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Abstract: Workers in many different fields depend upon their voice for job performance. Vocal load, the way a voice is used and how much it is used, increases as a function of the total time speech is produced and the intensity ("loudness") of the voice. Speakers tend to increase pitch, intensity, and duration of speech in the presence of noise, known as the *Lombard Effect*, which can lead to greater vocal fold stress and subsequent risk of vocal injury. In addition to increased risk of vocal injury, high levels of ambient noise might put workers at risk of auditory damage. The National Institute for Occupational Safety and Health recommended noise exposure limit for workers is 85 dBA (8-hour time-weighted average, equaling 100% dose) (NIOSH, 1998). Restaurants have been shown to have average sound levels exceeding 90 dBA with maximum peak sound pressure levels of up to 124 dB (Sadhra, Jackson, Ryder, Brown, 2002). Workers exposed to these conditions may be at risk for auditory and/or vocal damage. The purpose of the current research was to assess the relationship between ambient noise levels and vocal effort in five bartenders working full shifts in a popular chain restaurant. Methods included using a throat contact accelerometer placed on the neck to measure vocal intensity, and a noise dosimeter placed on their shoulder to measure ambient noise levels. Some key findings were that 40% (n=2) of the participants generated vocal intensities in excess of their comfortable vocal dynamic range, and noise doses were found to exceed NIOSH recommended exposure limits. Workers exposed to these conditions need to be aware of possible risks to vocal and hearing health and be enrolled in a hearing loss prevention program.

Keywords: *noise dosimetry, vocal accelerometery, vocal effort, ambient noise, restaurant bartender*

The human voice is used by workers in many different fields. Workers such as emergency dispatchers, air traffic controllers, vocal performers/singers, and telephone call center customer service workers are dependent upon their voice for job performance. The vocal "load" on the voice mechanism (larynx) is described as the way a voice is used and how much it is used (Koufman & Isaacon, 1991). Vocal load is increased as a function of the time the voice is used, and the vocal intensity (typically measured in decibels (dB) of sound pressure level (SPL)). Higher SPL results in greater vocal fold stress. The *Lombard Effect* describes the tendency for speakers to increase pitch, intensity, and duration in the presence of noise (Patel & Schell, 2008). Teachers have experienced auditory and vocal complaints such as hoarseness, discomfort, and increased effort while using their voice, related to talking in the presence of high-level ambient noise (Hunter & Titze, 2010; Kritstiansen et al., 2014; Roy, Merrill, Thibeault, Gray, & Smith, 2004).

Workers may also be at risk of auditory damage due to high sound levels in their work environment. The National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL) for workers is 85 dBA time-weighted average (TWA) or 100% noise dose (NIOSH, 1998). The TWA quantifies the maximum noise exposure a person can be exposed to over an 8-hour period. An individual accumulates noise exposure throughout the day, and if it repeatedly exceeds 100% dose, one may be at risk for hearing damage.

The average sound levels measured while working as a barista ranged from 73.8 to 83.6 dBA (Pursley & Saunders, 2016). Waitresses and bartenders full-shift noise exposure averaged 79 dBA (±4 dB), with 6.1% exceeding the NIOSH 85 dBA REL (Green & Anthony, 2015). Restaurant area sound level measurements have also been shown to have levels exceeding 90 dBA and peak levels of 124 dB SPL (Sadhra, Jackson, Ryder, Brown, 2002).

Bartenders must speak above high ambient noise levels to communicate with customers and co-workers, which may put them at risk for vocal damage in addition to potential auditory damage. The current study was designed to explore the relationship between a bartender's vocal effort and noise exposure while working in restaurants/bars.

LITERATURE REVIEW

The following literature review will cover distinct, yet relevant topics related to vocal and hearing health risks.

Noise Exposure and Auditory Damage

According to the National Institute on Deafness and Other Communication Disorders (NIDCD), approximately 15% of Americans between the ages of 20-69 have a high frequency hearing loss due to loud noise exposures at work or during non-occupational activities (NIDCD, 2015). In 1981, the Occupational Safety and Health Administration (OSHA) estimated 7.9 million U.S. manufacturing workers were exposed to daily noise levels of at least 80 dBA. NIOSH estimated more than 22 million people are exposed to noise levels above 85 dBA each year. (NIOSH, 2016). Service workers such as waitresses and bartenders are part of this occupational group.

Sound level meters are portable devices used for acoustic measurements. The main components of a sound level meter are a microphone for capturing sound, signal conditioning (preamplifier), time constant (fast, slow, impulse), frequency-weighting (A, C, Z) and data storage and display (Grason, 2014). Sound level meters are used to measure the decibel (dB) sound pressure level generated by a sound source at a particular location. Sound level meters can average the sound over selected increments of time.

A noise dosimeter can be used to measure and determine a worker's daily exposure to various noise sources as a worker changes location throughout the work shift. A noise dosimeter has the same components as a sound level meter plus an internal clock, calculator, and a memory to store data. The noise dosimetry outcomes can be used to determine if a hearing conservation program is needed as, well as to evaluate noise hazards for regulatory compliance (e.g. OSHA, 1983) and/or compare with best-practice exposure guidelines according to NIOSH (1998).

The legal requirements by OSHA 29 CFR 1910.95 mandate that workplaces institute a hearing conservation program when workers are exposed at or above 85 dBA time-weighted average (TWA) or 100% dose (OSHA, 1983). OSHA integrates the noise levels using a 5-dB exchange rate. In this case, the exchange rate (ER) specifies halving the allowable exposure time for each 5-dB increase in SPL. While the NIOSH REL uses a 3-dB exchange rate to reflect the doubling of sound energy every time the SPL increases by 3 dB. Noise dose refers to how much noise an individual can be subjected to for an 8-hour day. The noise dose will accumulate during the work shift and if it exceeds 100% dose (85 dBA TWA) based on NIOSH best practice recommendations, the worker is potentially at risk for auditory damage when high-level exposures are repeated over extended periods of time.

Noise-induced hearing loss (NIHL) is caused by over-exposure to high level sound. Permanent hearing loss occurs gradually due to damage to hair cells and other structures found in the cochlea. When a hearing evaluation is completed, the audiogram will show elevated hearing thresholds (softest sound a person can hear 50% of the time) (ASHA, 2005). In the early stages of NIHL, the audiogram may reveal a "noise notch", which is characterized by a v-shaped audiometric configuration due to decreased hearing thresholds at 3-6 kHz as compared to higher and lower test frequencies. If a noise notch is present on an audiogram, it suggests that the hearing loss may be due to hazardous noise exposure (Coles, Lutman, & Buffin, 2001; Rabinowitz et al., 2006). Listening at high-level events (e.g. concerts) can result in a perception of muffled voices, ringing in the ears (tinnitus) or a temporary decrease in hearing thresholds for up to a few hours following the exposure. This change in hearing thresholds is usually referred to as a temporary threshold shift (TTS). A permanent threshold shift (e.g. sensorineural hearing loss) may develop if hazardous unprotected exposures are repeated over time. An individual with NIHL may seek out hearing accommodations such as hearing aids. Workers with NIHL may also have an increased risk of accidents in the workplace; for example, individuals working in manufacturing or with heavy machinery run the risk of not hearing critical communications or machinery sounds (Lusk, Hong, Ronis, Eakin, Ker & Early, 1999). In the service industry, this may lead to misunderstanding patron and co-worker communications.

Workers do not need to lose their hearing at work; there are preventive measures that can be taken to avoid NIHL. A NIHL can be prevented by implementing one or more strategies; noise control (turn the volume down), administrative control (walk away, change job duties, reduce the time of exposure), and by utilizing hearing protection. Hearing protection should be fitted and worn if an individual's occupational exposure exceeds noise levels of 85 dBA TWA (NIOSH, 1998). There are specialized hearing protectors specifically made for workers who are subject to high noise levels during their job and who also need to communicate. These are known as "flat-attenuation" hearing protectors (Casali & Berger, 2010).

Restaurant Noise Levels

Restaurant workers may also be at risk of auditory damage due to high sound levels in their work environment. A study has been conducted measuring noise exposure and hearing impairment of restaurant workers (Lao et al., 2013). The purpose of this study was to investigate the occupational noise exposure and NIHL among Chinese restaurant workers and entertainment employees. Participants' audiometric data revealed that the main source of noise came from the stoves, and average hearing thresholds showed a noise notch at 3-6 kHz. For restaurant employees, 23.7% had decreased hearing thresholds at 3-6 kHz suggestive of NIHL, while 38.6% of entertainment employee audiograms demonstrated a noise notch at 6 kHz, consistent with NIHL.

Sadhra et al. (2002) focused on students working part time in music bars and discotheques at a university campus. The researchers conducted pre- and post-exposure audiometry to record hearing thresholds. Participants also wore personal dosimeters to collect noise exposures. In addition, the researchers provided a questionnaire asking participants about (1) length of employment, work shift patterns, and exposure to amplified music at work, (2) non-occupational exposure questions, (3) use of hearing protection, and (4) knowledge and attitudes toward hearing loss and noise levels. Three locations were specifically measured based on where the musical entertainment was taking place: area 1: bar; area 2: discotheque and bar; and area 3: discotheque. The average personal noise exposure levels for security staff and bar staff were above 90 dBA; the maximum peak SPL was recorded at 124 dB. Twenty-nine percent of the subjects had a mild to moderate hearing loss.

In addition, noise exposure research has been conducted on 180 employees working at six different restaurants in a college town (Green & Anthony, 2015). Researchers used a noise dosimeter to measure the occupational noise exposures. In addition, factors that were anticipated to significantly contribute to or reduce noise exposures, such as building materials, mechanical equipment, sound system information, and maximum occupancy were noted. After the participant's eight-hour shift ended, a brochure was handed out to them discussing the instrumentation used to collect the sound level data as well as information regarding the hazards of noise. The 95th percentile of the noise exposure was estimated to be 86 dBA (95% upper confidence limit of 87.5 dBA). Servers and bartenders full-shift noise exposure averaged 79 dBA (±4 dB), with 6.1% exceeding the NIOSH 85 dBA REL (Green & Anthony, 2015). Although the workers had a limited chance of being exposed to hazardous noise levels, about 8% of the population (cooks, dishwashers, cashiers) could be expected to have their noise exposure above NIOSH RELs. These researchers also noted that noise-exposure changed significantly depending on the type of restaurant, time of year, time of week, and job classification.

Recently, Pursley, and Saunders (2016) conducted noise dosimetry for 15 baristas at cafes and concluded that these workers' noise exposures did not exceed regulatory limits (85 dBA TWA / 100% dose), when measured with a consumer grade noise dosimeter (ER200) which integrated sound levels using a 3-dB exchange rate, from work alone during a partial work day. Average sound levels (Leq) ranged from 73.8 to 83.6 dBA and noise exposure doses ranged from 7.2% to 57% (with 100% equal to the maximum allowable exposure for an eight-hour work day). The authors did note that daily sound exposures may be exceeded if non-occupational sound exposures were also included in their daily noise dose. The baristas also completed a noise disturbance survey. In general, the baristas reported that of the sounds they were exposed during a normal work day, only the coffee grinder, espresso machine, and furniture banging were bothersome. These researchers did not assess concurrent auditory or vocal complaints or measure vocal effort as we propose to do in restaurants for this study.

Measuring noise exposure at a workplace is also important since increased vocal effort is needed to speak above high ambient noise levels and may put a restaurant worker at risk for vocal damage as well.

Vocal Effort

Vocal loading is a combination of prolonged voice use and additional loading factors (e.g. background noise, acoustics, air quality) affecting the fundamental frequency, type and loudness of phonation or the vibratory characteristics of the vocal folds as well as the external frame of the larynx (Vilkman, 2004). Vocal load is described as how much an individual uses their voice over time. The amount of exertion produced in vocalization may be considered "vocal effort". With greater vocal effort over time, the vocal load is increased. Vocalizing at greater intensities over a long period of time therefore results in greater vocal load and likely increases the stresses inflicted on the vocal folds.

To know that one is being heard/understood, humans tend to increase the intensity of our voice as the noise around us increases. The *Lombard Effect* describes the tendency for speakers to increase pitch, intensity, and duration in the presence of noise (Patel & Schell, 2008).

Vocal Dosimetry

Research has been conducted specifically on teachers' experience of auditory and vocal issues directly related to talking in the presence of high ambient noise levels. (Hunter & Titze, 2010; Kritstiansen, Lund, Persson, Shibuya, Nielsen, & Scholz., 2014; Roy et al., 2004).

Vocal dosimeter devices are used for unobtrusive monitoring of vocal load from occupational voice users by capturing skin vibration data from tissues overlying the larynx. Hunter and Titze (2010) used vocal dosimetry to evaluate characteristics of teachers' voices during occupational and non-occupational activities using voice dosimetry. The authors used the National Center for Voice and Speech voice dosimetry databank to calculate voicing percentage per hour (9:00 am- 3:00 pm weekdays and 4:00 pm-10:00 pm weekends) as well as the average dB SPL and fundamental frequency. Teachers were taught how to attach and use the dosimeter and wore it for the allotted time, and each wore two dosimeters to minimize the potential loss of data collection during the non-occupational and occupational measurements. Several times throughout the day teachers were asked to do vocal tasks: sustained soft phonation, soft upward pitch glide, five syllables repeated softly and at a high pitch, and to sing a portion of "Happy Birthday," softly and at a high pitch, as well as count "1, 2, 3," in their normal speaking voice. Background questions were asked before the study asking about their years spent teaching, their teaching schedule, their percent voicing at work and not at work, as well as their class size. Key findings revealed that teachers voicing percentage per hour is more than twice that of when they are not teaching, and teachers produced vocalization at a level that is 1dB higher during work than during non-occupational activities, and they exhibited an increased pitch as the work day progressed. It was stated that there may not be adequate time for teacher's daily repair cycle and the weekend recovery necessary to prevent a significant vocal health issue. The researcher's recommendations for future research was to determine whether voice breaks and frequency of such breaks could improve vocal health.

Kristiansen et al. (2014) found that the average ambient noise level during teaching was less than 72 dBA and noted a correlation between an increase in voice symptoms during the workday and ambient noise level. In this study, it was reported that the vocal load increased by 0.65 dB per 1 dB increase in noise level. The authors concluded that although there was not a risk NIHL, there was evidence that vocal load increased during work, suggesting that there may be a relationship between occupational noise exposure and development of vocal symptoms. Roy et al. (2004) also concluded that teaching is a high-risk occupation for voice disorders.

A study conducted by Titze and Hunter (2007) aimed to determine how various voicing periods and rest periods are distributed in a teacher's workday. The researchers measured how voicing and silence periods are distributed during work and after work as well as workdays versus weekends. The study was conducted on 31 teachers using a National Center for Voice and Speech Voice Dosimeter and data was collected on an average of 12.5 hours per day. The dosimeter calculated and stored the data in 30 minute intervals calculating phonation, skin acceleration intensity, fundamental frequency, and voice duration. Also, each worker had a daily log recording of their work and after work activities. It was reported that when individuals were teaching their vocal folds vibrated 23% of the time, as opposed to 12% of the time when they were not teaching. Voicing is not continuous for long periods of time, so distribution of voicing periods and silence periods are important. For teachers, voicing turns on and off about 20,000 times a day leading to a fatigue factor, meaning that teachers can't talk in a consecutive manner for a whole day without feeling fatigued. Vocal rest is needed for teachers to regain vocal strength. It was also reported that on weekends their vocal rest times increased in comparison to the weekdays. There are no studies of occupational noise exposure combined with vocal effort or voice dosimetry in bartenders or restaurant workers.

Research Questions

Q1: What is the noise exposure for bartenders during a typical work shift, and does it put them at risk for auditory damage when referencing NIOSH recommended exposure guidelines?

H1: Noise exposures of bartenders will exceed the allowable NIOSH daily recommended exposure level (100% dose).

Q2: What is the average ambient noise level that the bartender is exposed to?

Q3: What is the percentage of time that a bartender speaks during their work shift?

Q4: What percent of their voicing time are the bartenders speaking above the maximum limit of their comfortable voiced dynamic range (CVDR)?

METHODS

The relationship between noise exposure and vocal effort was investigated by having bartenders wear a noise dosimeter and an accelerometer attached to their throat to assess vocal effort during a typical work shift.

Participants

Participants were adults over 18-years-old that were employed part-time or full-time at a restaurant as a hostess, bartender, or server. The exclusion criteria omitted individuals with voice disorders diagnosed by a speech-language pathologist or otolaryngologist/physician, individuals with allergies to tape adhesive or physical contradiction to placement of the throat sensor, individuals not in good general health (e.g., sick coughing) and individuals wearing hearing aids or cochlear implants. Subject recruitment was done via a flyer delivered by the student researcher to the restaurant who agreed to support the research. Five participants wore both instruments for an 8-hr period or the duration of their shift, whichever was longer. The research protocol was approved by the Institutional Review Board (IRB) at the University of Northern Colorado and all data collected as specified.

Instrumentation

Noise Dosimeter

Participants were asked to wear a 3M Edge eg5 noise dosimeter on their right or left shoulder attached on their shoulder at ear-level, measuring noise exposures according to NIOSH (1998). This device incorporates two virtual noise dosimeters which allowed for the collection of noise data according to the NIOSH REL as well as at a low threshold parameter (70 dBA) for quantifying ambient noise levels in general. See Table 1 for noise sampling parameters.

Table 1. Noise Exposure Sampling Protocols

Parameter	NIOSH REL	Low Threshold
Weighting	A	A
Response	Slow	Slow
Exchange Rate	3	3
Threshold	80 dB SPL	70 dB SPL
Criterion Level	85 dBA	85 dBA
Criterion Time	8 hours	8 hours
Peak Weighting	Z	Z

Vocal Dosimeter

A miniature accelerometer (Knowles Electronics) coupled to a portable digital recorder (Sony ICD-UX71) was attached via medical adhesive to the skin overlying the anterior larynx approximately 2 cm above the sternal notch. Vocal calibration was accomplished by having the participant generate from a low-intensity vocal production of /a/ to a high-intensity vocal production of /a/ without screaming or singing. This represents the participants' comfortable vocal dynamic range (CVDR). The calibration was performed twice. In addition, the participants were asked to voice an /a/ at the lowest possible level, and then again separately at their highest possible voice level. Due to the recorder having a 4-5 hr. battery life the researcher came into the restaurant and switched the batteries out of the recorder half way through their shift, then had the participants continue working. Signals from the throat contact accelerometer were recorded into MP3 files by the portable digital recorder and digitized at a bit rate of 32 kbps (yielding a frequency range of 60Hz – 10kHz based on the performance specifications of the recorder).

The restaurant employee wore these two instruments for the duration of a typical work shift (see Figure 1). Once the shift was completed, the two devices were removed, and the data was transferred to computer for data analysis.

Figure 1. Instrumentation. A = noise dosimeter, B = throat contact vocal accelerometer, C = digital recorder. The vocal accelerometer captured vibration of the vocal folds reflective of vocal effort and the digital recorder stored vocal data. The noise dosimeter captured ambient noise levels in the restaurant. Neither devices recorded content of conversations.

Data Analysis

Noise Exposure

To analyze the noise exposure, data was downloaded via 3M Detection Management Software, and a descriptive summary of the noise exposure and sound levels in report and graphical format for the time period was generated. The outcomes were compared to the NIOSH RELs to assess the risk of hearing loss and the potential need for hearing conservation efforts.

Vocal Effort

Throat contact accelerometer data files from the portable digital recorder were downloaded into Goldwave (2016) audio editing software, band-pass filtered at between 30Hz and 1kHz, and down sampled to a 4kHz sampling rate. The data files were edited to eliminate non-voiced segments, and the duration of voicing was calculated. Praat (Boesrsma & Weenink, 2016) software was used to calculate the voice amplitude (relative dB scaling) throughout each recording. Vocal dynamic range was assessed by measuring the lowest consistent voicing amplitude level (scaled to 0% of dynamic range) as well as the maximum vocal amplitude (100% of dynamic range, or comfortable vocal dynamic range maximum (CVDRMax) during the calibration task.

RESULTS

Participants were exposed to varied levels of ambient noise levels during their work shift and produced associated vocal effort levels. There did not appear to be a clear relationship between ambient noise levels and associated vocal effort across participants (see Figure 2).

Noise Dosimetry

Each participant wore the noise dosimeter for their entire shift, which was between 8-9 hours each. Noise doses ranged from 23.9% to 135.8% (see Table 2). The noise exposure for participants one, four, and five did not exceed the allowable NIOSH daily recommended exposure level of 85 dBA TWA (100% dose). These participants were in the lower ranges that are described as safe and do not have a potential for a risk of hearing loss. However, participant three was exposed to an average ambient noise level of 86.8 dBA, which is over NIOSH REL. In addition, the dose level according to NIOSH REL for two participants was 130.6% and 135.8%.

Figure 2. Participants' average noise exposure and associated vocal effort. Blue bars represent the average sound level measured over the run time. The 85 dBA (red line) level is the NIOSH recommended maximum exposure for an 8-hour shift. Diamonds show the percent of vocalization time participants spent vocalizing at levels greater than their comfortable vocal dynamic range maximum (CVDRMax).

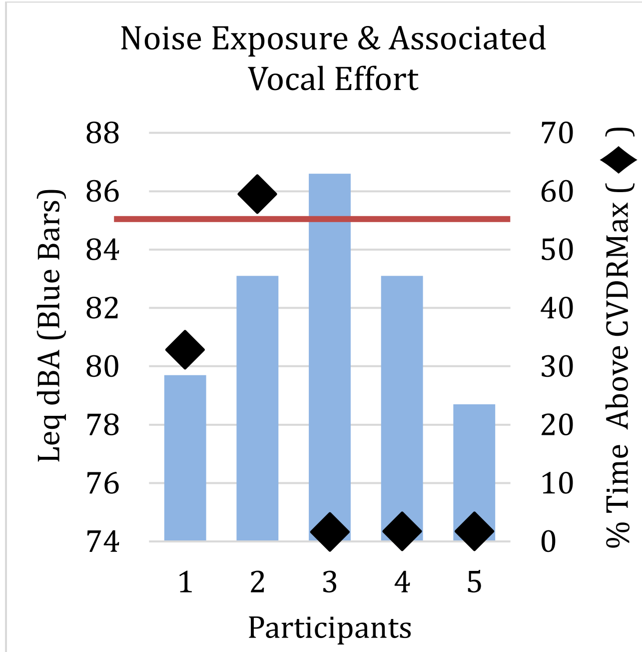

Table 2. Noise Exposure Results

Participant Number	Dose (%)	Leq (dBA)	Peak (dB SPL)
1	30.5	79.7	126.5
2	135.8	83.1	130
3	130.6	86.6	129.5
4	64.7	83.1	121.1
5	23.9	78.7	125.7

Vocal Effort/Dosimetry

Results indicated that the workers only vocalized between 11%-20% of their shift (see Table 3). Regarding the worker's vocal effort, participant one and three vocalized 32.8% and 59.5% of the total vocalization time respectively above their CVDRMax. These values suggest a relatively high vocal load for those participants during the voice recording session which could potentially put them at risk for vocal health issues if this behavior is repeated across multiple work shifts. These results were interpreted as the workers either screaming, shouting, or talking above their most comfortable vocalization level. Participants three, four, and five spent less than 2% of the total vocalization time above their CVDRMax.

Table 3. Vocal Effort Results

Participant Number	% of Work Shift Vocalized	% Vocalization above CDVRMax
1	11.4	32.8
2	14.8	59.5
3	15.6	1.6
4	13.1	1.7
5	20.0	1.7

Survey

Four questions were given to each participant after their shift had ended: (1) What is your impression of your how you used your voice during today's shift? (2) What is your impression of the workplace noise level during today's shift? (3) Have you experienced vocal problems after a shift in the past? If so, please describe. (4) Have you experienced hearing problems such as ringing in your ears, or temporary loss of hearing after a shift? Outcomes are summarized in the Appendix. Key findings from the survey suggest that as the ambient noise levels increased, participants reported that it was necessary to increase the intensity of their voice, and that during the late-night rush it was also necessary to speak using a greater vocal intensity to talk over the ambient noise. Participant two indicated that they had to yell due to the high level of ambient noise. With respect to vocalization, participants wrote that during their shift their voice feels "worn down a little" and seems to be worse when not hydrating. In addition, in regard to question (4), participant four reported symptoms suggestive of tinnitus and TTS associated with their work shift. This participant further described their hearing as not being able to hear mid pitches in their right ear very well, and that there are times when his hearing seems to worsen, but nothing that lasts longer than an hour or two (see Appendix). In conclusion, based on the answers to the brief survey questions, it's likely that the *Lombard effect* caused the participants to produce a greater vocal intensity in the presence of increased sound levels of background noise during their shift. The results from this survey suggest that these workers recognize that to be understood, it is necessary to speak louder than the ambient noise.

CONCLUSION

Overall, workers only spoke for 11-20 % of the shift time which is less than 1.6 hours and was less than expected (see Figure 2). Vocal effort as represented by the percent of the time that was spent vocalizing above the CVDRMax varied highly between subjects and did not appear to directly relate to the ambient noise level. Participant 2 reported that he had to "yell" during his shift in order to communicate, which could be a relation to the noise levels that he was being exposed to (see Appendix, question 2). In addition, 40% (n=2) of the bartenders may be at risk for hearing loss due to the fact that they were noise exposed above the NIOSH REL dose. It is also important to note that this study was conducted at 4 pm and later in the day. Participants may have been exposed to more noise earlier in their day, potentially increasing their daily NIOSH dose level.

Limitations

The first limitation was a small sample size. Having only five participants limits the understanding any direct or indirect relationships between vocal effort and noise exposure. The way researchers collected the vocal dynamic range could be changed to more accurately capture the range of participants' voice, however, researchers felt this was the best way to do it due to practical considerations. Also, the only participants that were studied were restaurant bartenders. Different results may present more of a risk for vocal or hearing damage depending on the location, for instance a bartender in a smaller venue with no restaurant and just a bar. Finally, the data was collected during the U.S. Major League Baseball World Series games, so it was particularly loud, or might have been louder than usual when the participants were working their shift. This could have resulted in data that was skewed toward greater risk for vocal and hearing damage.

DISCUSSION

Working as a restaurant bartender may present a risk of hearing loss (>100% NIOSH dose) and workers should be included in a hearing loss prevention program. It was concluded that being a restaurant bartender can cause risk to both ones auditory system as well as their vocal system. Bartenders, as well as others, should be aware of the implications of working in a loud environment as it could be damaging to their hearing as well as their vocal mechanism.

Implications

Outcomes from this study suggest that restaurant bartenders are a population that is exposed to high intensity ambient noise levels and may be at risk of hearing loss. The high noise levels may result in the need to raise their voice in order to communicate and be understood while working and result in using increased vocal intensity. There is a need to implement hearing loss prevention programs and vocal health promotion for these workers.

Future Research

Future research is needed to find a more accurate way to measure vocal effort, and a reliable way to measure vocal dynamic range. Continuing this study, it would be advantageous to have a larger sample size to try and describe any relationship between ambient noise level, noise exposure, and vocal effort. In addition, future studies should also have multiple samples across multiple work shifts to allow for better generalization across workers and workplaces to accurately research and collect data on their vocal dynamic range.

REFERENCES

American Speech-Language-Hearing Association. (2005). Guidelines for manual pure-tone threshold audiometry [Guidelines]. Available from www.asha.org/policy.

Boersma, Paul & Weenink, David (2016). Praat: Doing phonetics by computer [Computer program]. Version 6.0.19, retrieved 15 July 2016 from http://www.praat.org/

Casali, J. & Berger, E. H. (1996) Technology advancements in hearing protection circa 1995: Active noise reduction, frequency/amplitude-sensitivity, and uniform attenuation. *American Industrial Hygiene Association Journal, 57*(2,) 175-185, doi: 10.1080/15428119691015115

Coles, R.R.A., Lutman, M.E., Buffin, J.T. (2001) Guidelines on the diagnosis of noise-induced hearing loss for medicolegal purposes. *Clinical Otolaryngology, 41*(4), 347-357. doi: 10.1111/coa.12569

GoldWave Inc. (2016). Goldwave: Digital audio editing software [Computer program]. Version 6.24, retrieved 15 July 2016 from https://www.goldwave.com/

Grason, L. (2014). Sound level calibration: Microphones, ear simulators, couplers, and sound level meters. *Seminars in Hearing, 35*(4), 295-311. doi:10.1055/s-0034-1390160

Green, D. R., & Anthony, T. R. (2015). Occupational noise exposure of employees at locally-owned restaurants in a college town. *Journal of Occupational and Environmental Hygiene, 12*(7), 489. doi:10.1080/15459624.2015.1018517

Hunter, E. J., & Titze, I. R. (2010). Variations in intensity, fundamental frequency, and voicing for teachers in occupational versus nonoccupational settings. *Journal of Speech, Language, and Hearing Research: JSLHR, 53*(4), 862-875. doi:10.1044/1092-4388(2009/09-0040)

Koufman, J., & Isaacon, G. (1991). The spectrum of vocal dysfunction. *Otolaryngolic Clinics of North America, 24*(5), 985-988. Retrieved from https://www.oto.theclinics.com/

Kristiansen, J., Lund, S., Persson, R., Shibuya, H., Nielsen, P., & Scholz, M. (2014). A study of classroom acoustics and school teachers' noise exposure, voice load and speaking time during teaching, and the effects on vocal and mental fatigue development. *International Archives of Occupational and Environmental Health, 87*, 851-860. doi:10.1007/s00420-014-0927-8

Lao, X. Q., Yu, I. T., Au, D. K., Chiu, Y. L., Wong, C. C., & Wong, T. W. (2013). Noise exposure and hearing impairment among Chinese restaurant workers and entertainment employees in Hong Kong. *PloS One, 8*(8), e70674. doi:10.1371/journal.pone.0070674

Lusk, S. L., Hong, O. S., Ronis, D. L., Eakin, B. L., Kerr, M. J., & Early, M. R. (1999). Effectiveness of an intervention to increase construction workers' use of hearing protection. *Human Factors*, *41*(3), 487–494. doi:10.1518/001872099779610969

National Institute for Occupational Safety and Health. (1998). Criteria for a recommended standard: Occupational noise exposure (DHHS (NIOSH) Publication No. 98-126). Cincinnati: U.S. Department of Health and Human Services.

National Institute for Occupational Safety and Health. (2016). Retrieved from http://www.cdc.gov/niosh/index.htm

National Institute on Deafness and Other Communication Disorders. (2015). Tinnitus. Retrieved from http://www.nidcd.nih.gov/health/hearing/pages/tinnitus.aspx

OSHA. (1983). 29 CFR 1910.95, *Occupational Noise Exposure*. 29 CFR 1910.95, Washington, DC: U.S. Department of Labor, Occupational Safety and Health Administration. Fed. Reg. Vo. 48, 9738.

Patel, R., & Schell, K. (2008). The influence of linguistic content on the Lombard effect. *Journal of Speech, Language, and Hearing Research, 51*(1), 209-220. doi:10.1044/1092-4388(2008/016)

PPE Safety Solutions. (2016). 3M™ SoundPro™ sound level meters. Retrieved from: https://www.3m.com/

Pursley, A. J., & Saunders, G. H. (2016). Knowledge, attitudes, behaviors, and noise exposure of baristas. *International Journal of Audiology*, *55*(3), 184-5. doi:10.3109/14992027.2015.1124295

Rabinowitz, P.M., Galusha, D., Slade, M.D., Dixon-Ernst, C., Sircar, K.D., Dobie, R.A. (2006). Audiogram notches in noise-exposed workers. *Ear & Hearing*, *27*(6), 742-750. doi: 10.1097/01.aud.0000240544.79254.bc

Roy, N., Merrill, R. M., Thibeault, S., Gray, S. D., & Smith, E. M. (2004). Voice disorders in teachers and the general population: Effects on work performance, attendance, and future career choices. *Journal of Speech, Language, and Hearing Research*, *47*(3), 542-551. doi:10.1044/1092-4388(2004/042)

Sadhra, S., Jackson, C. A., Ryder, T., & Brown, M. J. (2002). Noise exposure and hearing loss among student employees working in university entertainment venues. *The Annals of Occupational Hygiene, 46*(5), 455-463. doi:10.1093/annhyg/mef051

The, E. (2015). 3M™ the edge eg5 personal noise dosimeter. Oconomowoc: 3M Personal Safety Division.

Titze, R. I., Hunter, J. E., & Svec, G. J. (2007). Voicing and silence periods in daily and weekly vocalizations of teachers. *Journal of the Acoustical Society of America, 121(1),* 469-478. doi:10.1121/1.2390676

Vilkman, E. (2004). Occupational safety and health aspects of voice and speech professions. *Folia Phoniatrica Et Logopaedica, 56*(4), 220-53. doi: 10.1159/000078344

Appendix

Survey Question Key Findings

Question	Participant Responses
What is your impression of how you used your voice during today’s shift?	• For the most part talking regularly, late night has louder music so I need to speak a bit louder. • Pretty normal, as the speed of service increased I think • I talked louder as a response. With the world series going • Tonight I felt like I used a fairly mild voice for the majority of my shift, we had a below average Saturday night, so I never got to that “crazy busy” level, but during our late night rush I do feel like I used a louder tone to talk over the music.
What is your impression of the workplace noise level during today’s shift?	• At times it gets way too loud and gets annoying having to yell. • Late night did slowly become louder as the night progressed.
Have you experienced vocal problems after a shift in the past? If so, please describe.	• If I have a busy shift and lots of people towards the end of the night or even morning after I wake up I will be a little hoarse. • Yes, maybe just getting worn down a little. It seems to be worse when I don’t keep up with drinking water. • I have not that I can think of. I know during sports games I need to increase my voice level significantly, though.
Have your experienced hearing problems such as ringing in your ears, or temporary loss of hearing after a shift?	• Not normally, maybe at most 5 times if it was super loud. • Never a ringing but it sometimes gets too loud to hear or feel like people can hear me. • Sometimes I have a slight ringing in my ears. I don’t hear mid pitches in my right ear very well, there are times when that seems to be a little worse, but nothing that lasts longer than an hour or two. • Only once, and that is because the music was pretty heavy, but that is not normal.