HHS Public Access
Author manuscript
J Occup Environ Hyg. Author manuscript; available in PMC 2016 February 15.

Published in final edited form as:
J Occup Environ Hyg. 2015 ; 12(7): 489–499. doi:10.1080/15459624.2015.1018517.

Occupational Noise Exposure of Employees at Locally-Owned Restaurants in a College Town

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Abstract

While many restaurant employees work in loud environments, in both dining and food preparation areas, little is known about worker exposures to noise. The risk of hearing loss to millions of food service workers around the country is unknown. This study evaluated full-shift noise exposure to workers at six locally-owned restaurants to examine risk factors associated with noise exposures during the day shift. Participants included cooks, counter attendants, bartenders, and waiters at full-service restaurants with bar service and at limited-service restaurants that provided counter service only. Assessments were made on weekdays and weekends, both during the summer and the fall (with a local university in session) to examine whether the time of week or year affects noise exposures to this population in a college town. In addition, the relationships between noise exposures and the type of restaurant and job classification were assessed. One-hundred eighty full-shift time-weighted average (TWA) exposures were assessed, using both Occupational Safety and Health Administration (OSHA) and National Institute for Occupational Safety and Health (NIOSH) criteria. No TWA measurements exceeded the 90 dBA OSHA 8 hr permissible exposure limit, although six projected TWAs exceeded the 85 dBA OSHA hearing conservation action limit. Using NIOSH criteria, TWAs ranged from 69–90 dBA with a mean of 80 dBA (SD = 4 dBA). Nearly 8% (14) of the exposures exceeded the NIOSH 8-hr 85 dBA. Full-shift exposures were larger for all workers in full-service restaurants ($p < 0.001$) and for cooks ($p = 0.003$), regardless of restaurant type. The fall semester ($p = 0.003$) and weekend ($p = 0.048$) exposures were louder than summer and weekdays. Multiple linear regression analysis suggested that the combination of restaurant type, job classification, and season had a significant effect on restaurant worker noise exposures ($p < 0.001$) in this college town. While evening/night shift exposures, where noise exposures may be anticipated to be louder, were not assessed, this study identified that restaurant type, job classification, time of week, and season significantly affected the noise exposures for day-shift workers. Intervention studies to prevent noise-induced hearing loss (NIHL) should consider these variables.

Keywords

dosimetry; noise; personal exposure; restaurant; service sector

INTRODUCTION

Over 22 million workers are exposed to potentially harmful noise each year in the United States, and over 10 million US workers have diagnosed noise-induced hearing loss (NIHL).[1] The U.S. Bureau of Labor Statistics reports 9.4 million workers are classified in food preparation and serving related occupations (Standard Occupational Classification = 35).[2] Little information exists on the long-term health risks of these workers, particularly in small locally-owned businesses with limited access to health and safety expertise. One risk factor for this population is exposure to hazardous sound levels, which is associated with both hearing loss and several non-auditory effects including elevated blood pressure, loss of sleep, increased heart rate, cardiovascular restriction, labored breathing, and changes in brain chemistry.[3–5] Several factors may contribute to elevated sound levels in restaurants. Sound levels are not only affected by occupancy levels, which affect both customer conversations and employee interactions, but the density and noise sources from surrounding businesses, audio systems, and food preparation equipment.[6] In towns where restaurants are located in highly populated areas, there is additional noise provided from traffic, increased business operations during evening hours, and other businesses located in close proximity.[7]

The majority of sound levels reported in restaurant studies[6–9] were below the 8-hour Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) of 90 dBA.[10] However, many studies reported measuring sound levels above 85 dBA. The National Institute of Occupational Safety and Health (NIOSH) and the American Conference of Governmental Industrial Hygienists (ACGIH®) recommend controlling occupational noise to a more protective limit to prevent permanent hearing damage, namely an 8-hour exposure limit of 85 dBA.[11]

Previous studies evaluating noise exposures in restaurants obtained short-term measurements to quantify environmental sound levels.[6–9,12] These studies concluded that environmental sound levels in restaurants can exceed 85 dBA during operating hours.[6,9] In a case study of 30 restaurants in Florida, Rusnock and Bush[7] found average restaurant sound levels ranged from 58 to 97 dBA. In a similar study of 27 restaurants in the San Francisco Bay area, Lebo et al.[8] observed restaurant sound levels ranging from 59 to 80 dBA, with a peak sound pressure level (SPL) of 87 dBA in several restaurants. Studies evaluating employee exposures in nightclubs and discotheques found average sound levels ranged from 90 to 98 dBA.[13–15] A study of 40 employees in discotheques in Singapore[13] concluded that all employees within all job classifications in this location—including disc jockeys, bartenders, waiters, cashiers, and security officers—were exposed to sound levels above 85 dBA, and many suffered from sensorineural hearing loss and tinnitus. To characterize the noise exposures of highly mobile workers, such as servers, or the time-dependent nature of noise exposures in restaurants (e.g., low versus high customer occupancy), personal dosimetry is needed to understand worker exposures and determine a worker time-weighted average (TWA).

Studies specifically using personal dosimetry to assess an employee's daily average exposure to sound levels over a shift are limited to restaurant workers outside of the United States. Lao et al.[12] performed a cross-sectional survey of hearing loss in non-manufacturing industries, which included personal noise assessment of 22 restaurant workers in Hong Kong. This work identified mean personal daily exposure among cooks (n = 20) was 92.9 dBA and among dishwashers (n = 2) 90.5 dBA, reporting that three personal exposures exceeded 100 dBA. Kelly et al.[6] measured personal exposures to 17 bar employees at nightclubs in Ireland and concluded that all nightclub bar noise exposures exceeded the Irish lower (80 dBA) and upper (85 dBA) exposure action limits, with mean 8-hr projected doses ranging from 88.6 to 96.8 dBA. These studies document an international concern that restaurant / bar workers are exposed to hazardous noise across a full-shift.

To understand the risk of noise exposure for U.S. restaurant workers, exposure assessments using full-shift dosimetry is ideal. A pilot study of noise exposures in a Midwestern college town was conducted to develop an understanding of noise variations in exposures for locally-owned restaurants offering either full- or limited-service. A monitoring plan was developed and deployed to evaluate whether restaurant type, job classification, time of week, or time of year influence personal noise exposures within a single community and to estimate whether noise-induced hearing loss may be a significant concern in this population.

METHODS

Participants

A list of locally-owned restaurants in Iowa City, Iowa, was compiled. For study purposes, only restaurants in the full-service (North American Industry Classification System [NAICS] 7221) and limited-service (NAICS 7222) restaurant categories were included. Both full-service and limited-service eating categories were selected based on their prevalence in Iowa City compared to special food service restaurants (NAICS 7223) and drinking places (NAICS 7224). Full-service restaurants were defined, for this study, as those that provided a table-service dining atmosphere, in which patrons pay after dining. For this study, only establishments that had a bar were considered for enrollment. In limited-service restaurants, guests order food at a service counter and pay before eating. These limited-service eating establishments do not have a table-wait service, but do provide limited-services such as cooking to order or off-site delivery. Fast food restaurants (e.g., those with a drive-through) and chain restaurants were excluded from the study. Locally-owned restaurants were presumed to have fewer health and safety resources compared to chain restaurants, and providing noise exposure monitoring for and interpretation to this population was an important outcome of this study.

To obtain a representative sample of subjects, restaurants meeting inclusion criteria were randomly contacted and invited to participate in the study. The first three restaurants within both categories that agreed to participate were selected and enrolled, totaling six restaurants. The worker categories varied between full- and limited-service restaurants. Each restaurant had at least one cook, defined as the employee(s) who spent the majority of their shift preparing food within the establishment's defined kitchen area. For each day of sampling at a given restaurant, at least one cook was recruited. Limited-service restaurants also had workers classified as counter attendants, who were workers that spent the majority of their shift operating the cash register and taking customer orders. In full-service restaurants, the equivalent job function was performed by wait staff who took customer orders, delivered food, and prepared bills. At least one waiter at the full-service businesses had exposures assessed each visit. In addition to waiters, full-service restaurants also had bartenders who spent the majority of their shift in the designated bar area preparing customer drinks and assisting customers seated at the bar.

On a given sampling day, a minimum of three job classifications (cook, wait staff, bartender) were recruited for monitoring at full-service restaurants, and at least two job classifications (cook, counter attendants) were recruited at limited-service restaurants. Due to dosimeter availability, workers at three participating restaurants were monitored on a given day, requiring two sequential monitoring days to assess exposure to workers at all six participating restaurants.

Procedure and Experimental Design

Because changes in resident population in this community were anticipated to affect sound levels in restaurants, two sampling "sessions" were established using the university academic calendar to allow a test of the hypothesis that exposures are louder when the local university is in session. In the study town, the local population was estimated at just under 72,000, but student enrollment at the university adds an additional 30,000 students to the population. Thus, the restaurant occupancy rates and customer demographics were hypothesized to change with the university calendar. The 2013 calendar was segregated into periods of time when the university was in session (September through November 2013, excluding Thanksgiving week) and when it was out (July through August 2013). During each session, three weeks were randomly selected in which weekday monitoring would be conducted, and three independent weeks were selected in which to conduct weekend monitoring. The weekdays included Monday through Thursday, and weekends included Friday and Saturdays. To accommodate restaurants that might be unable to participate on selected sampling dates, randomly selected alternative sampling weeks were also selected, one for both sessions. A total of 14 sample weeks, requiring 24 sample days, was targeted. Table I shows how many samples were included in each sample combination.

Participants within each restaurant were enrolled at the beginning of a selected day's first shift, either prior to or at the opening of the restaurant for customer service. Starting at the beginning of operating hours maximized the sample duration for a given participant, as the shift lengths varied between businesses and workers. Therefore, this study did not assess evening or nighttime exposures but rather focused only on day-shift noise exposures.

After workers agreed to participate each morning, dosimeters were deployed and information on job classification and anticipated shift length was recorded. Sampling was conducted for a minimum of 1 hour to a maximum of 8 hours per sampling event. At the end of a worker's shift, each participant was given a brochure that outlined the hazards of noise, recommended practices to protect hearing, and information on non-occupational noise hazards that may significantly contribute to the risk of hearing loss. On this brochure, their projected 8-hour exposure from that shift's monitoring was manually recorded, along with an interpretation of the measurement and a web link for additional information on the health risks of noise exposures.

In addition to noise exposure data, additional factors that were anticipated to significantly contribute to or reduce noise exposures were recorded during the sample period, including building materials, mechanical equipment, sound system information, and maximum occupancy.

Equipment

Both Quest Technologies NoisePro Personal Noise dosimeters and Edge 5 dosimeters (Quest Technologies, 3M, Oconomowoc, WI) were used to collect and process exposure data, recording time-series of one-minute sound level averages. Their instantaneous readout displays allowed the wearer to see information on noise exposures throughout the shift and allowed for immediate communication of the monitoring period time-weighted average noise exposure to workers. NoisePro dosimeters were attached to the participant's belt/ waistband, and the microphone was clipped onto the participant's shirt at the shoulder (near the seam, as close as possible to his/her ear). The smaller Edge dosimeters were clipped to the participant's shirt, positioned on the upper chest, with the units attached near the shoulder/ear. Dosimeters were set up to collect data to compare exposures to two noise criteria: the OSHA hearing conservation standard and the more health-based exposure recommendations provided by the American Conference of Governmental Industrial Hygienists (ACGIH) and NIOSH (Table II). To optimize the characterization of sound levels during quiet periods of restaurant activity, the noise threshold of the instruments were set to 70 dBA for all NIOSH/ACGIH settings. Each dosimeter was calibrated before and after each sample day using a Quest Technologies acoustic calibrator (Quest Technologies, 3M, Oconomowoc, WI). Windscreens were used on all dosimeter microphones.

Full-shift Noise Exposure Calculation

QuestSuite Professional II (Quest Technologies, Inc., St. Paul, MN) was used to download dosimeter measurements. One-minute average sound pressures were used to compute a time-weighted average (TWA) for each shift using both OSHA and NIOSH sampling criteria. NIOSH equations reference the 1998 recommended criteria,[1] and OSHA equations reference Appendix A of the OSHA hearing conservation standard.[10] To determine the exposure level using OSHA criteria, the time allowed to be exposed to a given sound level at work was computed using:

$$\mathrm{T}_{\mathrm{SPL}}=\frac{480\,min}{2^{\left(\frac{SPL-90}{5}\right)}} \quad (1)$$

where, T_{SPL} is the allowable time, in minutes, that can be spent at the associated Sound Pressure Level (SPL) in dBA. The time allowed using NIOSH criteria used the equation:

$$\mathrm{T}_{\mathrm{SPL}}=\frac{480\,min}{2^{\left(\frac{SPL-85}{3}\right)}} \quad (2)$$

For each 1-min average SPL measured, the T_{SPL} was computed. The dose was computed by considering the amount of time (C_n) spent at each sound level over the entire work shift. From the dosimeter 1-min averages, both OSHA and NIOSH doses, D, were computed using:

$$\mathrm{D}=\sum\frac{C_n}{T_{SPL}}=\sum\frac{1\,min}{T_{SPL}} \quad (3)$$

where, C_n is the number of minutes exposed at a given SPL, which was setup as 1 min for all of the dosimeters in this study. For shifts less than 8 hr, OSHA and NIOSH projected doses were calculated using Eq. 4:

$$\text{Projected Dose}=\text{Measured Dose}*\frac{480\,min}{Sample\ minutes} \quad (4)$$

From the dose, a TWA exposure was computed and compared to the OSHA PEL and hearing conservation limit and the NIOSH recommended exposure limit (REL). The OSHA 8-hr TWA was calculated using Eq. 5 and OSHA dose from Eq. 3 or Eq. 4:

$$\text{TWA}=[16.61\log \text{D}]+90 \quad (5)$$

The 8-hr TWAs were calculated using NIOSH criteria exposure data using dose (Eq. 3) or projected dose (Eq. 4) using:

$$\text{TWA}=[10\log \text{D}]+85 \quad (6)$$

The full-shift NIOSH TWAs were calculated for each worker on each sample day and were used as the full-shift exposure analyses that follows.

Data Analysis

Following data collection, individual exposure estimates were compared to the OSHA PEL and hearing conservation limits and to the NIOSH full-shift REL to assess the general noise levels of workers throughout the study period. Descriptive statistics were then generated, including mean and standard deviations of projected noise exposures by restaurant type, job classification, time of week, and time of year. Based on the resulting distribution of worker job classifications participating in the study, exposure data for counter attendants, bartenders, and waiters were combined into a single job classification (“not” cooks). The proportion of restaurant workers exceeding the NIOSH REL was then determined for all full-shift exposures (exceedance fraction). The uncertainty in the exceedance fraction was then characterized by calculating a one-sided 95% upper confidence limit (UCL 1, 95%) for the exceedance fraction. Following exceedance calculation using all worker data, the process was then repeated by worker classification.

An F-test was used to determine whether sample variances for each variable (job classification, restaurant type, season, time of week) were equal ($p > 0.05$) to establish appropriate variance assumptions in subsequent t-tests. The projected TWAs were then compared between restaurant type, job classification, time of week, and time of year using t-tests to evaluate the differences between the means of each group individually ($\alpha = 0.05$).

Each variable (restaurant type, job classification, time of week, or time of year) was then evaluated using multiple linear regression analysis techniques to determine the independent contribution of each variable on restaurant worker noise exposure in the presence of all other factors, using $\alpha = 0.05$. Table III provides a complete list and description of these variables.

Data analysis was performed using Microsoft Excel (Microsoft, Redmond, WA) and MiniTab 16 (Minitab, State College, PA).

RESULTS

Characteristics of each of the six participating restaurant are summarized in Table IV. Across the six restaurants, 180 full-shift noise exposure measurements were obtained. Only 64 (35%) of the study participants worked in the three limited-service restaurants; this smaller sample set was anticipated because these businesses had fewer employees than the full-service restaurants, with fewer participants available on each sampling day. Forty percent of participants (72) were cooks. Job classifications of the rest of the participants included bartenders (6, full-service), wait staff (58, full-service), hostess (8), dishwashers (5), cashiers (27, limited-service), and 4 packagers (limited-service). Other workers (6) had multiple job functions during the monitoring day, and these were grouped with the other 108 non-cooks for data analysis using job classification.

Restaurant worker NIOSH TWA exposures ranged from 69 to 90 dBA. The 180 full-shift exposures were normally distributed with a mean (standard deviation) NIOSH TWA of 80 dBA (3.7 dBA) and a median NIOSH TWA of 80 dBA. Figure 1 provides histograms of exposure distributions by restaurant type and job category, using 2 dBA band widths. The workers in the full-service restaurants had higher exposures than those in limited-service businesses, as did cooks compared to non-cooks. Table V details participants and mean exposures by participating restaurant.

No worker was exposed to noise above the OSHA 90 dBA PEL, even when monitoring using the lower hearing conservation threshold setting of 80 dBA. Six projected 8-hr TWAs at two businesses exceeded OSHA's hearing conservation limit (85 dBA), although four of these workers worked only 4-hr shifts on the monitoring day. Fourteen exposures (7.8%) had projected TWAs exceeding the NIOSH 8-hr REL, and these occurred at both limited- and full-service restaurants. Six of these workers actually worked less than the computed time-allowed based on that day's projected TWA (Eq.4), indicating lower risk to these workers. However, eight workers worked 16 to 70% longer than the time allowed at their projected TWA exposures. The job classifications of those exposed above the NIOSH REL varied by business: the cooks had the loudest exposures in full-service restaurant #3 (described in Table IV), while the wait staff had the loudest exposures at full-service restaurant #2 (Table IV). One limited-service restaurant had exposures above 85 dBA, and the dishwasher (only sampled once at this location) and the cashier (2 of 13 samples) were exposed to the loudest noise. All of the peak exposures occurred during the season when the local university was in session (“not summer”), although peaks occurred during both weekend and weekdays.

Using all data, the 95th percentile of the noise exposure was estimated to be 86 dBA (95% upper confidence limit of 87.5 dBA). While this population has a negligible risk of being exposed above the OSHA 90 dBA PEL, approximately 8% of this population can be expected to be exposed to noise at levels exceeding the NIOSH 8-hr 85 dBA REL using exceedance calculations.

Next, data were combined over all restaurants and grouped by the four independent variables under study. Table VI provides descriptive statistics for projected noise exposures by: restaurant type, job classification, time of week, and time of year. The full-shift exposures for cooks averaged 81 dBA (3 dBA), with 10.5% (UCL 95% = 16.7%) exceeding the NIOSH 8-hr 85 dBA REL. For the workers classified as “not” cooks, full-shift exposures averaged 79 dBA (4 dBA), with 6.1% (UCL 95% = 9.8%) exceeding the NIOSH 85 dBA REL.

Comparisons to determine whether these factors led to significant differences in worker noise exposures were performed. F-tests identified that exposure data within job classification and restaurant type both had equal variance ($p > 0.05$) and time of week and time of year exposure measurements had unequal variance ($p < 0.05$). Hence, t-tests comparing mean NIOSH TWAs by time of week and time of year used unequal variance and by job classification and restaurant type used the assumption of equal variance. As shown in Table VII, a significant difference in restaurant worker noise exposures was found between restaurant type ($p < 0.001$), job classification ($p = 0.003$), time of week ($p = 0.048$), and time of year ($p = 0.003$). Specifically, restaurant worker exposures were significantly greater for those employed in full-service restaurants, classified as cooks, working on weekends, and working during the fall semester when the university was in session and the town's population increased compared to the summer.

A multiple linear regression analysis was conducted to determine if restaurant type, job classification, time of week, and time of year significantly affect restaurant employee noise exposures. Table VIII summarizes the results of the multiple regression, which suggests that each of these factors provided significant contribution to the estimation of restaurant worker noise exposures ($p < 0.001$). The regression equation for this model was:

$$\mathrm{TWA}=76.2+2.35(\mathrm{Restaurant\ type})+1.96(\mathrm{Job\ classification})+1.35(\mathrm{Time\ of\ week})+1.84(\mathrm{Time\ of\ year}) \quad (7)$$

This model confirms the same findings of the t-tests, which indicated significant differences in restaurant worker exposures by job classification ($p = 0.003$), restaurant type ($p < 0.001$), time of week ($p = 0.048$), and time of year ($p = 0.003$). However, the low R^2 (0.219) indicates that this model accounts for a very small amount of the variation in noise exposures measured. Hence, additional factors associated with noise exposures require exploration. Additional qualitative factors that differed between restaurants included maximum occupancy and building characteristics (Table IV). Using these qualitative factors, significantly louder noise was identified in restaurants with maximum occupancy *smaller* than 100 compared to larger occupancies (t-test, $p = 0.025$) and when floors were tiled compared to concrete ($p = 0.044$). When these factors were included with the previous four in the full regression model, the maximum capacity and floor material were not significant and, therefore, were excluded from the final model. The power of this study was limited in its ability to include all these factors in a single exposure model.

DISCUSSION

Previous area noise exposure studies indicate restaurant employees are not overexposed to noise based on the 90 dBA OSHA noise criteria.[7,8] Exposures in this university town were similar, as identified using personal noise exposure dosimetry: No workers sampled in any of the restaurants exceeded the OSHA 8-hr TWA PEL. However, 8-hr projected exposures, measured with a 3 dB doubling rate and 70 dBA threshold, ranged from 69 to 90 dBA, indicating that even during daytime hours at restaurants, workers might be exposed to noise that can affect their hearing later in life and are at risk of developing NIHL. While many restaurant workers have shifts that are less than the traditional 8 hours, reduced shift length may be an option to control at-risk noise exposures. However, care must be taken to understand whether these workers are exposed to additional noise sources from other jobs or activities after the 8-hour noise limit is reached in the shorter restaurant shift.

The distribution of restaurant worker exposures from this study indicated that during day shifts (8:00 a.m. to 7:00 p.m.) approximately 8% of workers exceed the NIOSH REL of 85 dBA. With approximately 9.4 million workers in food preparation and serving related occupations,[2] our population estimates indicate that approximately 750,000 of these workers may be at risk of exposure to noise greater than 85 dBA. Since this study examined only day shift exposures, and indications that evening and night shifts may have increased sound levels, these may be underestimates of risk of hearing loss for this population. For workers classified as cooks in the full-service and limited-service restaurants, the mean (SD) full-shift exposure was 78 dBA (4 dBA) with an estimated 10.5% of workers exposed to noise above the NIOSH REL. With approximately 1.2 million U.S. workers classified as cooks,[2] an estimated 126,000 cooks may be exposed to potentially hazardous noise.

A statistically significant difference between job classification and restaurant worker noise exposures was found ($p = 0.003$). Additionally, regression analysis determined job classification had a significant effect on restaurant worker noise exposures, resulting in a TWA increase of approximately 2 dBA ($p < 0.001$) for cooks over non-cooks. The study conducted by Lao et al.[12] in Chinese restaurants identified cooks having a high risk of noise exposure, with mean exposures ranging from 87 to 95 dBA. Although no restaurant employees in our study were exposed above 90 dBA, the loudest exposures to restaurant workers in this university town were also identified as cooks. One reason for the difference in the magnitude of exposures between this and Lao et al. may be different food preparation equipment. The main noise source in Hong Kong was pressurized gas stoves, which none of the restaurants in our study used. Although the noise exposures of cooks differed in our study compared to Lao et al., results showed similarities in contributing factors when comparing between restaurants, including differences in stoves, dishwashing units, and ventilation systems.

The observation that noise exposure varied between our two restaurant types differs from findings in other studies. A significant and substantial increase (2 dBA) in exposures from limited-service eating establishments to full-service eating establishments was observed ($p < 0.001$). Lebo et al.[8] also analyzed the effects of restaurant type on ambient sound levels and found differences in sound levels between different restaurant types, but concluded restaurant classifications do not reliably predict loudness levels. Rusnock and Bush[7] analyzed restaurant type as a contributing factor to high sound levels and concluded no predictive association. Our study results also confirmed a significant difference in mean restaurant worker exposures between limited-service and full-service restaurants ($p < 0.001$); however, regression analysis determined restaurant type had a significant effect on restaurant worker noise exposures ($p < 0.001$). The differences in association of restaurant type and restaurant noise levels may be due to the differences in sampling equipment and study design. Both Lebo et al.[8] and Rusnock and Bush[7] used a sound level meter to take instantaneous sound level readings and visited each participating restaurant one time. Our study used noise dosimeters to identify individual restaurant worker exposures and visited each participating restaurant a total of 12 times.

Because the local population changes between summer and when the local university is in session, an effort was made to examine the effect of time of year on restaurant worker noise exposures. A statistically significant difference ($p = 0.003$) between school session and restaurant worker noise exposures was found, indicating noise exposures for restaurant workers increased in the fall semester compared to the summer. Regression analysis determined that restaurant worker exposures in this town significantly increased during the fall semester by approximately 2 dBA ($p < 0.001$). While this might not have applicability to communities where populations are stable year round, the implication is that variation in community populations should be considered when understanding this sector's cumulative exposure to noise.

This study also identified a significant difference ($p = 0.048$) between time of week and restaurant worker exposure. Although significant, this study was limited to daytime sampling, and, as restaurants move to evening hours, the day of the week may be more important. Over the study period, noise measurements ended by 7:00 p.m. at the latest. According to restaurant managers, all of the full-service restaurants were focused on food service from opening until about 9:00 p.m., and they switched to a “bar” focus from 9:00 p.m. to 2:00 a.m. Lee[13] found that between 10:00 p.m. and 3:00 a.m. noise exposure levels increase to greater than 85 dBA in Singapore discotheques. Sadhra et al.[15] found that between 9:00 p.m. and 2:00 a.m. mean sound levels in university entertainment venues in the United Kingdom ranged from 89 to 98 dBA, where employee exposures range from 87 to 97 dBA. Our measurements were solely focused on daytime exposures, specifically around the lunch and early dinner hours. Although regression analysis confirmed time of week significantly affected restaurant worker noise exposure ($p = 0.008$), further research involving evening and early morning sampling may result in greater changes in noise exposures from weekday to weekend.

The low R^2 value for the regression analysis indicates other variables may help to improve our ability to understand the variability of restaurant worker noise exposures. Rusnock and Bush[7] suggest occupancy, location, acoustical design, and music style can also significantly affect maximum sound pressure levels in restaurants. Additional factors considered but not included in the model that may account for variability in restaurant worker exposures include restaurant layout and the effects of building characteristics (i.e., ceiling types, floor materials) and occupancy are worth consideration. While this study was limited in the number of restaurants participating, the variability in the size, building characteristics, and machinery in use at each of the six businesses was apparent (Table IV). Alone, the maximum occupancy was significantly associated with noise exposure differences, where workers in businesses with *smaller* maximum occupancies had *larger* exposures. It may be hypothesized that the smaller businesses have workers positioned closer to equipment and may have more customers per square foot, which may contribute to noisier environments. The effects of these restaurant characteristics and equipment in use may contribute to estimates of noise exposure, and future studies should include consideration for both restaurant type and occupancy and building materials in a larger study design or when assessing a restaurant population's noise exposures.

A limitation of this study's findings to the generalizability of the general food service population may be in the willingness of worker participation in this study. Efforts were made to randomly select two cooks and three “not” cooks in full-service restaurants and one cook and two “not” cooks in limited-service restaurants during each sampling period to ensure a representative random sample of restaurant employees. However, the total number of samples per event depended upon worker participation. Because of the reluctance of some employees at each participating restaurant, participants were selected based on the willingness of workers during each sampling event. Therefore, many workers participated more than once and those exposed to louder noise may have been excluded from the study. To address this limitation, future research should consider offering incentives to participating employees to increase participation. While participants were monitored multiple times during the study, our agreements with participating restaurant owners, and in conformance with the University Institutional Review Board (IRB) approval, precluded identifying individual workers on data collection forms. Therefore, we cannot analyze the data to provide insights into individual changes to noise exposures as a result of the repeated sampling and communication of exposure results.

Another limitation to the generalizability of this study is the limited region of personal dosimetry to locally-owned restaurants in only one town. Rusnock and Bush[7] found a statistically significant restaurant sound level differences between urban and suburban areas. Restaurant worker exposures may be different in other geographical regions not considered in this study. While only 14 of 180 noise dosimetry measurements were found to exceed NIOSH exposure recommendations, consideration of worker shift and additional noise exposures are worthwhile. Since many restaurant workers have shifts that are less than the traditional 8 hours, reduced shift length may be an option to control at-risk noise exposures. However, care must be taken to understand whether these workers are exposed to additional noise sources from other jobs or activities after the 8-hour noise limit is reached during the shorter restaurant shift. Those identified with high projected TWA exposures in this study with short shifts (< 4 hours) had personal exposures below the NIOSH recommendations for an 8-hour workday. However, seven workers exceeded 88 dBA when projected over 8 hours, and shift length adjustments would not be as useful to administratively control these exposures.

CONCLUSION

The objectives of this study were to assess occupational noise exposures of restaurant workers in locally-owned restaurants and identify whether intervention efforts are needed to reduce exposures to this large, underserved workforce. In doing so, restaurant type, job classification, time of week, and time of year were important factors to understanding risk of exposure to this workforce to improve possible interventions with workers. Understanding that changes in community populations, unique to a university town, indicate that noise interventions, be it noise reduction or administrative controls by shift length restrictions, may be more necessary when the local university is in session rather than in summer. Additionally, focusing interventions to reduce exposures to cooks may be useful in some situations, but other restaurants have service staff or dishwashers as the most highly exposed workers, so customizing noise reduction plans to different job requirements is necessary.

Although restaurant employee noise exposures during the day shift were below the OSHA PEL, 3% of the exposure measurements resulted in exceeding OSHA's hearing conservation standard and nearly 8% exceeded NIOSH recommendations based on 8-hour exposure projections. This study excluded exposure assessment during evening shifts, for which the full service restaurants may significantly differ from the day shift environment, so the underlying restaurant population may have increased noise exposures than was reported here. Given the large number of workers in the food service and preparation sector, these small percentages may result in a large number of workers affected by noise who may be at risk of noise-induced hearing loss. Additional attention is likely needed to identify exposures, communicate the hazards of noise exposure, and implement feasible noise reduction methods to protect restaurant workers from possible noise-induced hearing loss.

Acknowledgments

The authors wish to thank Patrick T. O'Shaughnessy for his assistance with statistical analysis for this work.

FUNDING

This research was supported by a pilot project grant from the Healthier Workforce Center for Excellence (HWCE), from the National Institute for Occupational Safety and Health (NIOSH) (U19 OH008858), and with the support of a NIOSH Education and Research training grant (T42 OH008491). The contents are solely the responsibility of the authors and do not necessarily represent the official views of NIOSH.

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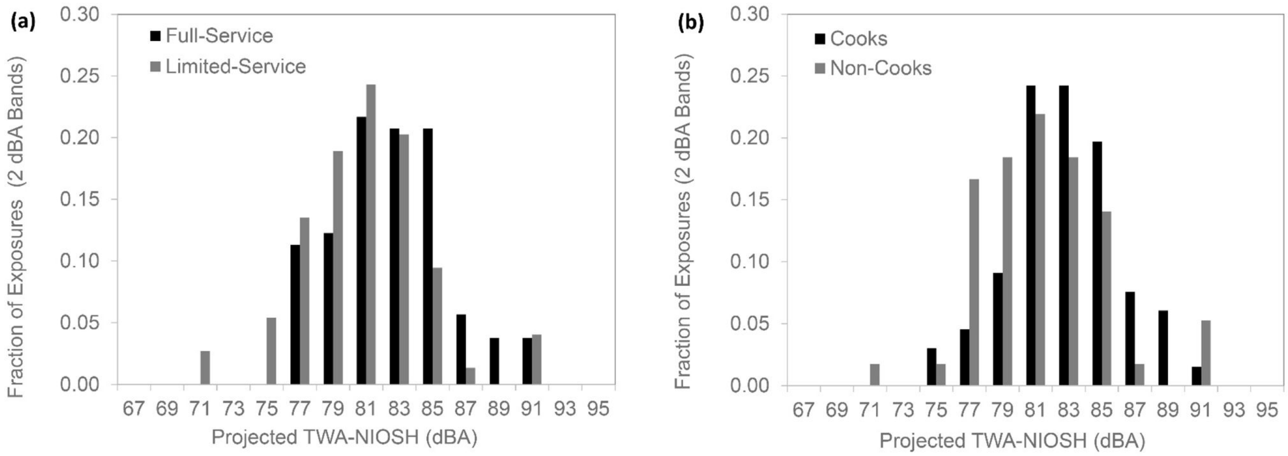

Figure 1.

Distribution of noise exposure data by (a) restaurant type and (b) job classification, using 8-hr projected TWAs from NIOSH sampling criteria with 70 dBA threshold

Table 1

Number of Samples within Each Combination of Factors, by Anticipated High (+) and Low ( ) Exposure Factor

Factor*				Number of Samples
Restaurant Type	**Job Classification**	**Time of Week**	**Time of Year**	
−	−	−	−	8
−	−	−	+	11
−	+	−	−	9
−	+	−	+	8
+	−	−	−	30
+	−	−	+	8
+	+	−	−	10
+	+	−	+	9
−	−	+	−	12
−	−	+	+	7
−	+	+	−	11
−	+	+	+	3
+	−	+	−	12
+	−	+	+	13
+	+	+	−	8
+	+	+	+	8

*Note: High (+) indicates full-service, cook, weekend, or fall; Low (−) indicates limited-service, not-cook, weekday, summer.

Table 2

Noise Dosimeter Settings for Noise Monitoring Equipment

Setting	OSHA	NIOSH*
Criterion Level (dB)	90	85
Criterion Time (hr)	8	8
Exchange Rate (dB)	5	3
Threshold (dB)	80	70
Response Rate	Slow	Slow
Weighting	A	A

*Threshold was reduced from 80 to 70 dBA for NIOSH setting to accommodate data collection to better characterize exposures during non-noisy periods of the shift.

Table 3

Contributing Factors to Restaurant Worker Noise Exposure

Factor	Values	Description
Restaurant Type	1 If full-service 0 If limited-service	All full-service restaurants in this study had bars; limited-service restaurants had counter order and customer seating.
Job Classification	1 If cook 0 If "not" cook	Workers who spent at least 90% of their time preparing food were considered cooks; workers with all other job classifications were grouped as "not" cooks.
Time of Week	1 If weekend 0 If weekday	Weekend sampling was conducted on Friday and Saturday; weekday sampling was conducted on Monday through Thursday.
Time of Year	1 If "not summer" 0 If summer	Fall ("not summer") sampling occurred during the local University fall semester calendar; summer sampling occurred prior to the start of the fall semester.

Table 4

Observational Factors and Building Characteristics Associated with Sound Levels in Restaurants

Restaurant	Maximum Capacity	Ceiling Material	Floor Material	Wall Material	Source of Maximum Sound Level, Maximum Sound Level in dBA
Limited 1	15	Foam tiles	Concrete	Painted drywall	Television, 85 Walk-in cooler, 77
Limited 2	50	Foam tiles	Tile	Painted wood and exposed brick	Sink in use, 105 Mixing machine, 99 Dishwashing machine, 79
Limited 3	130	Exposed	Concrete	Painted drywall and exposed brick pillars	Sink in use, 104 Pizza oven on, 92 Kitchen radio, 86 General food preparation area, 71–75
Full 1	200	Deep tiles, wooden panels and stained glass	Tile	Wall paper and wood	Deep fryers, 83 Ventilation system above stove, 75 General food preparation area, 79–92
Full 2	98	Pressed tin	Tile	Painted drywall and wood	Deep fryers, 79 Ventilation hood above stoves, 80 General kitchen area, 81
Full 3	180	Deep tiles and drop ceilings	Concrete	Painted drywall and wood	Stove during operation, 89 Kitchen radio, 81 Dining area televisions, 93 General kitchen area, 81

Over the duration of the study, actual worker shift lengths varied from 120 to 570 minutes. Cooks worked significantly longer shifts (t-test, $p = 0.02$), with an average of 332 minutes per day compared to 301 minutes per day for other job classifications. The shift length was also significantly longer (t-test, $p < 0.001$) for restaurant workers in limited-service establishments (mean = 341 min, median = 360 min) compared to full-service workers (mean = 292 min, median = 300).

Table 5

Exposure Summary, by Participating Restaurant, Using OSHA (5 dB Doubling, 80 dBA Threshold, 90 dBA Criterion) and NIOSH (3 dB Doubling, 70 dBA Threshold, 85 dBA Criterion) Settings

		Mean (Standard Deviation) Time-Weighted Average Exposure, dBA						Number of Exposures Exceeding:		
		All Employees		Cooks Only		Not-Cooks Only				
Restaurant Service	Number of Participants (Cooks)	OSHA	NIOSH	OSHA	NIOSH	OSHA	NIOSH	OSHA HC	NIOSH REL	Job classification, Season of High Exposure
Limited 1	14 (7)	69.1 (4.6)	77.8 (3.9)	68.3 (3.7)	77.3 (2.3)	70.1 (5.7)	78.2 (5.2)	0	0	-
Limited 2	35 (16)	72.1 (4.9)	79.2 (3.1)	71.8 (4.2)	79.4 (2.3)	72.3 (5.5)	78.9 (3.8)	0	0	-
Limited 3	15 (9)	68.9 (6.1)	78.3 (4.4)	69.1 (3.5)	78.2 (2.3)	68.8 (7.2)	78.4 (5.4)	2	3	Cashier/ Dishwasher, “not summer”
Full 1	30 (10)	70.3 (4.7)	78.7 (2.5)	73.8 (2.5)	80.7 (1.4)	68.3 (4.4)	77.5 (2.1)	0	0	-
Full 2	32 (4)	72.8 (6.5)	80.1 (4.0)	73.6 (2.9)	80.5 (2.3)	72.7 (6.9)	80.1 (4.2)	3	3	Waitresses, “not summer”
Full 3	44 (20)	75.5 (5.3)	82.1 (3.1)	79.3 (3.4)	84.4 (2.4)	72.3 (4.5)	80.2 (2.2)	1	8	Cooks, “not summer”

Table 6

Mean (Standard Deviation) 8-hour Projected Time-Weighted Average Personal Exposure (dBA), by Factor, Using OSHA and Modified NIOSH Settings

OSHA: 5 dB doubling rate, 80 dB threshold, 90 dB criterion			
Full-Service	73.2 (5.8)	Limited-Service	69.9 (6.1)
Cook	73.6 (5.2)	Not Cook	70.6 (6.3)
Weekday	70.6 (5.4)	Weekend	73.1 (6.9)
Summer	66.3 (5.1)	Not Summer	72.9 (7.0)

NIOSH: 3 dB doubling rate, 70 dB threshold, 85 dB criterion			
Full-Service	80.5 (3.5)	Limited-Service	78.6 (3.8)
Cook	80.8 (3.3)	Not Cook	79.1 (3.8)
Weekday	79.2 (3.3)	Weekend	80.4 (4.2)
Summer	79.0 (3.0)	Not Summer	80.7 (4.3)

Table 7

Comparison of Restaurant Worker Exposures by Season, Time of Week, Job Classification, and Restaurant Type

			Projected TWA, dBA			
Factor	**Level**	**n**	**Mean**	**SD**	**t-statistic**	**p**
Restaurant Type	Full-Service	107	80.5	3.5	3.57	<0.001
	Limited-Service	73	78.6	3.8		
Job Classification						
	Cook	66	80.8	3.3	−3.02	0.003
	Not Cook	114	79.1	3.8		
Time of Week						
	Weekday	103	79.2	3.3	−2.00	0.048
	Weekend	77	80.4	4.2		
Time of Year						
	Summer	99	79.0	3.0	−2.98	0.003
	Not Summer	81	80.7	4.3		

Table 8

Multiple Linear Regression Model

Predictor	Predictor Description	Coefficient (β)	Standard Error Coefficient	t	p
Constant		76.2	0.5	134.7	0.000
Restaurant Type	1 If full-service 0 If limited-service	2.3	0.5	4.6	<0.001
Job Classification	1 If cook 0 If “not” cook	1.9	0.5	3.8	<0.001
Time of Week	1 If weekend 0 If weekday	1.3	0.5	2.7	<0.001
Time of Year	1 If “not” summer 0 If summer	1.8	0.5	3.7	<0.001