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Noise Exposure Questionnaire: A Tool for Quantifying Annual Noise Exposure

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Abstract

Background: Exposure to both occupational and nonoccupational noise is recognized as a risk factor for noise-induced hearing loss (NIHL). Although audiologists routinely inquire regarding history of noise exposure, there are limited tools available for quantifying this history or for identifying those individuals who are at highest risk for NIHL. Identifying those at highest risk would allow hearing conservation activities to be focused on those individuals.

Purpose: To develop a detailed, task-based questionnaire for quantifying an individual's annual noise exposure (ANE) arising from both occupational and nonoccupational sources (aim 1) and to develop a short screening tool that could be used to identify individuals at high risk of NIHL (aim 2).

Research Design: Review of relevant literature for questionnaire development followed by a cross-sectional descriptive and correlational investigation of the newly developed questionnaire and screening tool.

Study Sample: One hundred fourteen college freshmen completed the detailed questionnaire for estimating ANE (aim 1) and answered the potential screening questions (aim 2). An additional 59 adults participated in data collection where the accuracy of the screening tool was evaluated (aim 2).

Data Collection and Analysis: In study aim 1, all participants completed the detailed questionnaire and the potential screening questions. Descriptive statistics were used to quantify participant participation in various noisy activities and their associated ANE estimates. In study aim 2, linear regression techniques were used to identify screening questions that could be used to predict a participant's estimated ANE. Clinical decision theory was then used to assess the accuracy with which the screening tool predicted high and low risk of NIHL in a new group of participants.

Results: Responses on the detailed questionnaire indicated that our sample of college freshmen reported high rates of participation in a variety of occupational and nonoccupational activities associated with high sound levels. Although participation rates were high, ANE estimates were below highest-risk levels for many participants because the frequency of participation in these activities was low in many cases. These data illustrate how the Noise Exposure Questionnaire (NEQ) could be used to provide detailed and specific information regarding an individual's exposure to noise. The results of aim 2 suggest that the screening tool, the 1-Minute Noise Screen, can be used to identify those participants with high- and low-risk noise exposure, allowing more in-depth assessment of noise exposure history to be targeted at those most at risk.

Conclusions: The NEQ can be used to estimate an individual's ANE and the 1-Minute Noise Screen can be used to identify those participants at highest risk of NIHL. These tools allow audiologists to focus hearing conservation efforts on those individuals who are most in need of those services.

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Key Words: hearing loss, noise, noise induced, screening, self-report

Abbreviations: ABR = auditory brainstem response; ANE = annual noise exposure; A_{ROC} = area under the relative operating characteristic curve; EPA = Environmental Protection Agency; HPD = hearing protection device; L_{Aeq24h} = continuous sound level averaged over 24 hours using a 3-dB exchange rate and A-weighted sound levels; $L_{Aeq2000h}$ = continuous sound level averaged over 2000 hours using a 3-dB exchange rate and A-weighted sound levels; $L_{Aeq8760h}$ = continuous sound level averaged over 8760 hours using a 3-dB exchange rate and A-weighted sound levels; NEQ = Noise Exposure Questionnaire; NIHL = noise-induced hearing loss; NIOSH = National Institute for Occupational Safety and Health; OSHA = Occupational Safety and Health Administration; REL = recommended exposure limit; SE = standard error; TTS = temporary threshold shift

INTRODUCTION

Noise-induced hearing loss (NIHL) is a common condition in the United States, with an estimated 15% of Americans aged 20–69 yr, or 26 million individuals experiencing hearing loss due to noise exposure encountered during occupational or leisure activities (NIDCD, 2008). Noise exposure may first cause only a temporary worsening of hearing, called a temporary threshold shift (TTS). Repeated exposure to loud sound eventually leads to permanent threshold shift, when the auditory system is so severely damaged that it can no longer recover. Traditional views of TTS include the idea that, if thresholds return to normal, no permanent damage has been done. Recent data from animal models have challenged this viewpoint. Kujawa and colleagues induced TTS in mouse (Kujawa and Liberman, 2009) and guinea pig (Lin et al, 2011). Histology was completed on the animals following full TTS recovery (as measured by recovery of distortion-product otoacoustic emission and auditory brainstem response [ABR] thresholds). Results indicated permanent loss of up to 50% of synapses between inner hair cells and afferent auditory nerve fibers in the frequency region that experienced the greatest TTS. Recent data suggests a similar mechanism may be operating in human ears (Stamper and Johnson, 2015). These data provide evidence suggesting noise exposures resulting in TTS have the potential to lead to permanent damage in the inner ear even though hearing thresholds for pure-tone stimuli are normal.

Although NIHL is widespread and noise exposure may be more hazardous than previously believed, noise exposure is widely recognized as one of the leading preventable causes of hearing loss (Dobie, 2008). Indeed, decreasing the prevalence of NIHL is a goal of the Healthy People 2020 initiative (Healthy People 2020, n.d.). One strategy that might help meet this goal is to target people who are at greatest risk for developing NIHL and focus hearing conservation efforts accordingly.

A variety of regulatory agencies have made recommendations for noise exposure limits, primarily for workplace exposure. The selection of an exposure limit typically depends on defining a maximum acceptable hearing loss over a lifetime and determining the percentage of the noise-exposed population for which the maximum acceptable hearing loss will be tolerated (NIOSH, 1998; Suter, 2000). Three agencies that have issued recommendations for exposure limits are the Occupational Safety and Health Administration (OSHA), the National Institute for Occupational Safety and Health (NIOSH), and the U.S. Environmental Protection Agency (EPA). The exposure limits issued by each of these agencies take into account three parameters related to the exposure: level ("how loud"), frequency ("how often"), and duration ("how long").

Typically, OSHA and NIOSH recommendations are applied to an occupational setting where recommendations are based on an 8-hr work day over the course of a 40-yr working lifetime. OSHA's permissible exposure limit is 90 dBA with a 5-dB exchange rate (e.g., 90 dBA for 8 hr, 95 dBA for 4 hr). Adherence to the OSHA limits could result in hearing impairment for 25% of the working population over a 40-yr working lifetime (NIOSH, 1998). NIOSH's recommended exposure limit (REL) is more conservative at 85 dBA with a 3-dB exchange rate (e.g., 85 dBA for 8 hr, 88 dBA for 4 hr). NIOSH estimates that adherence to these limits could result in hearing impairment in 8% of the working population (NIOSH, 1998). The EPA specifies a REL of 70 dBA over the course of the entire year (not restricted to working hours). Adherence to the EPA limit is intended to protect the entire population (EPA, 1974) and is considered a safe level for protection from hearing loss (Hammer et al, 2014).

The NIOSH and OSHA limits were designed for occupational settings; however, noise exposure is not limited to the workplace. Many nonoccupational activities can reach sound levels that have the potential to be damaging to the auditory system. Neitzel, Sexias, Goldman, et al (2004) surveyed sound levels reported in the literature for various leisure and recreational activities, including operating equipment (e.g., power tools, motorcycles, snowmobiles, and light aircraft), and attendance at loud recreational events (e.g., rock concerts or commercial sporting events). Based on this literature survey, Neitzel et al obtained the range of levels encountered for common recreational activities and computed an average level for each activity. The average level was >90 dBA for all activities. This suggests some recreational activities are associated with sound levels that may be hazardous, particularly if the activity is engaged in regularly or when combined with occupational noise exposure.

More recently, Flamme et al (2012) collected exposure data from a sample of 210 men and 76 women. Participants wore dosimeters for extended time periods ranging from 23 hr to 20 days, with a median of 9.8 days. Because the participants wore the dosimeters continuously, the data reflect both occupational and nonoccupational exposures. The Flamme et al data indicated that 65–70% of participants exceed the EPA REL while ~7% of women and 18% of men exceeded the NIOSH limit. Although the Flamme et al data did not directly assess the source of noise exposure, it appears that, for many participants, occupational noise was a substantial contributor to exposure levels, even though the study did not target participants working in traditionally noisy occupations. Flamme et al note that it was necessary to sample exposure over a time period of ≥1–2 wk to capture infrequent, high-level exposures.

Although it is clear that sound levels for some recreational activities may be hazardous and it is widely recognized that exposure to all noise sources (occupational and nonoccupational) is cumulative, few studies have attempted to characterize exposures for nonoccupational noise (Carter et al, 2014). The most detailed information on nonoccupational noise comes from studies conducted at the University of Washington as part of a multiyear evaluation of noise exposure in the construction industry (Seixas, 2004). This project included evaluation of the contribution of nonoccupational noise exposures to NIHL risk for 112 apprentice construction workers. Neitzel, Seixas, Goldman, et al (2004) and Neitzel, Seixas, Olson, et al (2004) used a variety of approaches to quantify workers' exposure, including a task-based approach where the workers completed a detailed questionnaire describing their participation in a variety of activities over the previous year. The task-based approach used by Neitzel et al is an extension of the original application of the task-based exposure assessment model described by Stephenson (1995), where activities are broken into specific tasks that have specific associated sound-exposure values. Responses on the Neitzel questionnaire were used to provide an estimate of annual nonoccupational exposure by using the sound levels associated with each of these activities (as determined through the literature survey described earlier) and integrating them into an exposure level (dBA). Based on this work, Neitzel, Seixas, Goldman, et al (2004) reported that 19% of apprentice workers had nonoccupational noise exposures that exceeded the NIOSH REL of 85 dBA. In other words, 19% of apprentice workers reported participation in leisure activities that exceeded what was considered to be safe per NIOSH occupational recommendations; this was in addition to being in a loud work environment on a regular basis.

Although the Neitzel, Seixas, Goldman, et al (2004) data suggest that a task-based questionnaire could be used to estimate noise exposure, it was not clear from their data if participants could recall their activities with sufficient precision to provide an accurate estimate of their actual exposure levels, as measured by dosimetry. To address this question, Reeb-Whitaker et al (2004) assessed the relationship between exposure levels obtained via a task-based recall questionnaire of workplace activities occurring 6 mo prior and the dosimetry measures taken from those participants on the same day. Although the sound level estimates obtained from both the task-based recall and the dosimetry were not identical, there was a strong correlation between the two ($r = 0.77$), with an average difference between the two exposure-level estimates of ~2 dB. Based on these findings, the authors concluded that construction workers were able to accurately report past noise exposures using the task-based recall questionnaire approach.

A task-based questionnaire for quantifying noise exposure has also been used with professional symphony musicians (Schmidt et al, 2014) and for quantifying other occupational hazards such as exposure to fumes (Susi et al, 2000) or repetitive work tasks (Fallentin et al, 2001). It is impractical to have members of the general population wear dosimeters for long periods of time to assess their occupational *and* nonoccupational exposures. Therefore, the development of a task-based questionnaire for use in the general population is one possible way to assist clinicians with targeting hearing conservation efforts to individuals who may be at highest risk for NIHL. Because the Neitzel, Seixas, Goldman, et al (2004) questionnaire only queries nonoccupational exposures and the Schmidt et al (2014) questionnaire can only be used to query workplace exposures for a very specific group (symphony musicians), a more general task-based questionnaire is needed.

The purpose of this project was to develop a task-based questionnaire to quantify noise exposure history in the general public by querying both occupational and nonoccupational exposures. This metric could be used by clinicians and researchers to identify individuals at risk for NIHL. The second objective was to establish a subset of questions from the task-based questionnaire that could be used to screen for individuals who are at higher risk for NIHL and, therefore, might benefit from a more in-depth assessment of their noise exposure history.

METHODS

Participants

A sample of 114 college freshmen (18–19 yr old) participated in the first aim of the study, 49 males and 65 females. Students from local colleges were recruited with the assistance of introductory-level course instructors. An additional 59 participants (19 males, 40 females) were recruited to participate in activities where the accuracy of a screening model was evaluated. These additional participants were 19–30 yr old. All study procedures were approved by the University of Kansas Medical Center Institutional Review Board.

Aim 1: Development of the NEQ

Questionnaire Overview

Each participant completed the self-administered NEQ (Appendix 1), which required ~10 min to complete. Participants were asked to recall participation in specific noisy activities during the past year. A 1-yr time period was chosen to capture noisy activities that are seasonal and infrequent (e.g., hunting, snowmobiling, attending sporting events). The NEQ consisted of three sections: (a) basic demographic information (gender and age), (b) six potential screening questions for determining individuals with high-risk noise exposure (Q 1–6), and (c) eleven detailed questions related to participation in loud, noisy activities used to quantify the annual noise exposure (ANE) (Q 7–17).

The NEQ was based on the task-based questionnaire described in Neitzel, Seixas, Goldman, et al (2004) but differed in several ways. First, two questions (Q 16–17) pertaining to occupational noise exposure (school year and summer) were inserted. Secondly, questions pertaining to playing a musical instrument (Q 13) and music listening via earphones (Q 14) or speakers (Q 15) were incorporated. Finally, response options were added to each question to query, on average, how many hours each noisy activity lasted.

Calculation of the ANE Estimate

Protocols used to compute the ANE estimate for each participant were based on those previously described by Neitzel, Seixas, Goldman, et al (2004). In this approach, episodic (occasional) and routine (daily) exposures are calculated separately and then combined to produce an overall ANE estimate. Examples of activities that would be considered episodic exposures in this approach include the use of power tools and heavy machinery, attendance at loud sporting or entertainment events, and playing or listening to music. In contrast, routine exposures include daily actions not readily associated with high-risk noise exposures such as sleeping, reading, computer work, travel by bus or car, and shopping. The frequency of participation in each episodic noise activity was gathered from NEQ responses.

Representative sound levels for each episodic exposure activity queried were determined by a review of the available literature and are summarized in Table 1. Studies included in the determination of sound levels for each activity were drawn from several sources. For those activities queried by Neitzel, Seixas, Goldman, et al (2004), the studies and associated sound levels they reported were used. For those activities not queried by Neitzel et al, we surveyed the relevant literature. In order for sound levels from a study to be included, the study was required to report A-weighted sound levels measured at appropriate distances and representative (not maximum) sound levels. These are the same inclusion criteria used by Neitzel et al. For studies meeting these inclusion criteria, the "low" values reported in Table 1, represent the mean of the lowest sound levels reported for the activity across studies. Likewise, the "high" values represent the mean of the highest reported sound levels. The "mid" values are the mean of the high and low values.

For purposes of the present study, estimates of each participant's ANE were expressed in $L_{Aeq8760h.}$ In this metric, "L" represents sound pressure level in dB, "A" represents use of an A-weighted frequency response, "eq" represents a 3-dB exchange rate for calculation of the time/level relationship, and "8760h" represents the total duration of the noise exposure in hours (24 hr/day × 365 days/yr).

Figure 1 provides an overview of the ANE exposure computation. Using NIOSH-recommended formulas (NIOSH, 1998) and following the approach used by Neitzel, Seixas, Goldman, et al (2004), doses were computed for each of the episodic, continuous-noise exposure activities queried on the NEQ (Q 7–11 and 13–17, Appendix 2) and for routine exposure activities using the following equation:

$$D=\left[\frac{C}{T}\right]\times 100$$

Here, C refers to the number of hr/yr reported by the participant for the activity. Frequency of participation responses on the NEQ were assigned values as follows: "daily" = 200, "weekly" = 50, "monthly" = 12, "every few months" = 1, and "never" = 0. Similarly, for duration responses, the values were as follows: "≥8 hr" = 8, "4–8 hr" = 6, "1–4 hr" = 3, and "<1 hr" = 1. The frequency of participation and duration values were multiplied to arrive at the episodic frequency value, or C. The calculation of C for routine exposure activities is 8,760 minus the combined episodic values across all episodic exposures. In other words, C for routine exposures is the number of hours in a year not spent in noisy, episodic activities. The NEQ queries one additional episodic activity (Q 12, Appendix 1) whose value is not included in the computation of D. This activity, firearm use, is associated with impulse-noise exposure. Because there currently is no accepted protocol for integrating impulse-noise exposures with the continuous-noise exposures queried for other questions, firearm

Table 1. Sound Levels Obtained from Review of the Literature for Various Episodic Noise Activities Queried on NEQ

Q No.	Noise Activity Category and Description of Activities	Representative L_{Aeq} (dBA) Levels from Literature: Low	Mid	High	References
For the following: representative dBA levels were identified by Neitzel, Seixas, Goldman, et al (2004); references used by Neitzel, Seixas, Goldman, et al (2004) listed for each category.					
7	Power tools: use power tools, chainsaws, other shop tools, outside of a paid job	75	94	113	Cohen et al, 1970; U.S. Office Noise Abatement and Control, 1978; McClymont and Simpson, 1989
8	Equipment/machinery: drive heavy equipment, use loud machinery (such as tractors, trucks, or farming or lawn equipment like movers/leaf blowers), outside of a paid job	87	97	106	Jones and Oser, 1968; U.S. Office Noise Abatement and Control, 1978; Holt et al, 1993
9	Sporting/entertainment: attend car/truck races, commercial/school sporting events, music concerts/dances, and any other events with amplified public announcement/music systems	81	94	106	Cohen et al, 1970; Yassi et al, 1993; Axelsson, 1996; Roberts, 1999
10	Motorized vehicles: ride/operate motorized vehicles such as motorcycles, jet skis, speed boats, snowmobiles, or four-wheelers	88	98	107	Cohen et al, 1970; Bess and Poynor, 1974; U.S. Office Noise Abatement and Control, 1978; Ross, 1989; Anttonen et al, 1994; McCombe et al, 1994
11	Aircraft: ride/pilot small aircraft/private airplanes	88	91	94	Tobias, 1969; Cohen et al, 1970; Smith et al, 1975
For the following: not addressed by Neitzel, Seixas, Goldman, et al (2004); representative dBA levels identified by authors' review of literature					
13	Musical instrument: play a musical instrument	74	87	99	O'Brien et al, 2008; Chasin, 2009
14	Music listening (earphones): listen to music, radio programs, etc. using personal headsets or earphones	60	76	93	Rice et al, 1987; Airo et al, 1996; Fligor and Ives, 2006; Portnuff et al, 2009; Smith et al, 2000; Williams, 2005; Worthington et al, 2009
15	Music listening (other speakers): listen to music, radio programs, etc. from audio speakers in a car or at home (other than music concerts and earphone use)	70	78	85	Neitzel, Seixas, Olson, et al, 2004; Neitzel, personal communication, 2009*
16 and 17	Occupational noise: work a noisy paid job during summer or school year	80	90	100	Lempert and Henderson, 1973; OSHA, 1981**
For the following: impact-type noise cannot be included in annual L_{Aeq} exposure calculation					
12	Firearms: around/shoot firearms such as rifles, pistols, shotguns.	Nonapplicable (impact noise cannot be integrated into annual L_{Aeq})			

Notes: *Personal communication from Neitzel (2009) indicated the range for music listening in Neitzel, Seixas, Olson, et al (2004) was 70–85 dBA. **Due to OSHA requirements, occupational data are computed using a 5-dB exchange rate; therefore, 5-dB exchange rate data were included to represent the range of typical noisy job exposures. The discrepancy between 3- and 5-dB exchange rates is expected to be small for most occupational situations, 1–3 dB (Royster et al, 2000).

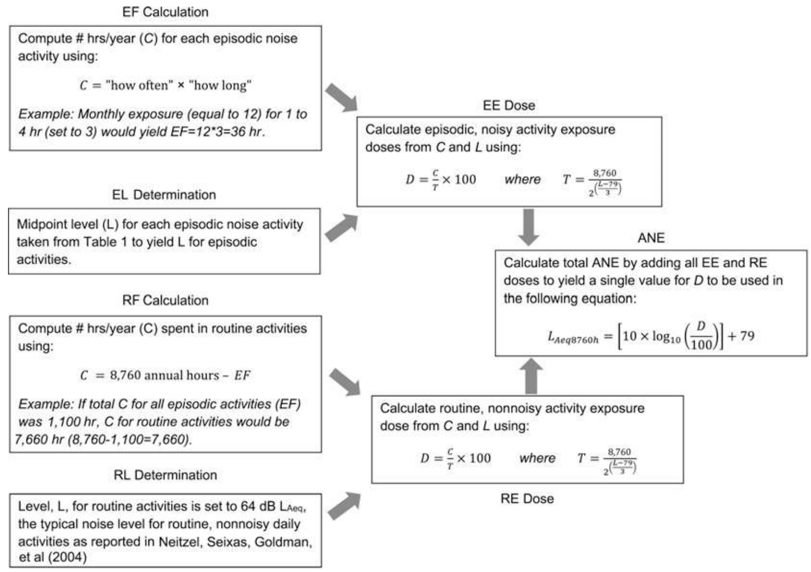

Figure 1. Overview of the computation of ANE in $L_{Aeq8760h}$ from responses to NEQ. These procedures follow protocols described by Neitzel, Seixas, Goldman, et al (2004) and noise exposure calculations extrapolated from those recommended by NIOSH (1998) for computing occupational exposures for a 40-hr work week. EE = episodic exposure; EF = episodic frequency; EL = episodic level; RE = routine exposure; RF = routine frequency; RL = routine level. *"Frequency" refers to "how often."

exposures were not included in the dose calculation and will be described separately.

T represents the number of hr/yr at which the activity is considered hazardous using our REL over a 1-yr time period. It is calculated using the following equation, with L representing the "mid" values listed in Table 1:

$$T = \frac{8,760}{2^{\left(\frac{L-79}{3}\right)}}$$

These computations will yield ten episodic exposure doses and one routine exposure dose. Individual doses can be added arithmetically to result in a final ANE dose (see Appendix 2 for an example calculation). This total dose, D, is subsequently used in the following equation to calculate ANE:

$$L_{\text{Aeq8760h}} = \left[10 \times \log_{10}\left(\frac{D}{100}\right)\right] + 79$$

Determination of NIHL Risk

The NIOSH REL, or 100% dose, for occupational settings is 85 dBA, weighted over 2,000 hr with a 3-dB exchange rate, or 85 $L_{Aeq2000h}$. This limit represents hearing risk from occupational noise exposures over a typical work year (8 hr/day × 250 workdays/yr). For purposes of assessing annual exposures consisting of both occupational and nonoccupational sources, it is necessary to consider an entire year's time, or 8,760 hr (24 hr/day × 365 days). The U.S. EPA recommends an annual exposure limit of 70 dBA to prevent hearing loss in the entire population (EPA, 1974). The purpose of the current study, however, was to identify individuals at highest risk of NIHL. Therefore, we referenced the NIOSH occupational noise limit of 85 $L_{Aeq2000h}$ (NIOSH, 1998). Using the recommended 3-dB exchange rate, we extrapolated the NIOSH REL of 85 $L_{Aeq2000h}$ to an annual equivalent exposure limit of 78.6 $L_{Aeq8760h}$. For purposes of our study, participants with $L_{Aeq8760h}$ values of ≥79 were considered to be at highest risk for developing NIHL.

Statistical Approach

The kappa test was used to determine intratest reliability of the NEQ by analyzing responses to repeated questions about firearm use and working a noisy job. Descriptive statistics were used to quantify participant participation in noisy activities and their associated ANE.

Aim 2: Development of the 1-Minute Noise Screen

Six screening questions (Q 1–6) were used as potential predictors of high-risk noise exposure. The first three items (Q 1–3) pertained to time spent firing guns, working a noisy job, and exposure to any other type of loud sounds (e.g., power tools, lawn equipment, and loud music). Firearms and occupational noise are generally considered to pose the greatest risk to hearing (Johnson and Riffle, 1982; Franks et al, 1989; Neitzel, Seixas, Goldman, et al, 2004; Neitzel, Seixas, Olson, et al, 2004; Fligor, 2010). The next three potential screening items (Q 4–6) addressed the presence of common physiologic symptoms related to noise exposure: tinnitus, temporary hearing loss/TTS, and pain, fullness, or discomfort of the ears following exposure to loud sounds. These ear/hearing symptoms were selected as potential screening questions because they are generally accepted to be among the most common physiologic indicators of harmful noise exposure (Dobie, 2001; Ward et al, 2000).

Statistical Analysis

Multiple linear regression analyses were used to test the ability of each of the six screening questions (singly and in combination) to predict ANE values in $L_{Aeq8760h}$. Accuracy of the screening model identified from the regression analysis was assessed using clinical decision theory (Swets and Pickett, 1982; Swets, 1988).

RESULTS

Aim 1: Development of the NEQ

Reliability

To test the internal consistency of the NEQ, intraparticipant reliability was assessed using repeated questions regarding the regularity of firearm exposure (Q 1, 12) and working a noisy job (Q 2, 16, 17). Kappa statistics of agreement across these matched data were 0.871 ($p < 0.001$) for firearms and 0.590 for noisy jobs ($p < 0.001$), which represents almost perfect and moderate agreement for firearms and noisy jobs, respectively (Landis and Koch, 1977). Therefore, the NEQ was considered to be a reliable indicator of participants' noise activities.

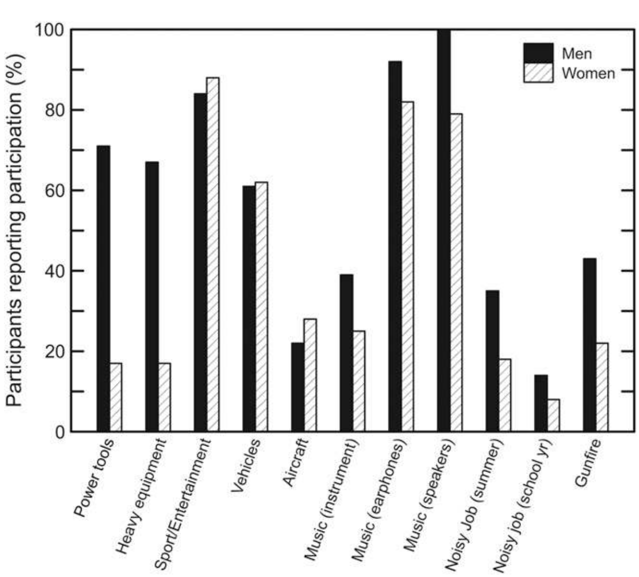

Figure 2. Percentage of participants reporting participation in each of the ten continuous-noise activities and one impulse-noise activity queried on the NEQ in aim 1. Results for men and women are displayed separately, as indicated in the legend.

Participation in Episodic Noise Activities

Participant responses to the NEQ provide information regarding the noise sources and activities to which these 18- and 19-yr-old participants were exposed in the previous year. Figure 2 and Table 2 provide a summary of these data for our sample. Figure 2 shows the reported involvement in the eleven episodic activities included in the NEQ (ten continuous-type noise activities and one impulse-type noise activity). Data are reported separately for men and women in Figure 2, but are described here as a combined sample. Music listening received the highest rate of participation, with 86% reporting listening to music via earphones and 98% listening to music via speakers. Commercial sporting/entertainment event attendance was also high at 86%. Use of recreational motorized vehicles was reported by 61% of participants. Occupational noise exposures were less frequent, with 25% of participants reporting working a noisy summer job and 11% working a noisy school year job. Participation in other continuous-type episodic noise activities varied, with 25% reporting flying in small/private aircraft during the past year, ~40% reporting using power tools or heavy equipment, and 31% reporting playing a musical instrument. For impulse-type episodic noise, 31% of participants reported exposure to gunfire. In general, women reported less exposure to power tools, heavy equipment/machinery, firearms, and occupational noise than men. These data suggest many of our participants participated in activities associated with high sound levels.

An additional, and perhaps more important, parameter to consider is the amount of time spent in the activity. Table 2 presents episodic frequency of participation data overall and summarized for broad general categories of continuous-type episodic noise: noisy general recreational activities (power tools, equipment/machinery, sporting/entertainment events, motorized vehicles, aircraft), music-related activities, and job-related noise activities. This group of college freshmen reported far more hours per year spent in music-related activities (mean = 765 hr/yr) than spent participating in noisy general recreational activities (mean = 119 hr/yr) or working a noisy job (mean = 148 hr/yr). The total time spent across all continuous-type episodic activities ranged from 5 to 2,985 hr/yr, with a mean of 1,032 hr/yr (or ~20 hr/wk). Overall, men reported more hours engaged in noisy activities than women (1,217 and 893 hr/yr, respectively). For impulse-type episodic noise (not shown in Table 2), men reported more shots/yr than women for firearms (193 versus 26). While a high percentage of participants in this study reported participating in various noisy

Table 2. Episodic Frequency* (EF) and Routine Frequency* (RF) Overview

Activity category (continuous-type noise)		Range	10th Percentile	50th Percentile	90th Percentile	Mean
Episodic activities						
General recreational activities	All participants	0–903	0	39	309	119
(power tools, equipment/machinery,	Men	0–903	0	153	639	202
sporting/entertainment events,	Women	0–408	0	10	157	56
motorized vehicles, aircraft)						
Music-related activities (playing	All participants	0–1,950	153	643	1,400	765
musical instrument, music listening	Men	2–1,800	153	653	1,800	800
earphones, music listening speakers)	Women	0–1,950	163	636	1,350	739
Occupational noise activities (noisy	All participants	0–1,550	0	0	500	148
summer job, noisy school year job)	Men	0–1,250	0	0	870	214
	Women	0–1,550	0	0	400	98
Overall EF: hours per year for all	All participants	5–2,985	205	862	2,050	1,032
continuous-type episodic activities	Men	5–2,985	239	896	2,480	1,217
combined	Women	54–2,959	187	807	1,649	893
Routine activities						
Overall RF: hours per year spent in	All participants	5,775–8,755	6,710	7,899	8,555	7,728
routine/everyday, nonnoisy activities	Men	5,775–8,755	6,280	7,864	8,521	7,543
(calculated for each participant by	Women	5,801–8,706	7,111	7,953	8,573	7,868
subtracting participant's EF from						
8,760 total hours per year)						

Notes: Number of hours per year reported for broad categories of continuous-type episodic noise activities and routine (everyday) activities.
*"Frequency" refers to "how often."

activities, the number of hours (episodic frequency) spent in each of these activities was fairly low.

Participation in Routine Activities

Table 2 also includes a summary of participation in routine, nonnoisy activities. For our purposes, routine activities were considered to be those daily activities not readily associated with risk of high noise exposure. These activities included time spent at home engaged in eating, sleeping, reading, computer/television use, travel by bus/car, shopping, or eating at a quiet restaurant. Routine activities would also include any other activity not considered to be associated with high noise levels and not specifically queried on the NEQ. The number of hours spent in these activities (routine frequency) was calculated as 8,760 hr minus the participant's reported episodic frequency of participation hr. As a direct reflection of the calculated episodic frequency of participation values for this group of participants, overall routine frequency of participation data ranged from 5,775 to 8,755 hr/yr, with a mean of 7,728 hr/yr (or ~149 hr/wk). As expected, men spent less time in routine (nonnoisy) activities than woman (mean of 7,543 hr/yr versus 7,868 hr/yr). Overall, although participants reported a high rate of participation in noisy activities, hr/yr spent engaged in episodic noise activities were much less than the number of hr/yr spent in routine (nonnoise) daily activities.

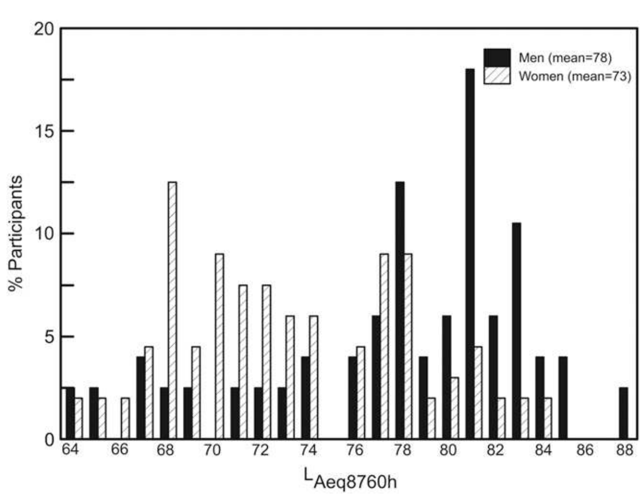

Figure 3. Distribution of ANE values in $L_{Aeq8760h}$ for the participants participating in aim 1. Results for men and women are displayed separately, as indicated in the legend.

ANE Values

ANE values were calculated for each participant by combining the episodic exposure values for nonimpulse-noise categories (i.e., all episodic categories except gunfire) with routine exposure values according to the methods described earlier. An example of the ANE calculation for an individual participant is given in Appendix 2.

Figure 3 and Table 3 show the range of ANE values for all participants. If a participant reported minimal or no participation in episodic noise activities, then routine

Table 3. ANE for All Participants

	ANE ($L_{Aeq8760h}$)				
	Range	10th Percentile	50th Percentile	90th Percentile	Mean
All participants	64–88	68	77	83	75
Men	64–88	68	80	83	78
Women	64–84	68	72	80	73

exposures would form the basis of their ANE, resulting in an annual exposure of 64 $L_{Aeq8760h}$ (the minimum possible value). ANE values for the group ranged from 64 to 88 $L_{Aeq8760h}$ with a mean of 75 $L_{Aeq8760h}$. The mean ANE was higher in men than women (78 $L_{Aeq8760h}$ versus 73 $L_{Aeq8760h}$). This was expected, given men reported more frequent participation in high-level episodic noise activities, such as the use of power tools and heavy equipment.

Determination of "Highest Risk" Noise Exposures

The determination of what $L_{Aeq8760h}$ value is considered "high risk" varies depending on which criterion is used to assess risk. Basing extrapolated annual risk on an occupational criterion such as NIOSH (1998) results in values ≥79 $L_{Aeq8760h}$ being considered highest risk. The EPA considers ANE values ≥71 $L_{Aeq8760h}$ as high risk. Table 4 summarizes the number and percentage of participants in the current study who met the highest-risk criteria for NIHL based on their responses to the questionnaire. As expected, when using the higher cutoff of 79 $L_{Aeq8760h}$, a smaller number of participants are considered at high risk for NIHL when compared to the EPA criterion. Because unprotected exposure to gunfire is generally considered to pose a risk to hearing (e.g., Dobie, 2001; Neitzel, Seixas, Goldman, et al, 2004; Neitzel, Seixas, Olson, et al, 2004; Fligor, 2010), Table 4 also lists participants who reported firearm exposure, regardless of whether the participants reported wearing hearing protection. We will return to the issue of hearing protection in the discussion.

Aim 2: Development of the 1-Minute Noise Screen

The second objective of this study was to develop a set of screening questions that could be used to identify individuals at high risk for NIHL. This could be of interest to clinicians in busy practices and school settings because it would allow them to more quickly identify individuals likely to be highest risk who would benefit from a more in-depth assessment of their ANE.

The six potential screening questions (Q 1–6) were evaluated for their ability to predict self-reported noise exposure (i.e., as defined by the ANE value). Multiple linear regression analyses revealed that a model consisting of all six screening questions was statistically significant ($F = 12.65$; $p < 0.001$). The r^2 value indicated that ~42% ($r^2 = 0.415$) of the variance in ANE could be accounted for by the six screening questions. However, only three items significantly contributed to the overall model. These three variables included firearm usage (Q 1; $p = 0.001$, $B = 2.24$, standard error [SE] = 0.65), working a noisy job (Q 2; $p = 0.000$, $B = 1.56$, SE = 0.34), and exposure to any other loud noise (Q 3; $p = 0.002$, $B = 1.36$, SE = 0.43). As expected, the relationship between these variables was positive, indicating that increasing frequency of participation in these noisy activities was associated with increasing ANE.

In contrast, the three screening items that assessed the rate at which auditory symptoms were experienced (Q 4: tinnitus, Q 5: TTS, or Q 6: other ear symptoms) were not found to be significant predictors of ANE. Two symptoms, TTS and other ear symptoms, showed a negative relationship with the high-risk measure. In other words, for these participants a higher occurrence of these symptoms was associated with lower ANE values, although this relationship was not statistically significant ($p > 0.05$).

Based on the results of the regression analyses, the following questions were selected for inclusion in the 1-Minute Hearing Screen: Q 1, gunfire usage ($p < 0.001$, $B = 2.40$, SE = 0.62); Q 2, noisy job ($p < 0.001$,

Table 4. Participants Meeting High-Risk Criteria for NIHL

		Participants Meeting Criteria		
		All Participants (n = 114)	Men (n = 49)	Women (n = 65)
Current study (≥79 $L_{Aeq8760h}$)	Count	36	27	9
	Percentage	32	55	14
EPA (≥71 $L_{Aeq8760h}$)	Count	85	43	42
	Percentage	75	88	65
Firearm exposure	Count	35	21	14
	Percentage	31	43	22

$B = 1.50$, SE = 0.33); Q 3, any other loud noise ($p = 0.003$, $B = 1.23$, SE = 0.41). Screening items based on symptoms (tinnitus, temporary shift in hearing, and ear pain/fullness/other symptom) were rejected due to insufficient association with $L_{Aeq8760h}$. The final regression model indicated that these three screening questions were able to account for 40% of the variance ($r^2 = 0.400$, $p \leq 0.0001$) in $L_{Aeq8760h}$.

Sensitivity and Specificity of the 1-Minute Noise Screen

While the regression model containing Q 1–3 described earlier was statistically significant, clinical decision theory (Swets and Pickett, 1982; Swets, 1988) was used to evaluate the accuracy with which the 1-Minute Noise Screen could be used to screen for participants at highest risk for NIHL. To complete this analysis, data were collected from a new group of 59 participants. These participants completed both the 1-Minute Noise Screen (Q 1–3) and the full, detailed NEQ (Q 7–17). This yielded a screening score for each participant that could be compared to the $L_{Aeq8760h}$ value obtained from the full NEQ. Here, the subject's $L_{Aeq8760h}$ value is considered the gold standard for determination of NIHL risk. Using our cutoff for exposure limit, participants with $L_{Aeq8760h}$ values ≥79 were considered highest risk. Screening scores were generated by assigning numerical values to each of the five possible response alternatives on the screening questions (never = 0, every few months = 1, monthly = 2, weekly = 3, and daily = 4). By obtaining a mathematical sum, a screening score was generated (0–12) and evaluated for its ability to predict the $L_{Aeq8760h}$ value.

When using the screening score to predict risk based on the $L_{Aeq8760h}$ value, the area under the relative operating characteristic curve (A_{ROC}) was 0.937, significantly better than chance ($p < 0.0001$). This suggests that the screening score can be used to identify those participants at highest risk for NIHL. Table 5 lists sensitivity and specificity values for several possible screening scores. A screening score of ≥5 provides the best balance between sensitivity and specificity. However, it is possible to choose other scores to indicate risk according to the needs of a given population. For example, a screening score of ≥3 could be chosen to indicate risk in cases where it is more important to identify individuals who may be at highest risk of NIHL than it is to reduce the number of individuals who complete the detailed NEQ but do not have high $L_{Aeq8760h}$ values. In this scenario, the high sensitivity obtained for a screening score of 3 was prioritized over the lower specificity.

Table 5. Sensitivity and Specificity Values for Several Possible Screening Scores

Screening Score	Sensitivity	Specificity
≥3	1.00	0.596
≥4	0.917	0.702
≥5	0.917	0.830
≥6	0.833	0.894

Note: A score greater than or equal to the screening score value would be interpreted as positive for noise exposure exceeding our criterion for highest risk ($L_{Aeq8760h}$ ≥79).

DISCUSSION

Quantification of ANE

The data reported here describe the development of a task-based questionnaire that can be used to quantify an individual's ANE. The NEQ differs from other similar questionnaires that have been developed (i.e., Neitzel, Seixas, Goldman, et al, 2004; Schmidt et al, 2014) by querying both occupational and nonoccupational exposures and by being applicable to the general population. One potential advantage of using a questionnaire like the NEQ to query history of noise exposure is that the respondents are asked to report not only participation in noisy activities but also to quantify the time spent in those activities. It is the combination of sound level and duration that increases a participant's risk. It is difficult to fully ascertain an individual's risk through standard case history approaches. These typically focus on whether a person participates in noisy activities but typically do not systematically quantify the time spent in these activities or the level to which the individual is exposed during each activity.

An example of this is that, although reported participation in episodic noise activities, such as music listening under earphones, is commonly viewed as evidence that young people are exposed to a great deal of noise, simple rates of participation miss the more important combination of both sound level and duration or regularity of exposure. In our sample (aim 1), listening to music through earphones was reported by 86% of participants and represents an activity with high frequency of participation (mean of 250 hr/yr), but a relatively low sound level (mean typical listening level of 76 L_{Aeq}). Listening to music via earphones would, therefore, contribute only a 1.5% dose to an individual's overall ANE calculation. In contrast, operating heavy machinery such as tractors or lawn equipment carries a relatively low participation frequency (mean for our group was 20 hr/yr) but high sound level (mean typical sound level of 97 L_{Aeq}). Exposure to heavy equipment/machinery for only 20 hr/yr would contribute a much higher dose, 15%, to an individual's ANE calculation. Therefore, when estimating an individual's risk of developing NIHL, it is imperative that both sound level and exposure time be taken into account.

When compared to reports in the literature, our overall ANE results (mean for all participants $L_{Aeq8760h}$ = 75, see Table 3) are comparable to the available 24-hr L_{Aeq} studies. Investigations of daily nonoccupational noise exposures of adults in the United States have resulted in mean values of 74–77 L_{Aeq24h} (Schori and McGatha, 1978; Berger and Kieper, 1994; Banach and Berger, 2003; Thompson et al, 2003; Neitzel, Seixas, Olson, et al, 2004). Studies outside the United States have yielded similar results, 73–76 L_{Aeq24h} (Kono et al, 1982; Garcia and Garcia, 1993; Zheng et al, 1996). Our data are also comparable to the annual nonoccupational exposures reported by Neitzel, Seixas, Goldman, et al (2004) for construction workers. Neitzel et al reported the mean annual exposure for their group to be 73 $L_{Aeq6760h}$. The 6,760-hr nonoccupational exposure metric can be considered interchangeable with $L_{Aeq8760h}$ values in cases where there is no occupational exposure (i.e., it is assumed that the participant's activities for the remaining 2,000 hr would be equivalent to the derived nonoccupational exposure values). Although our quantification of ANE included occupational exposures, because the majority of our participants were full-time students, occupational noise exposure rates were relatively low (see Figure 3) and the majority of the exposures for our participants came from nonoccupational sources.

Although the NEQ can be used to provide a more complete picture of a participant's noise exposure history and his or her risk of NIHL compared to standard clinical history techniques, it is important to recognize the limitations of the instrument. Reliance on questionnaires for calculating ANE values may be limited by participant recall or understanding of the survey. Surveys such as the NEQ also rely on typical sound levels as reported in the literature for various noise activities. In reality, there are large ranges of possible sound level experiences, and assuming all participants are exposed to midpoint sound levels may result in a somewhat crude estimate. Despite these limitations, protocols used here were previously validated in other studies (Neitzel, Seixas, Goldman, et al, 2004; Reeb-Whitaker et al, 2004; Seixas, 2004). Furthermore, estimates of annual exposure require consideration of infrequent (episodic) noise activities, not just daily (routine) exposures. Capturing both frequent and infrequent exposures with dosimetry would require a participant to wear the dosimeter continuously for a year, which is not realistic. A task-based questionnaire, such as the NEQ, is a more feasible approach to obtaining an ANE estimate.

It should be noted that the NEQ includes a question regarding impulse-noise exposure (firearms, Q 12) that is not used in the calculation of the ANE estimate. Although it is well known that high-level impulse-noise exposure can be hazardous to hearing, there are no accepted protocols for integrating impulse-noise exposure into an ANE estimate based on continuous noise sources. Although exposure to gunfire was not used in the computation of $L_{Aeq8760h}$, participation in this activity should be considered to place the person at risk for NIHL. The NEQ also queries regarding use of hearing protection devices (HPDs) when participating in the various episodic noise activities. No attempt was made to adjust the sound level estimates to account for the use of HPDs because the NEQ was designed to quantify the environmental exposure, as is typical in occupational noise monitoring programs, and not the quality of the protection strategy.

Although neither impulse-noise exposure nor HPD use are incorporated into the calculation of $L_{Aeq8760h}$, their inclusion on the NEQ provides the audiologist important information for counseling individuals regarding risks associated with impulse noise and use of HPDs. While 31% of our sample reported exposure to gunfire, only 47% of our participants reported using HPDs sometimes or always when firing a gun. Similar findings were reported recently by Stewart et al (2014) where 25% of young (10–17 yr) recreational firearm users reported usually or always wearing HPDs while hunting and 72% reported usually or always wearing HPDs while target shooting. Counseling regarding the hazards associated with impulse noise and need to use HPDs consistently remains an area of need. By examining an individual's responses regarding the frequency with which HPDs were used for various episodic noise activities, the audiologist can more appropriately counsel regarding the need to add, modify, or continue HPD use.

Screening for Individuals at High Risk of NIHL

In addition to developing a tool for quantifying ANE, our second aim was to develop a tool, the 1-Minute Noise Screen, for screening for high-risk noise exposure. Regression analyses revealed that only three of our six proposed screening items adequately predicted high-risk noise exposure for our participants. The three questions included in the final screening model assessed a participant's exposure over the previous year to firearms (Q 1), a noisy job (Q 2), and any other loud (recreational) noise (Q 3). The proposed screening questions that assessed regularity of ear/hearing symptoms (tinnitus, TTS, other ear symptoms) did not contribute to the prediction capabilities of the final screening model and were excluded from the 1-Minute Noise Screen.

Because NIHL is a result of damage to the inner ear, certain ear/hearing symptoms are often associated with the progression of hearing loss due to noise exposure. TTS and tinnitus are frequently reported in the NIHL literature (e.g., Chung et al, 2005; Holgers and

Pettersson, 2005), while ear pain or a feeling of fullness in the ears are only occasionally listed as possible symptoms of noise exposure (Ward et al, 2000; IOM, 2005). Other studies have found that participants attribute ear symptoms, including tinnitus, to causes other than noise (Jokitulppo and Bjork, 2003) and that there may be a long delay (23 yr, on average) in the appearance of tinnitus as a clinical complaint following the start of a noisy job (Axelsson and Prasher, 2000). Given this inconclusive relationship between ear symptoms and noise exposure, it may not be surprising that tinnitus, TTS, and other ear pain/symptoms were not clear predictors of ANE. It is likely that these ear symptoms are not highly specific to noise and/or are not sufficiently predictive of early noise exposure.

The three items that were included in the 1-Minute Noise Screen were shown to predict risk based on ANE values in a new group of participants (aim 2) with a high degree of accuracy (A_{ROC} = 0.937). The data provided in Table 5, where sensitivity and specificity values are given for various screening scores, allow flexibility in the implementation of the screening tool. Circumstances where it may be important to identify all individuals at risk would suggest the use of a lower screening score (i.e., 3 or 4) as the referral criterion. In contrast, in circumstances where it is more important to reduce the number of likely false positives, a higher screening score (i.e., 5 or 6) would be a more appropriate criterion. The costs associated with a false positive are primarily the time involved in administering and interpreting results of the full NEQ and time spent discussing hearing-conservation activities, so there may be less incentive to reduce false positives than for other screening tests where the diagnostic procedure is more costly or invasive.

It should be emphasized that the current study relied on higher cutoff exposure limits than those recommended by the EPA (1974) due to our desire to identify participants who may be at highest risk. Should future investigators wish to apply more stringent criteria, or if the state of knowledge regarding noise risk changes, then adjustments to the REL can be made accordingly. Stamper and Johnson (2015) explored the relationship between ABR wave I amplitude and ANE (quantified via the NEQ) in a group of normal-hearing, young adults. Their data suggested that ABR amplitude for high-level stimuli decreased as ANE increased. There was considerable variability in their data, but there did not appear to be one exposure level that would clearly separate those with small ABR amplitudes from those with large ABR amplitudes. Instead, the relationship between the two variables appeared to be continuous. The Stamper and Johnson data need to be replicated; however, to the extent that ABR amplitude reflects the number of afferent fibers contributing to the response in humans, as has been shown in animals (Kujawa and Liberman, 2009), these results may indicate the need to reassess noise hazards. Until it is clearer whether noise exposure can produce permanent damage in humans before permanent threshold shift, tools like the NEQ can be useful for counseling participants regarding their behavior and risk of damage to their auditory systems.

CONCLUSIONS

In summary, the data described here illustrate the development of a task-based questionnaire, the NEQ, that can be used to estimate a participant's ANE, and the development of a screening tool, the 1-Minute Noise Screen, that can be used to screen for participants who are at risk of NIHL. The final version of the detailed NEQ is available in Appendix 3 and the 1-Minute Noise Screen is available in Appendix 4. Additionally, an Excel worksheet that can be used to calculate ANE based on responses on the NEQ is available by contacting the authors. These tools can be used by audiologists to help focus hearing-conservation efforts on those individuals who are at greatest risk of NIHL.

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APPENDIX 1

The questionnaire used to query participant noise exposure, including both screening and detailed questions.

Noise Exposure Questionnaire	
INSTRUCTIONS:	
Please answer the following questions about yourself, your hearing, and any noise you may have been around during the past year. Write an answer in the blank [______] or check [√] the best answer to each question.	
Be sure to complete all pages.	
Today's date: _______________________	
You are: ☐ Male ☐ Female Your age: _____________ years	
Please answer these general questions about your hearing and any loud sounds.	
DURING THE PAST YEAR (12 months):	
1.	How often were you around or did you shoot firearms such as rifles, pistols, shotguns, etc.?
	☐ Never ☐ Every few months ☐ Monthly ☐ Weekly ☐ Daily
2.	How often were you exposed to loud sounds while working on a paid job? By loud sounds, we mean sounds so loud that you had to shout or speak in a raised voice to be heard at arm's length.
	☐ Never ☐ Every few months ☐ Monthly ☐ Weekly ☐ Daily
3.	How often were you exposed to any other types of loud sounds, such as power tools, lawn equipment, or loud music? By loud sounds, we mean sounds so loud that you had to shout or speak in a raised voice to be heard at arm's length.
	☐ Never ☐ Every few months ☐ Monthly ☐ Weekly ☐ Daily
4.	How often were you exposed to loud sound that made your ears "ring" or "buzz"?
	☐ Never ☐ Every few months ☐ Monthly ☐ Weekly ☐ Daily
5.	How often were you exposed to loud sound that made your hearing seem muffled for a while?
	☐ Never ☐ Every few months ☐ Monthly ☐ Weekly ☐ Daily
6.	How often were you exposed to loud sound that made your ears hurt, feel "full," or bother you in any other way?
	☐ Never ☐ Every few months ☐ Monthly ☐ Weekly ☐ Daily
Please answer these detailed questions about any loud sounds.	
DURING THE PAST YEAR (12 months):	
7.	Outside of a paid job, how often did you use power tools, chainsaws, or other shop tools?
	☐ Never ☐ Every few months ☐ Monthly ☐ Weekly ☐ Daily
	If you used power tools, on average, how many hours did each time/session last?
	☐ ≥8 hr ☐ 4 hr up to 8 hr ☐ 1 hr up to 4 hr ☐ <1 hr
	If you used power tools, how often did you wear earplugs or earmuffs during this activity?
	☐ Never ☐ Sometimes ☐ Always
8.	Outside of a paid job, how often did you drive heavy equipment or use loud machinery (such as tractors, trucks, or farming or lawn equipment like mowers/leaf blowers)?
	☐ Never ☐ Every few months ☐ Monthly ☐ Weekly ☐ Daily
	If you drove/used loud machinery, on average, how many hours did each time/session last?
	☐ ≥8 hr ☐ 4 hr up to 8 hr ☐ 1 hour up to 4 hr ☐ <1 hr
	If you drove/used machinery, how often did you wear earplugs or earmuffs during this activity?
	☐ Never ☐ Sometimes ☐ Always
9.	How often did you attend car/truck races, commercial/high school sporting events, music concerts/dances, or any other events with amplified public announcement/music systems?
	☐ Never ☐ Every few months ☐ Monthly ☐ Weekly ☐ Daily
	If you attended these events, on average, how many hours did each time/session last?
	☐ ≥8 hr ☐ 4 hr up to 8 hr ☐ 1 hr up to 4 hr ☐ <1 hr
	If you attended these events, how often did you wear earplugs or earmuffs during this activity?
	☐ Never ☐ Sometimes ☐ Always

10.	How often did you ride/operate motorized vehicles such as motorcycles, jet skis, speed boats, snowmobiles, or four-wheelers?
	☐ Never ☐ Every few months ☐ Monthly ☐ Weekly ☐ Daily
	If you rode motorized vehicles, on average, how many hours did each time/session last?
	☐ ≥8 hr ☐ 4 hr up to 8 hr ☐ 1 hr up to 4 hr ☐ <1 hr
	If you rode motorized vehicles, how often did you wear earplugs or earmuffs during this activity?
	☐ Never ☐ Sometimes ☐ Always
11.	How often did you ride in or pilot small aircraft/private airplanes?
	☐ Never ☐ Every few months ☐ Monthly ☐ Weekly ☐ Daily
	If you flew airplanes, on average, how many hours did each time/session last?
	☐ ≥8 hr ☐ 4 hr up to 8 hr ☐ 1 hr up to 4 hr ☐ <1 hr
	If you flew airplanes, how often did you wear earplugs or earmuffs during this activity?
	☐ Never ☐ Sometimes ☐ Always
12.	How often were you around or did you shoot firearms such as rifles, pistols, shotguns, etc.?
	☐ Never ☐ Every few months ☐ Monthly ☐ Weekly ☐ Daily
	If you were around/shot firearms, on average, how many shots did you fire each time/session?
	__________ **shotgun/rifle** shots per session __________ **pistol** shots per session
	If you were around/shot firearms, how often did you wear earplugs or earmuffs while shooting?
	☐ Never ☐ Sometimes ☐ Always
13.	How often did you play a musical instrument?
	☐ Never ☐ Every few months ☐ Monthly ☐ Weekly ☐ Daily
	If you played, please tell us what musical instrument: ____________________________________
	If you played a musical instrument, on average, how many hours did each time/session last?
	☐ ≥8 hr ☐ 4 hr up to 8 hr ☐ 1 hr up to 4 hr ☐ <1 hr
	If you played a musical instrument, how often did you wear earplugs or earmuffs while playing?
	☐ Never ☐ Sometimes ☐ Always
14.	How often did you listen to music, radio programs, etc. using personal headsets or earphones?
	☐ Never ☐ Every few months ☐ Monthly ☐ Weekly ☐ Daily
	If you listened through earphones, on average, how many hours did each time/session last?
	☐ ≥8 hr ☐ 4 hr up to 8 hr ☐ 1 hr up to 4 hr ☐ <1 hour
15.	Other than music concerts and headset use (*already covered in questions 9 and 14*), how often did you listen to music, radio programs, etc. from audio speakers in a car or at home?
	☐ Never ☐ Every few months ☐ Monthly ☐ Weekly ☐ Daily
	If you listened via speakers, on average, how many hours did each time/session last?
	☐ ≥8 hr ☐ 4 hr up to 8 hr ☐ 1 hr up to 4 hr ☐ <1 hr

NOTE DIFFERENT TIME-FRAMES:	
16.	**Now think back to this past summer. Over the summer months,** did you work a noisy paid job, such as in construction, farming, a factory, lawn service, carwash, or other indoor or outdoor job working around loud equipment or machinery? By noisy job, we mean sounds so loud that you had to shout or speak in a raised voice to be heard at arm's length.
	☐ Yes ☐ No *(if no, skip to # 17)*
	If yes, please describe this noisy job: ____
	If you worked a noisy job, please estimate the number of hours you worked in a typical week:
	________ hours worked per typical week this summer
	If you worked a noisy job this summer, did your employer give you earplugs or earmuffs to wear at work? ☐ Yes ☐ No
	How often did you wear earplugs or earmuffs when around loud noise at this summer job?
	☐ Never ☐ Sometimes ☐ Always
17.	**Other than during the summer, over the past year**, did you work one or more noisy paid jobs, such as in construction, farming, a factory, lawn service, carwash, or other indoor or outdoor job working around loud equipment or machinery? By noisy job, we mean sounds so loud that you had to shout or speak in a raised voice to be heard at arm's length.
	☐ Yes ☐ No *(if no, you're done with the survey)*
	If yes, please describe the noisy job(s): ____
	If you worked a noisy job, please estimate the number of hours you worked in a typical week:
	________ average hours worked per typical week during the school year
	If you worked a noisy job during the school year, did your employer give you earplugs or earmuffs to wear at work? ☐ Yes ☐ No
	How often did you wear earplugs or earmuffs when around loud noise at this noisy job(s)?
	☐ Never ☐ Sometimes ☐ Always

APPENDIX 2

The following provides an example of the calculation of annual noise exposure for an individual participant. The majority of this participant's annual noise exposure is attributable to attendance at commercial sporting and entertainment events and playing a musical instrument.

Activity (Q no.)	Participant response for how often and duration (value assigned)	Reported hr (C)	*L* (L_{Aeq})	Reference hr (*T*)*	*D* (%)
Power tools	Every few months (1)	3	94	274	1.09
	1–4 hr (3)				
Heavy equipment/machinery	Never (0)	0	97	137	0
	n/a				
Commercial sporting and entertainment events	Weekly (50)	150	94	274	54.74
	1–4 hr (3)				
Motorized vehicles	Every few months (1)	6	98	109	5.50
	4–8 hr (6)				
Small/private aircraft	Never (0)	0	91	548	0
	n/a				
Musical instrument playing	Daily (200)	1,200	87	1,380	86.96
	4–8 hr (6)				
Music listening (earphones)	Daily (200)	600	76	17,520	3.42
	1–4 hr (3)				
Music listening (speakers)	Daily (200)	600	78	11,037	5.44
	1–4 hr (3)				
Occupational exposure (summer and school year)	10 hr/week (10)	100**	90	690	14.49
	Summer (10)				
Routine activities		6,101	64	280,320	2.18
				Total dose	173.82
				$L_{Aeq8760h}$	81

Notes: *According to our REL of 79 L_{Aeq} for 8,760 hr, the duration of exposure in hours that would be needed at this sound level to achieve 100% dose for this activity (examples: 8,760 hr at 79 L_{Aeq}; 4,380 hr at 82 L_{Aeq}; 2,190 hr at 85 L_{Aeq}; 17,520 hr at 76 L_{Aeq}). **Episodic frequency for occupational exposure (*C*) is computed by multiplying the estimated number of hours per typical work week by 10 wk/yr for a summer job or by 40 wk/yr for a school year job.

APPENDIX 3

Final Noise Exposure Questionnaire

Noise Exposure Questionnaire	
Name: ________________________________ Date: _____________________	
INSTRUCTIONS:	
Please answer the following questions about yourself, your hearing, and any noise you may have been around during the past year. Write an answer in the blank [______] or check [√] the best answer to each question.	
Please answer these questions about any loud sounds.	
DURING THE PAST YEAR (12 months):	
1.	Outside of a paid job, how often did you use power tools, chainsaws, or other shop tools?
	☐ Never ☐ Every few months ☐ Monthly ☐ Weekly ☐ Daily
	If you used power tools, on average, how many hours did each time/session last?
	☐ ≥8 hr ☐ 4 hr up to 8 hr ☐ 1 hr up to 4 hr ☐ <1 hr
	If you used power tools, how often did you wear earplugs or earmuffs during this activity?
	☐ Never ☐ Sometimes ☐ Always
2.	Outside of a paid job, how often did you drive heavy equipment or use loud machinery (such as tractors, trucks, or farming or lawn equipment like mowers/leaf blowers)?
	☐ Never ☐ Every few months ☐ Monthly ☐ Weekly ☐ Daily
	If you drove/used loud machinery, on average, how many hours did each time/session last?
	☐ ≥8 hr ☐ 4 hr up to 8 hr ☐ 1 hr up to 4 hr ☐ <1 hr
	If you drove/used machinery, how often did you wear earplugs or earmuffs during this activity?
	☐ Never ☐ Sometimes ☐ Always
3.	How often did you attend car/truck races, commercial/high school sporting events, music concerts/dances or any other events with amplified public announcement/music systems?
	☐ Never ☐ Every few months ☐ Monthly ☐ Weekly ☐ Daily
	If you attended these events, on average, how many hours did each time/session last?
	☐ ≥8 hr ☐ 4 hr up to 8 hr ☐ 1 hr up to 4 hr ☐ <1 hr
	If you attended these events, how often did you wear earplugs or earmuffs during this activity?
	☐ Never ☐ Sometimes ☐ Always
4.	How often did you ride/operate motorized vehicles such as motorcycles, jet skis, speed boats, snowmobiles, or four-wheelers?
	☐ Never ☐ Every few months ☐ Monthly ☐ Weekly ☐ Daily
	If you rode motorized vehicles, on average, how many hours did each time/session last?
	☐ ≥8 hr ☐ 4 hr up to 8 hr ☐ 1 hr up to 4 hr ☐ <1 hr
	If you rode motorized vehicles, how often did you wear earplugs or earmuffs during this activity?
	☐ Never ☐ Sometimes ☐ Always
5.	How often did you ride in or pilot small aircraft/private airplanes?
	☐ Never ☐ Every few months ☐ Monthly ☐ Weekly ☐ Daily
	If you flew airplanes, on average, how many hours did each time/session last?
	☐ ≥8 hr ☐ 4 hr up to 8 hr ☐ 1 hr up to 4 hr ☐ <1 hr
	If you flew airplanes, how often did you wear earplugs or earmuffs during this activity?
	☐ Never ☐ Sometimes ☐ Always
6.	How often were you around or did you shoot firearms such as rifles, pistols, shotguns, etc.?
	☐ Never ☐ Every few months ☐ Monthly ☐ Weekly ☐ Daily
	If you were around/shot firearms, on average, how many shots did you fire each time/session?
	_________ shotgun/rifle shots per session _________ pistol shots per session
	If you were around/shot firearms, how often did you wear earplugs or earmuffs while shooting?
	☐ Never ☐ Sometimes ☐ Always
7.	How often did you play a musical instrument?
	☐ Never ☐ Every few months ☐ Monthly ☐ Weekly ☐ Daily
	If you played, please tell us what musical instrument: ___________________________________

	If you played a musical instrument, on average, how many hours did each time/session last?
	☐ ≥8 hr ☐ 4 hr up to 8 hr ☐ 1 hr up to 4 hr ☐ <1 hr
	If you played a musical instrument, how often did you wear earplugs or earmuffs while playing?
	☐ Never ☐ Sometimes ☐ Always
8.	How often did you listen to music, radio programs, etc. using personal headsets or earphones?
	☐ Never ☐ Every few months ☐ Monthly ☐ Weekly ☐ Daily
	If you listened through earphones, on average, how many hours did each time/session last?
	☐ ≥8 hr ☐ 4 hr up to 8 hr ☐ 1 hr up to 4 hr ☐ <1 hr
9.	Other than music concerts and headset use (already covered in questions 3 and 8), how often did you listen to music, radio programs, etc. from audio speakers in a car or at home?
	☐ Never ☐ Every few months ☐ Monthly ☐ Weekly ☐ Daily
	If you listened via speakers, on average, how many hours did each time/session last?
	☐ ≥8 hr ☐ 4 hr up to 8 hr ☐ 1 hr up to 4 hr ☐ <1 hr
NOTE DIFFERENT TIME-FRAMES:	
10.	**Now think back to this past summer. Over the summer months,** did you work a noisy paid job, such as in construction, farming, a factory, lawn service, carwash, or other indoor or outdoor job working around loud equipment or machinery? By noisy job, we mean sounds so loud that you had to shout or speak in a raised voice to be heard at arm's length.
	☐ Yes ☐ No *(if no, skip to # 11)*
	If yes, please describe this noisy job: ____
	If you worked a noisy job, please estimate the number of hours you worked in a typical week:
	________ hours worked per typical week this summer
	If you worked a noisy job this summer, did your employer give you earplugs or earmuffs to wear at work? ☐ Yes ☐ No
	How often did you wear earplugs or earmuffs when around loud noise at this summer job?
	☐ Never ☐ Sometimes ☐ Always
11.	**Other than during the summer, over the past year**, did you work one or more noisy paid jobs, such as in construction, farming, a factory, lawn service, carwash, or other indoor or outdoor job working around loud equipment or machinery? By noisy job, we mean sounds so loud that you had to shout or speak in a raised voice to be heard at arm's length.
	☐ Yes ☐ No *(if no, you're done with the survey)*
	If yes, please describe the noisy job(s): ____
	If you worked a noisy job, please estimate the number of hours you worked in a typical week:
	________ average hours worked per typical week during the school year
	If you worked a noisy job during the school year, did your employer give you earplugs or earmuffs to wear at work? ☐ Yes ☐ No
	How often did you wear earplugs or earmuffs when around loud noise at this noisy job?
	☐ Never ☐ Sometimes ☐ Always

Note: Noise Exposure Questionnaire/University of Kansas Medical Center/Hearing & Speech Department/© 2016.

APPENDIX 4

1-Minute Noise Screen

Name: ____________________________ Date: _____________________

DURING THE PAST YEAR (12 months),	
1.	How often were you around or did you shoot firearms such as rifles, pistols, shotguns, etc.?
	☐ Never ☐ Every few months ☐ Monthly ☐ Weekly ☐ Daily
2.	How often were you exposed to loud sounds while working on a <u>paid</u> job? By loud sounds, we mean sounds so loud that you had to shout or speak in a raised voice to be heard at arm's length.
	☐ Never ☐ Every few months ☐ Monthly ☐ Weekly ☐ Daily
3.	How often were you exposed to any other types of loud sounds, such as power tools, lawn equipment, or loud music? By loud sounds, we mean sounds so loud that you had to shout or speak in a raised voice to be heard at arm's length.
	☐ Never ☐ Every few months ☐ Monthly ☐ Weekly ☐ Daily
	Noise exposure score: ___________

Note: 1-Minute Noise Screen/University of Kansas Medical Center/Hearing & Speech Department/© 2016.

How to Score Your 1-Minute Noise Screen

First, give yourself the following number of points for your answer to each question:

Question	Never	Every Few Months	Monthly	Weekly	Daily
1	0	1	2	3	4
2	0	1	2	3	4
3	0	1	2	3	4

Then, add your three individual scores together to get your total Noise Exposure Score. Enter this total number of points in the box in the lower right corner of your card.

See the reverse side of this sheet for an explanation of your Noise Exposure Score and suggestions for how to manage your risk of developing noise-induced hearing loss.

Example:

1-Minute Noise Screen	
Name: ***<u>Example</u>*** Date: ***<u>07/01/2015</u>***	
DURING THE PAST YEAR (12 months),	
1.	How often were you around or did you shoot firearms such as rifles, pistols, shotguns, etc.?
	☐ Never ☐ Every few months ☑ Monthly ☐ Weekly ☐ Daily
2.	How often were you exposed to loud sounds while working on a <u>paid</u> job? By loud sounds, we mean sounds so loud that you had to shout or speak in a raised voice to be heard at arm's length.
	☐ Never ☐ Every few months ☐ Monthly ☑ Weekly ☐ Daily
3.	How often were you exposed to any other types of loud sounds, such as power tools, lawn equipment, or loud music? By loud sounds, we mean sounds so loud that you had to shout or speak in a raised voice to be heard at arm's length.
	☐ Never ☑ Every few months ☐ Monthly ☐ Weekly ☐ Daily
	Noise exposure score: *<u>6</u>*

Note: 1-Minute Noise Screen/University of Kansas Medical Center/Hearing & Speech Department/© 2016.

1-Minute Noise Screen: Recommendations

If your Noise Score is in this range:	Then your Noise Risk is:	Explanation
0 to 4	Lower risk	Based on your noise experiences during the past year, your risk of developing noise-induced hearing loss is relatively low if you continue to experience similar levels of noise in the future. However, if your noise exposures increase, your risk of developing hearing loss will increase as well.
		Everyone is different in their tolerance to noise, and it is difficult to predict your individual susceptibility. Still, it is important to remember that risk increases: the louder the sounds, the longer you spend around them, and the more often you are exposed. See the following tips for how you can manage your risk of developing noise-induced hearing loss.
		Special note for firearm users: If you use firearms, you are at high risk of hearing loss, even if you only use firearms every few months and have a low-risk score on the 1-Minute Noise Screen. See the following tips for things you can do to manage your risk.
5 and above	Higher risk	Based on your noise experiences during the past year, you are at risk of developing noise-induced hearing loss if you continue to experience similar or higher levels of noise in the future.
		Everyone is different in their tolerance to noise, and it is difficult to predict your individual susceptibility. Still, it is important to remember that risk increases: the louder the sounds, the longer you spend around them, and the more often you are exposed. See the following tips for how you can manage your risk of developing noise-induced hearing loss.

What You Can Do To Manage Your Risk:

- **Avoid loud noise when you can:** This may go without saying, but avoiding loud noise is a first step toward conserving your hearing for a lifetime. Remember, when you feel the need to shout to be heard by someone just a few feet away, the background noise levels are probably in a hazardous range. Look for quieter products when you buy noisy appliances or tools such as leaf blowers and lawn mowers. And turn down the volume when using electronic devices such as cell phones and music players.

- **Wear hearing protection whenever you are around loud noise**: When you can't avoid loud noise, be sure to wear well-fitted earplugs or earmuffs, even if your noise experiences are only occasional. Hearing protectors can be purchased at many pharmacies, and convenience, hardware, and sporting goods stores. Be sure you have proper training in the use and care of your hearing protectors, and replace them as needed. Proper and consistent use of hearing protection can lower your risk. This is especially true if you shoot firearms, where even one exposure to gunfire can damage your hearing if you are not wearing hearing protection.

- **Get regular hearing tests:** Keep an eye on your ears! Get a routine hearing test once a year if you are in the higher risk category listed earlier or if you experience any increase in your exposure to noise. Keep track of your hearing test results and ask your audiologist to compare annual tests to your earliest test to look for any significant changes that may signal a concern.

- **Take care of your ears:** See your doctor if you notice problems such as sudden changes in hearing, or pain, "fullness," or ringing in your ears.