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Estimation of Permanent Noise-Induced Hearing Loss in an Urban Setting

Ryan C. Lewis[†], Robyn R. M. Gershon[‡], and Richard L. Neitzel^{§,*}

[†]Occupational & Environmental Epidemiology Program, Department of Environmental Health Sciences, University of Michigan School of Public Health, Ann Arbor, Michigan 48109, United States

[‡]Department of Epidemiology and Biostatistics and Philip R. Lee Institute for Health Policy Studies, School of Medicine, University of California, San Francisco, California 94118, United States

[§]Risk Science Center and Department of Environmental Health Sciences, University of Michigan School of Public Health, Ann Arbor, Michigan 48109, United States

Abstract

The potential burden of noise-induced permanent threshold shift (NIPTS) in U.S. urban settings is not well-characterized. We used ANSI S3.44-1996 to estimate NIPTS for a sample of 4585 individuals from New York City (NYC) and performed a forward stepwise logistic regression analysis to identify predictors of NIPTS >10 dB. The average individual is projected to develop a small NIPTS when averaged across 1000–4000 Hz for 1- to 20-year durations. For some individuals, NIPTS is expected to be substantial (>25 dB). At 4000 Hz, a greater number of individuals are at risk of NIPTS from MP3 players and stereos, but risk for the greatest NIPTS is for those with high occupational and episodic nonoccupational (e.g., power tool use) exposures. Employment sector and time spent listening to MP3 players and stereos and participating in episodic nonoccupational activities associated with excessive noise levels increased the odds of NIPTS >10 dB at 4000 Hz for 20-year durations. Our results indicate that the risk of NIPTS may be substantial for NYC and perhaps other urban settings. Noise exposures from “noisy” occupational and episodic nonoccupational activities and MP3 players and stereos are important risk factors and should be a priority for public health interventions.

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*Corresponding Author: Phone: 1-734-763-2870. Fax: 1-734-763-8095. meitzel@umich.edu. Corresponding author address: Risk Science Center, Department of Environmental Health Sciences, University of Michigan School of Public Health, 1415 Washington Heights, Ann Arbor, MI 48109.

Notes

The authors declare no competing financial interest.

Supporting Information

Details on the ANSI S3.44-1996 equations used to estimate NIPTS. This material is available free of charge via the Internet at <http://pubs.acs.org>.

INTRODUCTION

Noise is one of, if not the, most common exposures in both occupational and community settings, and there are very few individuals who do not have the potential for at least occasional exposures to substantial levels of noise. Noise exposures of sufficient intensity and duration can result in noise-induced permanent threshold shift (NIPTS), a permanent decrement in hearing acuity with substantial social and economic ramifications. The primary consequence of NIPTS is difficulty understanding speech, which can range from small distortions to complete hearing loss. Roughly 15% of the U.S. population aged 20–69 (26 million people) may have NIPTS caused by excessive exposures to workplace or leisure noise.¹ The estimated economic burden from NIPTS is 0.2–2.0% of the gross domestic product for developed countries;² in the U.S. this is equivalent to \$30–300 billion annually. The prevalence of NIPTS in developed countries may be greatly underestimated,³ and in developing countries, the prevalence may be as great, or even greater than, as developed countries. Worldwide, rates of NIPTS are expected to increase over the next 20 years.⁴ In response, the World Health Organization (WHO) has declared NIPTS a “high public health priority”.⁵ In addition to NIPTS, occupational and environmental noise exposure has been linked to nonauditory health effects, such as coronary heart disease,⁶ hypertension,⁷ sleep disturbance, perceived stress,⁸ and reduced life quality.⁹

The U.S. Environmental Protection Agency¹⁰ and WHO⁵ have recommended a 24-h equivalent continuous average (L_{Aeq24h}) noise exposure limit of 70 A-weighted decibels (dBA). This limit, which incorporates both workplace and leisure noise, is designed to protect against any measurable NIPTS among the exposed population. Nonauditory health

effects of exposure to noise can occur well below limits designed to prevent NIPTS^{10–12} and may result in a far greater public health burden than NIPTS alone.

NIPTS can be quantitatively estimated using American National Standards Institute (ANSI) S3.44-1996 (R2006), *Determination of Occupational Noise Exposure and Estimation of Noise-Induced Hearing Impairment*.¹³ Briefly, this standard provides mathematical formulas for estimating NIPTS in adult populations free of auditory impairment beyond noise- and age-induced impairment (see the Supporting Information). Given estimated 8-h equivalent continuous average levels (L_{Aeq8h}) of noise for the population of interest, NIPTS can be predicted for a variety of desired combinations of noise exposure durations (range: 0–40 years), audiometric frequencies (range: 500–6000 Hz), and population fractiles of noise-related hearing loss susceptibility (range: 0.05–0.95). Based on the mathematical formulas given in the standard, NIPTS is predicted to be zero in the absence of noise exposure and positive when noise exposure is greater than the audiometric frequency-specific thresholds. Although this standard is primarily intended for occupational exposures, NIPTS can be estimated for total (i.e., workplace and leisure) exposures by normalizing 24-h daily exposures to L_{Aeq8h} .¹³

Neitzel and colleagues¹⁴ recently published estimates of annual average noise exposures ($L_{Aeq8760h}$) for a sample of 4585 adult men and women living and/or working in New York City (NYC). These people were recruited from 33 neighborhood street fairs in 2007–2009 in the NYC boroughs of Manhattan, Brooklyn, Queens, and the Bronx and represented a wide range of ages and occupations (Table 1). The age, gender, and race/ethnicity distribution of the sample was roughly representative of NYC.¹⁴ Noise exposures were estimated for five common sources and for all sources combined (i.e., total exposure). These five noise sources were occupational activities and episodic non-occupational activities (e.g., attending concerts, referred to subsequently as “non-occupational activities”) as well as frequent nonoccupational activities, including listening to MP3 players and stereos, mass transit use, and time spent at home and doing other miscellaneous activities. Approximately 90% of subjects had total $L_{Aeq8760h}$ that exceeded the 70 dBA EPA and WHO limit (grand mean: 76 dBA, standard deviation: 5 dBA) and therefore are at risk of developing some NIPTS. The noise sources associated with the highest percentage of $L_{Aeq8760h} > 70$ dBA were listening to MP3 players and stereos, nonoccupational activities, occupational activities, and use of mass transit. These results suggest that contemporary approaches to hearing loss prevention, which focus almost exclusively on workplace exposures, may need to be reevaluated.

Our study had two objectives. The first was to quantitatively estimate NIPTS using the noise exposure estimates from our original analysis.¹⁴ The second was to identify lifestyle and demographic factors associated with NIPTS >10 dB. A NIPTS >10 dB can negatively impact the understanding of speech, and the impact increases with increasing NIPTS.⁸ The overarching goal was to better characterize the potential burden of NIPTS in urban U.S. settings, which in turn could better inform public health interventions.

METHODS

Estimating NIPTS

Annual average noise exposures for each subject ($L_{Aeq8760hi}$) were assumed to be equivalent to the average exposure over any 24-h period ($L_{Aeq24hi}$). All $L_{Aeq24hi}$ were then normalized to 8-h exposures to allow for their use in the ANSI S3.44-1996 prediction equations. NIPTS in decibels (dB) was estimated for each subject for audiometric frequencies important to human speech (1000, 2000, 3000, and 4000 Hz)^{4,15,16} and for exposure durations of 1, 5, 10, and 20 years, using the equations and methodology described in the Supporting Information. Our primary focus was on the 20-year exposure period, which represents a compromise between 40 years (the basis of the EPA and WHO recommended limits) and shorter durations representative of temporary urban residents. NIPTS assuming 50th percentile noise-damage susceptibility ($N_{0.50}$) was estimated for each of the five individual sources and across all sources (i.e., total exposure). In any given population, there is a distribution of susceptibility to hearing loss damage caused by noise exposure.¹³ Thus, the same noise exposure to any individual may result in hearing loss of varying severity depending on that individual's noise-damage susceptibility. The median is the default noise-damage susceptibility in ANSI S3.44-1996¹³ and likely provides a reasonable estimate of the "average" NIPTS. NIPTS was estimated using MS Excel 2010 (Microsoft, Redmond, WA), and associated summary statistics were calculated using SAS 9.3 (SAS Institute, Cary, NC).

Source Apportionment Analysis

An analysis was performed to calculate the apportionment of estimated $N_{0.50}$ at 4000 Hz for each of the five individual noise sources (% of total $N_{0.50}$) by both categories of age group and primary source of exposure (the source that contributed the most to the estimated total dose, which we estimated in our previous analysis¹⁴). To calculate source apportionment, the estimated $N_{0.50}$ for all subjects belonging to the category of interest were first summed for each of the five noise sources individually, resulting in five total $N_{0.50}$ (one for each noise source). These source-specific $N_{0.50}$ summations were then summed to generate a grand total. Source apportionment for each of the five noise sources was accomplished by dividing the source-specific $N_{0.50}$ total by the grand total and multiplying this value by 100. Source apportionments were calculated using SAS 9.3.

Forward Stepwise Logistic Regression Analysis

A forward stepwise logistic regression (FSLR) analysis was performed to identify factors associated with odds of $N_{0.50} > 10$ dB at 4000 Hz from total noise exposure. This threshold and audiometric frequency was selected because at this level of impairment some individuals may experience degraded communication ability.^{5,10} Variables considered for entry in the model by the FSLR procedure included the following: time spent riding/waiting for mass transit, listening to MP3 players and stereos, playing in a band, attending concerts, attending sporting events, using lawn tools, using power tools, and riding a motorcycle; NYC residential status; NYC employment status; gender; age; sector of employment; and NYC borough of employment. Additional details on these exposure variables are presented

elsewhere.^{14,17} Variables were entered and retained in the final model when $p < 0.05$. The FSLR analysis was performed using the PROC LOGISTIC statement in SAS 9.3.

NIPTS Simulation

A small-scale simulation was conducted to assess the potential effects of introducing variability in noise-damage susceptibility among the sample on the odds ratios associated with the significant predictors identified by the FSLR procedure. In this simulation, all subjects were randomly assigned to different susceptibility fractiles: 80% to $N_{0.50}$, 10% to $N_{0.10}$ (greater susceptibility), and 10% to $N_{0.90}$ (less susceptibility); previously we assumed 100% $N_{0.50}$. This simulation was repeated nine times, resulting in ten sets of NIPTS estimates, each with a different but equal-size pool of subjects with $N_{0.10}$, $N_{0.50}$, and $N_{0.90}$. The NIPTS estimates for each simulated data set were then used in a logistic regression model with the significant predictors identified by the FSLR procedure to generate a new set of odds ratios associated with each predictor. This simulation exercise was also performed for NIPTS averaged across 1000, 2000, 3000, and 4000 Hz to evaluate the potential health effects of including different hearing frequencies on NIPTS. The simulation and NIPTS estimation were performed using MS Excel 2010, and the logistic regression modeling was conducted using the PROC LOGISTIC statement in SAS 9.3.

RESULTS

Table 2 shows estimated $N_{0.50}$ at 20 years of exposure at each audiometric frequency for subjects with source-specific $L_{Aeq8hni}$ that exceeded the threshold level for NIPTS, L_0 . Most subjects exceeded L_0 at 2000, 3000, and 4000 Hz from exposure to MP3 players and stereos, between half and two-thirds of subjects exceeded L_0 at 3000 and 4000 Hz from nonoccupational exposure, and about one-fourth exceeded L_0 at 3000 and 4000 Hz from occupational exposure. The mean $N_{0.50}$ from total exposure at 4000 Hz was 4.20 dB (standard deviation: 4.40 dB), and 90% of the cohort had total exposures that exceeded 75 dBA $L_{Aeq8hni}$ (equivalent to the 70 dBA L_{Aeq24h} EPA/WHO recommended limit). When each source was considered separately, mean $N_{0.50}$ for subjects exceeding L_0 was the greatest between 1000 and 3000 Hz from nonoccupational activities and essentially identical at 4000 Hz from occupational and nonoccupational activities.

Figure 1A depicts the estimated $N_{0.50}$ at 4000 Hz for exposure durations of 1 to 20 years. The mean $N_{0.50}$ at 1, 5, 10, and 20 years of exposure was 0.95, 2.46, 3.30, and 3.79 dB, respectively. As expected, the magnitude of NIPTS increases with increasing exposure duration. Most subjects are expected to retain relatively normal hearing over these exposure periods, but 338 subjects (7.3%) are expected to accrue an $N_{0.50} > 10$ dB, and 26 subjects (0.05%) are expected to accrue an $N_{0.50} > 25$ dB. The range of predicted NIPTS is large – from virtually no NIPTS at 4000 Hz to over 40 dB. Figure 1B depicts the estimated $N_{0.50}$ for NIPTS averaged across 1,000, 2,000, 3,000, and 4000 Hz. The mean $N_{0.50}$ at 1, 5, 10, and 20 years of exposure was 0.42, 1.08, 1.45, and 1.79 dB, respectively. A positive trend between exposure duration and $N_{0.50}$ was observed, and the range of predicted $N_{0.50}$, while not as large as seen at 4000 Hz, still approaches 30 dB.

Table 3 shows the source apportionment of predicted $N_{0.50}$ at 4000 Hz and 20 years of exposure by age category. Across all subjects, the primary contributor to $N_{0.50}$ was listening to MP3 players and stereos, followed by nonoccupational activities, occupational activities, and use of transit; home and other miscellaneous activities contributed nothing to $N_{0.50}$. The same pattern was observed in the 19–29 and 30–39 year-old age categories. Occupational activities become increasingly important with age, until, by the time the 60–97 year old age group is reached, occupational activities represent the primary contributor to NIPTS.

Table 4 shows the source apportionment of $N_{0.50}$ at 4000 Hz and 20 years of exposure by primary exposure source. Listening to MP3 players and stereos was the primary exposure source for the majority of subjects and accounted for 88% of $N_{0.50}$ on average, whereas nonoccupational, occupational, and transit only accounted for 8%, 3%, and 1%, respectively. Among subjects for whom occupational activities, nonoccupational activities, and use of transit were the primary sources of exposure, the average percentage of $N_{0.50}$ attributable to these sources was 82%, 79%, and 75%, respectively. For most subjects, the vast majority of estimated $N_{0.50}$ resulted from the primary exposure, and secondary exposures contributed little to NIPTS risk.

Table 5 shows the results from the FSLR analysis for predicted $N_{0.50} > 10$ dB at 4000 Hz and 20 years of exposure. Greater time spent listening to MP3 players and stereos and performing nonoccupational activities associated with excessive noise levels increased the odds of NIPTS > 10 dB. A 100-h increase in attending concerts or using lawn tools, for example, increased the likelihood of $N_{0.50} > 10$ dB by 133% and 213%, respectively. Employment in the construction, entertainment, maintenance, manufacturing, or utility industries increased the odds of $N_{0.50} > 10$ dB substantially, although the results associated with military employment were unstable due to small sample size ($n = 26$). Older age and living in NYC were protective factors. A likely explanation for this observation is that both NYC residents and older subjects (30–97 year-olds) on average spent less time listening to MP3 players and stereos, participating in occupational and nonoccupational activities and experienced lower noise exposure levels from these sources compared to non-NYC residents and younger subjects (19–29 year-olds), respectively (data not shown).

The results of the simulation exercise, in which expected NIPTS susceptibility was allowed to vary from $N_{0.10}$ to $N_{0.90}$, did not markedly change the FSLR model odds ratios for any of the predictor variables except military employment. Table 6 shows the results of the simulation exercise for expected NIPTS averaged across 1000, 2000, 3000, and 4000 Hz after 20 years of exposure. The mean of the ten simulation $N_{0.10}$ means was 2.63 dB (95% confidence interval [CI]: 2.51, 2.75 dB), while the mean of the ten simulation $N_{0.50}$ and $N_{0.90}$ means were 1.80 dB (95% CI: 1.79, 1.81 dB) and 1.17 dB (95% CI: 1.10, 1.24 dB), respectively. The mean fraction of subjects predicted to exceed an NIPTS of 10 dB averaged across 1000, 2000, 3000, and 4000 Hz was $< 5\%$.

DISCUSSION

We estimated NIPTS from occupational activities, nonoccupational activities (e.g., using power tools), listening to MP3 players and stereos, mass transit use, and time spent at home

and doing other miscellaneous activities as well as across all sources (i.e., total exposure) using a large sample of NYC area residents and workers. The average member of our sample is projected to develop a small NIPTS at 4000 Hz (mean NIPTS: 3.79 dB) after 20 years of exposure. Our estimated NIPTS is less than what is expected for age-related hearing loss at 4000 Hz over a 20-year period (e.g., mean age-related hearing loss for a 30 year-old over 20 years: 11 dB¹³). However, for some subjects, NIPTS at 4000 Hz is expected to be substantial (>25 dB), which, in turn, will result in a significant degradation of communication ability independent of age-related hearing loss. Furthermore, both occupational and nonoccupational exposures generally made a greater contribution to total exposure and subsequent NIPTS at 4000 Hz than did listening to MP3 players and stereos. Employment sector and time spent listening to MP3 players and stereos and participating in nonoccupational activities associated with excessive noise levels were identified as risk factors for NIPTS >10 dB at 4000 Hz assuming 20 years of exposure as well.

Our study is one of a handful^{18–20} that have estimated the potential burden of NIPTS in the U.S. and is possibly the only one to have done so in an urban population and across multiple sources. There has been a recent increase in the published literature on the potential NIPTS risk associated with use of MP3 players, particularly with regards to NIPTS risk in young people.^{21–23} While our results are not generalizable to minors, they do suggest that many adults in urban areas are at risk of a small NIPTS from listening to music. However, the individuals at highest risk of NIPTS >25 dB are those with high exposures to occupational and nonoccupational activities; for these individuals, listening to MP3 players and stereos make a relatively small contribution to total NIPTS. In other words, listening to music may put many people at risk of a small NIPTS, but the risk of a substantial NIPTS is greater from other sources of exposure. Given the ubiquity of music exposure in the U.S., the total NIPTS incurred by listening to music may nevertheless present a substantial public health burden.

Dobie¹⁸ and Nelson et al.²⁰ have suggested that occupational noise accounts for about 10% of the total burden of hearing loss in the U.S. and the Americas, respectively. Dobie has suggested that occupational noise accounts for 100% of NIPTS in individuals <40 years of age. Conversely, Nelson and colleagues²⁰ estimated that, among the 15–29 and 30–44 year-old age groups, the percentage of occupationally attributable NIPTS was 20% for males and 9% for females. Our own estimates for similar age groups (19–29 and 30–39 year-olds) suggest that occupational noise may account for 15–25% of NIPTS. Collectively, these findings highlight the importance of considering sources of noise beyond occupational noise.

NIPTS among 5400 U.S. individuals evaluated in the 1999–2004 National Health and Nutrition Examination Survey (NHANES) was recently examined by Mahboubi et al.¹⁹ As with our study, Mahboubi et al. found higher prevalence of NIPTS among those who reported military service, occupational noise exposure, and recreational noise exposure. Several other NHANES-based studies have indicated that hearing loss risk is greater among individuals with occupational and nonoccupational noise exposure^{24,25} and among smokers.²⁶

Despite our finding that transit use contributes little to risk of NIPTS, the potential importance of transit-associated noise cannot be discounted. Data from a sample of NYC residents ($n = 756$) collected by Gershon et al.¹⁷ indicated that mass transit ridership was significantly associated with self-reported temporary threshold shift symptoms after controlling for demographic variables and occupational and nonoccupational exposures. Also, we have previously demonstrated^{27,28} that transit noise can vary widely within a system, and riders of certain lines and those with long rides may be at greater risk of NIPTS than the average rider.

There are a number of limitations in the exposure data upon which this study was based.¹⁴ These include a heavy reliance on self-reported exposure durations and use of literature-derived noise levels to create exposure estimates. Both of these data sources may have contained substantial measurement error, and this error would have propagated into the NIPTS estimates created here. Additional error may have been introduced through the use of ANSI S3.44-1996. The performance of the model in estimating highly variable noise exposures is not well understood, and it may under-²⁹ or overpredict¹⁸ actual NIPTS.

We made several additional assumptions that may have influenced the validity of our NIPTS estimates. We assumed that the subject-specific annual noise exposures estimated by Neitzel et al.¹⁴ were representative of exposures over any 24-h period within a year and did not allow these exposures to vary from year-to-year. We also made assumptions regarding exposure duration, creating estimates ranging from 1 to 20 years of exposure but focusing primarily on 20 years. Clearly there is a wide distribution of urban residence times in the U.S., and the simplified approach used here does not adequately represent this distribution. However, even relatively short exposure durations may result in NIPTS in a fraction of a population (Figure 1). Our study excluded at least one potential cause of NIPTS, firearms.^{18,30} However, in our earlier study, only 5.9% of NYC individuals reported using firearms annually or more often,¹⁷ which suggests that firearms may contribute little to NIPTS for urban dwellers in the U.S. Nevertheless, additional efforts are needed to elucidate the contribution of firearms noise to NIPTS.

Our study appears to be the first to estimate the burden of NIPTS associated with multiple sources of noise exposure for individuals living in an urban U.S. environment. Risk of NIPTS may be substantial for residents of the NYC area and perhaps other densely populated cities in the U.S. Our results suggest that, in addition to occupational noise exposure – the historically dominant and most studied source of NIPTS – listening to MP3 players and stereos and nonoccupational activities are important risk factors for NIPTS and, consequently, should be a priority for future public health interventions. Justification for such interventions comes both from the prevention of hearing loss and hearing disability, which in the U.S. alone likely costs billions of dollars per year,² but also from the benefits associated with the potential prevention of nonauditory health effects (e.g., cardiovascular disease)⁸ that are increasingly linked to noise and that may result in substantial health-related costs.³¹ The burden of NIPTS in the U.S. may be greatest in large urban settings, due to the sheer number of individuals exposed (~58% of the U.S. population in 2000),³² but residents of rural areas may in fact be at greatest risk, since they may be more likely to use firearms. Future research in other urban settings is warranted to confirm our findings, and

similar research in rural areas and among children is also needed. Finally, direct, longitudinal measurements of hearing acuity in urban dwellers – with concurrent long-term exposure monitoring – are needed to assess the validity of our exposure and NIPTS estimates.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1. Estimated NIPTS (dB) at 4000 Hz (A) and averaged across 1000, 2000, 3000, and 4000 Hz (B) for subjects assuming 50th percentile noise-damage susceptibility ($n = 4585$).

Table 1Demographics of Cohort Recruited by Neitzel et al.¹⁴ ($n = 4585$)

variable/category	<i>n</i>	%
gender		
male	2456	53.6
female	2129	46.4
age (years old)		
19–29	1167	25.4
30–39	715	15.5
40–49	901	19.6
50–59	917	20.0
60–69	885	19.3
work in NYC	2816	61.4
live in NYC	4347	94.8
transit user	4436	96.7
occupation		
agriculture	12	0.3
construction	420	9.2
education/research	638	13.9
entertainment	217	4.7
food services	169	3.7
healthcare	362	7.9
homemaker	118	2.6
landscaping	5	0.1
maintenance	93	2.0
manufacturing	56	1.2
military	26	0.6
professional	1666	36.3
retail	222	4.8
retired	317	6.9
transportation	63	1.4
unemployed	179	3.9
utility	22	0.5

Table 2

Estimated NIPTS Assuming 20 Years of Exposure for Subjects with Source-Specific $L_{Aeq8hni}$ That Exceeded L_0^b

source	n exposed to source	1000 Hz				2000 Hz				3000 Hz				4000 Hz			
		$L_{Aeq8hni} > 89 \text{ dBA}^a$		$N_{0.50} \text{ (dB)}$		$L_{Aeq8hni} > 80 \text{ dBA}^a$		$N_{0.50} \text{ (dB)}$		$L_{Aeq8hni} > 77 \text{ dBA}^a$		$N_{0.50} \text{ (dB)}$		$L_{Aeq8hni} > 75 \text{ dBA}^a$		$N_{0.50} \text{ (dB)}$	
		n	%	mean	SD	n	%	mean	SD	n	%	mean	SD	n	%	mean	SD
home/ miscellaneous activities	4585	0	0	NA	NA	0	0	NA	NA	0	0	NA	NA	0	0	NA	NA
MP3 players/ stereos	3563	0	0	NA	NA	1868	52	0.27	0.32	3562	99	0.87	1.13	3562	99	1.69	1.68
non-occupational	2175	128	6	1.83	2.28	670	31	2.05	3.10	1062	49	3.56	5.50	1407	65	3.80	5.90
occupational	3957	33	1	0.18	0.32	596	15	1.43	1.10	868	22	3.18	2.92	1073	27	3.80	3.77
transit	4436	0	0	NA	NA	22	1	0.14	0.20	120	3	0.32	0.56	392	9	0.32	0.63
total	4585	252	6	1.15	1.93	2895	63	1.23	1.91	4029	88	2.88	3.73	4138	90	4.20	4.40

^a L_0 , audiometric frequency-specific sound pressure level threshold (the minimum level that can cause NIPTS).

^b $L_{Aeq8hni}$, 8-h equivalent continuous average noise exposure level; $N_{0.50}$, NIPTS assuming 50th percentile noise-damage susceptibility; SD, standard deviation.

Table 3
Estimated NIPTS Source Apportionment by Age Group Assuming 20 Years of Exposure ($n = 4585$)^a

source	% of total N _{0.50} at 4000 Hz						
	total ($n = 4585$)	19–29 yr ($n = 1167$)	30–39 yr ($n = 715$)	40–49 yr ($n = 901$)	50–59 yr ($n = 917$)	60–69 yr ($n = 885$)	70–79 yr ($n = 885$)
home/ miscellaneous activities	0	0	0	0	0	0	0
MP3 players/ stereos	39	51	41	32	26	32	32
non-occupational	34	33	33	41	37	23	23
occupational	26	15	25	26	36	44	44
transit	1	1	1	1	1	1	1

^aN_{0.50}, NIPTS assuming 50th percentile noise-damage susceptibility; yr, years old.

Table 4
Estimated NIPTS Source Apportionment by Primary Source of Exposure^a Assuming 20 Years of Exposure (*n* = 4585)^b

source	% of total N _{0.50} at 4000 Hz					
	home/other activities (<i>n</i> = 25)	MP3 players/stereos (<i>n</i> = 2688)	nonoccupational (<i>n</i> = 703)	occupational (<i>n</i> = 755)	transit (<i>n</i> = 414)	total (<i>n</i> = 4585)
home/miscellaneous activities	0	0	0	0	0	0
MP3 players/stereos	0	88	14	9	12	39
nonoccupational	0	8	79	8	8	34
occupational	0	3	6	82	5	26
transit	0	1	1	1	75	1

^aThe source that contributed the most to total dose (estimated previously by Neitzel et al.¹⁴).

^bN_{0.50}, NIPTS assuming 50th percentile noise-damage susceptibility.

Table 5

Logistic Regression Model of Estimated NIPTS >10 dB Assuming 20 Years of Exposure ($n = 4585$)^f

variable/category ^c	nonsimulated cohort at 4000 Hz ^d			10 simulated cohorts at 4000 Hz ^b		
	OR	95% CI		mean OR	95% CI	
		LB	UB		LB	UB
age ^d	0.98	0.97	0.99	0.99	0.98	0.99
live in NYC	0.54	0.33	0.89	0.56	0.51	0.62
MP3 players/stereos ^e	1.06	1.04	1.08	1.07	1.06	1.07
nonoccupational ^e						
band	1.15	1.08	1.22	1.13	1.10	1.16
concerts	2.33	1.86	2.94	2.30	2.19	2.42
lawn tools	3.13	2.41	4.05	3.03	2.85	3.21
power tools	1.24	1.14	1.36	1.20	1.16	1.24
sporting events	1.30	1.14	1.48	1.28	1.24	1.31
occupational						
construction	10.67	7.39	15.39	10.40	9.90	10.90
entertainment	8.95	5.96	13.45	8.43	7.68	9.17
maintenance	3.07	1.42	6.63	3.09	2.75	3.43
manufacturing	21.84	11.30	42.21	20.29	18.64	21.94
military	72.05	29.65	175.09	53.91	45.45	62.36
utility	5.62	1.61	19.59	6.19	5.40	6.97

^a Assumes 50th percentile noise-damage susceptibility.

^b For each simulation, subjects were randomly assigned 10th, 50th, or 90th percentile noise-damage susceptibility.

^c Logistic regression model developed using forward stepwise logistic regression analysis.

^d One unit increase = 1 yr.

^e One unit increase = 100 h.

^f CI, confidence interval; LB, lower bound; OR; odds ratio; UB, upper bound.

Table 6
Estimated NIPTS for Subjects in 10 Simulated Cohorts Assuming 20 Years of Exposure^b

noise-damage susceptibility	n per simulation ^a	NIPTS averaged across 1000, 2000, 3000, 4000 Hz				
		mean of simulation means		95% CI (dB)		
		NIPTS (dB)	LB	UB	mean	% >10 dB
10th percentile	459	2.63	2.51	2.75		4
50th percentile	3667	1.80	1.79	1.81		2
90th percentile	459	1.17	1.10	1.24		1

^a For each simulation, subjects were randomly assigned 10th, 50th, or 90th noise-damage susceptibility. CI, confidence interval; LB, lower bound; UB, upper bound.
^b CI, confidence interval; LB, lower bound; UB, upper bound.