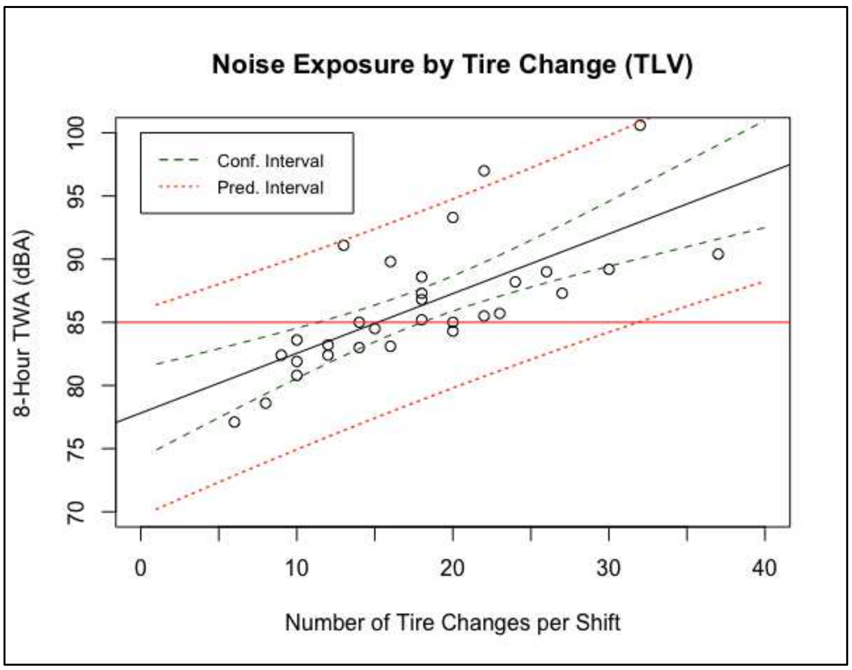

Figure 5.6 Noise Exposure by Tire Change (TLV)

Table 5.3 is a list of intervals of tire changes with the associated upper and lower limits for both the confidence and prediction intervals. For example, if one randomly selected employee was monitored using TLV criteria, the range of expected values when changing 25 tires would be 82.1 to 97.2dBA. Additionally, the average noise exposure for all employees changing 25 tires would be 89.6dBA with a lower limit of 87.8dBA and upper limit of 91.5dBA.

Table 5.3 ACGIH TLV Confidence and Prediction Limits

ACGIH TLV Confidence and Prediction Limits					
Tire Changes	Average	Lower Confidence	Upper Confidence	Lower Prediction	Upper Prediction
			TWA (8) dBA		
20	87.3	85.9	88.7	79.8	94.8
25	89.6	87.8	91.5	82.1	97.2
30	92.0	89.4	94.6	84.2	99.8
35	94.4	91.0	97.8	86.3	102.5
37	95.3	91.6	99.0	87.1	102.5

Area Noise Sampling

Area noise samples were collected using a sound level meter to determine the noise levels of specific tasks and tools commonly found at these tire shops. A description of these tasks along with the associated sound pressure levels (SPL) of each can be found in Table 5.4 below.

Table 5.4 Task or Tool Area Noise Measurements

Task or Tool Area Noise Measurements		
Task / Tool	**SPL (LAeq)**	**SPL (LCeq)**
Area sample, background, nonspecific	73.3 dBA	75.6 dBC
Air ratchet at 2' from employee hearing zone – wheel removal	75.9 dBA	78.6 dBC
Air ratchet at 2' from employee hearing zone – wheel attachment	86.9 dBA	89.9 dBC
Air ratchet at two feet without a load	89.6 dBA	90.6 dBC
Tire change machine at two feet – valve stem insertion	83.2 dBA	82.4 dBC
Cheetah – compressed air discharge	111.3 dBA	109.6 dBC
Tire change machine at two feet – inflating tire	98.5 dBA	96.8 dBC

As indicated in Table 5.4, the loudest piece of equipment was found to be the Cheetah. The Cheetah is a compressed air dischange that is sometimes used in order to get difficult tires to seat on a wheel. The process is quickly accomplished and only lasts a short duration of time. The tire inflation using the changing machine, however, is often used by all tire technicnans during their shifts. This exposure lasts considerably longer than the use of the Cheetah and is more likely to contribute to overall noise exposure using all three analyses.

CHAPTER 6: DISCUSSION

The purpose of this study was to determine if workers in the tire-changing industry are exposed to levels of hazardous noise as defined by OSHA and the ACGIH, as well as determine if there is a relationship between noise exposure and the number of tires changed in a shift. The researchers found that only one of 30 employees sampled was exposed at the OSHA action level of 85dBA, but 18 of the 30 employees sampled exceeded the ACGIH TLV.

Due to these overexposures, it is reasonable to conclude that a proportion of workers in this industry are at increased risk for noise-induced hearing loss. NIOSH, in its 1998 Criteria for a Recommended Standard, cites that a criterion level of 90dBA, over a 40-year working life, allows for a 25% excess risk of developing NIHL. The ACGIH TLV, however, has an 85dBA criterion level that only allows for a 8% excess risk (National Institute for Occupational Safety and Health, 1998). These projections are only applicable when the standards are not exceeded so the tire technicians that exceeded the TLV, but not the PEL, could possibly have an excess risk of NIHL between 8 and 25%. This is compounded with the fact that no employees during the study were observed wearing hearing protection devices.

Anecdotally, from personal communication during this study, several of the older workers who have worked in the industry for some years claimed that they had some degree of hearing loss, but it is unknown if this hearing loss was from working in an automotive garage, free-time recreational activities, or presbycusis caused by aging.

OSHA Action Level (AL)

Upon examination of the data for the OSHA AL criteria, only one employee was exposed at this level. This employee was found to have an exposure of 85.1dBA, just above the limit. Based on the prediction and confidence intervals, it is feasible that many of the tire technicians will exceed the OSHA AL at some point during their career. None of these employees are currently enrolled in a hearing conservation program, as defined by OSHA, but should be enrolled unless engineering controls can lower the exposure. Limiting the number of tires changed during a shift may be feasible as an administrative control to reduce noise exposure under this analysis. This is due to the average number of tires changed for a shift in this study was 18 and the upper limit of the prediction interval doesn't reach 85dBA until 23 tire changes. Often, there was a noticeable discrepancy between the number of tire changes between employees working the same shift, meaning if the workload of tire changing were allocated equally among workers it could possibly reduce exposures.

OSHA Permissible Exposure Limit (PEL)

The researchers found that none of the employees' noise measurements based on the OSHA PEL approached this limit. This is partly because the threshold for this measurement is at 90dBA, so no noise lower than 90dBA is recorded by the dosimeter. This difference in threshold explains why the OSHA AL measurements (threshold of 80dBA) are higher than the PEL measurements even though the limits have the same criterion level (90dBA) and exchange rate (5dBA). Even when extrapolating the polynomial regression up to 40 tire changes in a shift, the upper limit for the prediction interval is only 88.6dBA.

Based on these data, and assuming that the data collected is representative of the normal workload at the sampled tire shops, workers should not be at risk of exceeding the OSHA PEL.

ACGIH Threshold Limit Value

The ACGIH TLV for noise exposure is the most conservative and protective of the three noise exposure limits that were examined in this study. This helps explain why more than half (60%) of the employees sampled were overexposed to this limit. While this limit is not mandated by law, unlike the OSHA AL and PEL, this is a more protective limit to prevent NIHL. The main factors that caused the TLV exposures to be higher than the other two was the exchange rate of 3dB and a threshold of 80dBA. The importance of the exchange rate becomes more apparent at higher sound pressure levels. For example, the TLV only allows a worker to be exposed to a continuous noise of 94dBA for one hour, while the OSHA PEL allows the same worker to be exposed to 95dBA for four hours. Note that at these limits the worker has reached a maximum exposure during a portion of their shift, meaning they can't be exposed to any noise above either threshold without being overexposed for the day.

Considering this research, it would not be recommended to use the number of tires changed in a shift as an administrative control for the ACGIH TLV. This is due to the fact that a majority (60%) of employees were found to be overexposed to this limit. Additionally, using the confidence interval, it would only require 12 tire changes for the average noise exposure to surpass this limit. Controls should instead be focused on engineering controls to reduce exposure and providing hearing protection devices. NIOSH recommends that any employee that exceeds its Recommended Exposure Limit (REL) of 85dBA should be enrolled in a hearing loss prevention program (HLPP), which has many elements similar to a hearing conservation program (National Institute for Occupational Safety and Health, 1998). The NIOSH REL and ACGIH TLV use the same criteria such as a 85dBA criterion, 80dBA threshold, and 3dB exchange rate. From a measurement perspective, both the REL and TLV should be considered equivalent.

Comparison with Relevant Studies

The results of this study were found to have both similarities as well as differences with the current literature in similar automotive facilities. The primary difference between this study and the others is the focus on tire changing facilities as opposed to automotive garages and body shops.

The Loupa (2013) study focused on workers in automotive repair facilities in Greece and found that their full shift noise exposure was 69.3 ± 3.4dBA, which is lower than what was found in this study (Loupa, 2013). Regardless of the analysis performed in this study, the results at the tire changing facilities in this study were consistenly higher than those found in the Loupa studied repair facility. This difference may be caused due to the difference in tasks performed between the two types of shops. Auto repair technicnans do not constantly need to use power tools throughout their shift and have less of a dependence on pneumatic tools, which can highly impact noise exposure. Tire technicians, on the other hand, constantly using pneumatic tools and compressed air throughout their shifts.

In the Bejan, Brosseau, and Parker (2011) study, noise monitoring was performed on workers in auto collision repair shops. The researchers found that no employees were exposed above the OSHA PEL, but four of the 17 sampled were exposed above the ACGIH TLV (Bejan et al., 2011). These results are similar to the results in this study in that no employees were found to be exposed above the PEL, but this study had a higher portion of the sampled group that was exposed above the TLV (24% vs 60%). This difference could be caused by a difference in the tools and tasks performed by the two types of facilities.

The researchers Jayjock and Levin, in their 1984 study, studied noise exposures in a small automotive body repair shop. Based on the dosimetry results, the reserachers found exposures up to 160% based on the OSHA PEL criteria (Jayjock, 1984). These exposure results differ from this study in that no employees were found to exceed the OSHA PEL. This difference could be contributed to the difference in tools and tasks performed in the two types of facilities. Also, since the Jayjock study site was a small two-person shop and the study was performed in 1984, the difference in tools could greatly contribute to the difference in noise exposure. Manufacturers consistently get better at reducing noise exposure caused by their tools with each iteration.

NIOSH, in its 1996 Health Hazard Evaluation Report, evaluated noise exposure at an auto body shop. In this study, NIOSH only collected a measurement on one employee and found his or her exposure to be 94.4dBA based on OSHA criteria. This same employee also exceeded both NIOSH and ACGIH criteria for noise exposure (McCammon & Sorensn, 1996). As with the Jayjock and Levin study, these exposure results are higher than those found in this study. The difference in results may be caused do to a difference in tools and tasks performed between the two types of facilities.

<u>Factors that Likely Contributed to Noise Exposure</u>

Tire technicians at the three studied shops are not only subject to noise exposure from the tasks they are completing. The three shops included in this study also had mechanics on staff who performed less routine work activities. The noise exposure caused by this non-routine work adds to the general background noise at any given time and could impact the exposure to the tire technicians. In addition, a substantial amount of noise generated in these shops is elevated impact or intermittent noise. This type of noise has a very short duration, but at a high intensity, such as banging a hammer on a piece of metal or using an air wrench on a lug nut. The three analyses for the OSHA AL, OSHA PEL, and ACGIH TLV integrate the impact and intermittent noise into the overall average exposure and calculate an overall noise exposure. Figure 6.1 below is a typical time history graph of a noise exposure measurement during a tire technician's shift using the Larson Davis Blaze® software (Provo, UT). Figure 6.2, is a print out of noise measurements for one employee measurement. In Figure 6.2, Dose 1 is the OSHA AL, Dose 2 is the OSHA PEL, and Dose 3 is the ACGIH TLV.

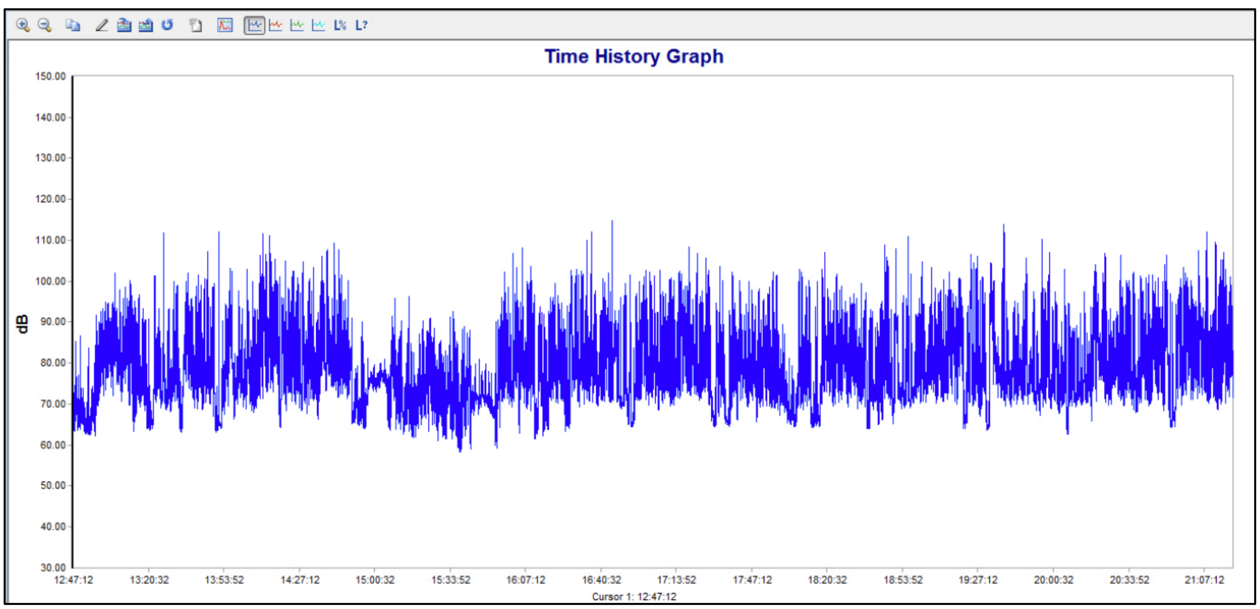

Figure 6.1 Time History of Noise Exposure – Tire Technician

Results	Dose 1	Dose 2	Dose 3	
Dose:	50.5	36.1	346.5	%
Projected Dose:	47.3	33.8	324.3	%
Leq:	90.2	90.2	90.2	dBA
TWA:	84.6	82.2	90.1	dBA
TWA (8)	85.1	82.7	90.4	dBA
Lmax:	116.0	116.0	116.0	dBA
Lpeak (max):	152.3	152.3	152.3	dB
Lmin:	58.2	58.2	58.2	dBA
Lep (8)	90.5	90.5	90.5	dBA
SE:	3.6	3.6	3.6	Pa²hr
Overload?				Yes
Statistics				
L10			91.0	dBA
L30			82.5	dBA
L50			77.0	dBA
L70			72.5	dBA
L90			68.0	dBA
Settings				
Exchange Rate:	5	5	3	
Threshold:	80	90	80	dBA
Criterion Level:	90	90	85	dBA
Criterion Duration:	8	8	8	hours
RMS Weight:				A Weighting
Peak Weight:				Unweighted
Detector:				Slow
Gain:			0	dB

Figure 6.2 Noise Exposure Results – Tire Technician

When reviewing the time history graph, as well as the noise exposure results, impact noise is evident. On the graph in Figure 6.1 several peaks can be found in excess of 110dB as well as the results recording a L_{Max} value of 116dB. L_{Max} is the highest root mean squared level of noise found in a measurement. One can infer that workers are exposed to levels of noise close to 116dB at several times during their shift as well as across their tenure as a tire technician.

<u>Area Noise Sampling</u>

The area noise sampling in this study was not intended to have any statistical significance, but was more to examine the noise sources in the facilities. These results were recorded in both dBA and dBC to determine if the sources were primarily higher or lower frequencies in nature. It was noted that the air ratchet, Cheetah, and tire changing machine when measured independently had exposures higher than 85dBA. This means that the more an employee uses one of these tools, the more likely they are to have a higher overall noise exposure and risk of NIHL.

Study Limitations

As with most research, there were several limitations that may have unintentionally affected the results of this study. One of these limitations was that the study participants did other tasks than just changing tires during their shifts. While mechanics were excluded from this study, the tire technicians had a lot of variability in the work they performed on a vehicle. For example, a tire technician may participate in rotating tires, patching holes without removing a tire, patching holes by removing the tire from the rim, removing old tires from a rim to add new, and many other tasks. These variations were not accounted for in this study, instead employees were instructed to only count any time a tire was pulled off a hub and then put back on as one tire change. Additionally, while performing non-tire changing tasks, tire technicians could have used other pieces of equipment that could have contributed to their noise exposures.

There is a possibility that some measurement/recall bias is included in the number of tires changed per shift because the number of tire changes were self-reported by the tire technicians. At the beginning of their shift, the technicians were given a sheet of paper to tally every tire change they completed. It was observed that this would not be done after every change, but periodically the technician would add several tallies at once to catch up. This process may have resulted in the number of tire changes being over- or under-reported.

CHAPTER 7: CONCLUSION AND FUTURE WORK

The evaluation of occupational noise exposure to workers in the tire changing industry was used to answer the following questions:

1. Are workers in the tire changing industry exposed to levels of noise that exceed the OSHA AL, OSHA PEL, and ACGIH TLV during their shifts?

In regard to the OSHA AL of 85dBA as an 8-hour TWA, one employee was found to be at or above this level. This measurement along with the associated confidence and prediction intervals show that workers are likely to exceed this limit at some point. It was also concluded that none of the employees monitored in this study reached the OSHA PEL. Also, the confidence and prediction intervals up to 40 tire changes did not reach the OSHA PEL of 90dBA as an 8-hour TWA. The ACGIH TLV of 85dBA was exceeded by more than half (17/30) of the workers sampled in this study. Also, the confidence and prediction intervals crossed 85dBA at a low number of tire changes (11 and one, respectively) per shift meaning most employees will eventually exceed this limit, assuming the same condition as this study.

2. What is the maximum number of tire changes that can be performed without exceeding occupational exposure limits?

The 95% prediction intervals calculated in this study were used to determine the range of values a single, randomly sampled employee could be exposed to during a shift based on the number of tire changes.

It was found that when using the OSHA AL criteria, a worker could change up to 23 tires in a shift without exceeding this limit. The OSHA PEL was not exceeded during this study so a limit was not able to be formed. The ACGIH TLV criteria had the potential for an overexposure even at zero tire changes.

Future Work

This study addressed the potential for noise exposure to workers in the tire changing industry and aimed to use the number of tires changed in a shift to estimate exposure. The shops sampled in this study had both tire technicians as well as mechanics working in close proximity, therefore future work should examine shops that only perform tire changes to determine if noise exposure monitoring results change. In addition, this technique of comparing a piece-rate to noise exposure to help estimate exposure can be used in a variety of workplaces as an administrative control. For example, how many sleeves of nails could a roofer install before being exposed above the OSHA AL?

The intermittent, impact noise that workers in tire changing facilities encounter should be studied further as well as the impact on temporary threshold shifts. Audiometric testing should be used to determine if workers exposed to this level of impact noise experience any threshold shifts throughout the workday. These data can be used to determine if intermittent, impact noise exposure in tire-changing facilities can increase the risk of hearing loss.

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APPENDIX A

Record of Tire Changes

Date: ___________________ **Facility: ______________________**

** Tire Change = Any time you take a tire off of a vehicle then put it back on. i.e. rotating four tires = four tire changes*

Name	Serial #	Calibrated (Pre/Post)	On Time	Off Time	Number of Tire Changes (Tally Throughout Shift)