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Mass Transit Ridership and Self-Reported Hearing Health in an Urban Population

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ABSTRACT *Information on prevalence and risk factors associated with self-reported hearing health among mass transit riders is extremely limited, even though evidence suggests mass transit may be a source of excessive exposure to noise. Data on mass transit ridership were collected from 756 study participants using a self-administered questionnaire. Hearing health was measured using two symptom items (tinnitus and temporary audiometric threshold shift), two subjective measures (self-rated hearing and hearing ability), and two medical-related questions (hearing testing and physician-diagnosed hearing loss). In logistic regression analyses that controlled for possible confounders, including demographic variables, occupational noise exposure, nonoccupational noise exposure (including MP3 player use) and use of hearing protection, frequent and lengthy mass transit (all forms) ridership (1,100 min or more per week vs. 350 min or less per week) was the strongest predictor of temporary threshold shift symptoms. Noise abatement strategies, such as engineering controls, and the promotion of hearing protection use should be encouraged to reduce the risk of adverse impacts on the hearing health of mass transit users.*

KEYWORDS *Noise, Mass transit, Urban ridership, Hearing protection, Hearing health*

INTRODUCTION

Public transportation is a critical urban infrastructure, providing affordable, energy efficient, and convenient transportation to millions of city dwellers.[1] Growing urbanization, especially in developing nations, is driving rapid development of mass transit systems. A good example of this is the increase in the number of subway systems: in 2001, there were 143 subway systems throughout the world, and today there are 178, a 20 % increase in 10 years.[2]

These and other mass transit systems support massive ridership. In the United States (US) alone, the complex mass transit infrastructure, comprised of networks of multiple occupancy vehicles (e.g., buses, heavy rail, light rail, cable cars, tramways, and ferries), provides over 10 billion passenger rides each year.[3] The subway system in New York City (NYC), the largest in the US, serves nearly 7 million passengers each weekday.[4,5]

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The efficiency and convenience of these systems, however, is being compromised by increasingly lengthy commutes and more frequent transfers, often involving multiple forms of mass transit. The impact of mass transit on the health and well-being of this large ridership is capturing the attention of public health researchers, urban health specialists, city planners, and community activists.[6,7]

One aspect, in particular, which has garnered special attention, is the issue of noise associated with mass transit use. Data from recent studies suggest that transit users are potentially exposed to noise that is in excess of recommended community limits (i.e., 70 dBA/24-h period),[8,9] especially for those riders with extensive commute times.[10,11] Hazardous levels may be of particular concern in some urban centers with older transit systems, as these have generally not benefitted from newer sound-dampening design features or engineering controls. In the US, there are five subways systems that are more than 75 years old, and four (Boston, Chicago, NYC, and Philadelphia) are more than 100 years old. Excessively loud noise has also been documented on newer systems, such as the regional Bay Area Rapid Transit (BART), which operate at much higher speeds than older systems.[10]

Subways are not the only mass transit source of excessive levels of noise. Hazardous levels have been reported for all forms of mass transit in NYC.[12] In addition to subways (mean equivalent continuous exposure level, or L_{EQ}, of 80.4 dBA), excessive levels were recorded in NYC for buses (mean L_{EQ} = 75.7 dBA), above ground commuter rails (Long Island Rail Road, mean L_{EQ} = 74.9 dBA, Staten Island Rail Road, mean L_{EQ} = 76.7 dBA, and Metro-North Railroad, mean L_{EQ} = 75.1 dBA), ferries (mean L_{EQ} = 75.3 dBA), and trams (mean L_{EQ} = 77.0 dBA).[12] Potentially hazardous noise levels were noted both inside vehicles as well as on waiting platforms, although platforms were generally 1–5 dBA higher than inside of vehicles.[12] It should be noted that at many of the subway transit hubs in NYC, musicians playing loud music are not uncommon, and this adds to the platform or station noise levels.

Irrespective of the noise source, excessive exposure can negatively impact hearing health, potentially causing communication disorders and irreversible noise-induced hearing loss (NIHL). The World Health Organization (WHO) estimates that over 200 million people worldwide have NIHL, although most of this is believed to be related to work exposure.[13]

Excessive noise exposure has also been linked to a wide range of other, nonauditory health effects, such as hypertension, cardiovascular disease, stress hormone disruptions, poor sleep quality, and adverse effects on learning and concentration.[14–17] Both sporadic nuisance noise (e.g., noisy neighbors, car alarms and horns, sirens, etc.) and excessive chronic noise exposure can negatively impact quality of life.[16,18–25]

The precise effects of chronic exposure to mass transit-related noise on hearing health and other health outcomes is unknown. Research on the health effects of mass transit noise on riders and the dose–response relationships between noise and nonauditory health outcomes has been hampered by difficulties associated with measuring the duration of exposure. Because noise exposure is a function of both frequency-weighted sound levels, measured in A-weighted decibels (dBA), as well as duration, information on both factors is required to estimate risk of exposure associated with mass transit use. Furthermore, as exposure is both cumulative and additive, levels and durations for *all other potential sources* of excessive noise exposure must also be estimated in order to determine the independent contribution of transit on hearing health.

To address this research challenge, we conducted a community-based survey to characterize mass transit usage and ride durations and to estimate noise exposure

associated with mass transit, occupational, and nonoccupational sources. We explained variation in self-reported hearing health in terms of transit-related noise exposure using logistic regression analyses while controlling for other hearing health risk factors, such as age and nontransit sources of exposure.

SUBJECTS AND METHODS

A four-page, 40-item risk assessment questionnaire was constructed for the study. To facilitate completion, the questionnaire was written at an eighth grade reading level using the Flesch–Kincaid Grade Level Readability Test, automated in Microsoft Word.[26] Photographs of four modes of mass transportation (underground subway, above ground commuter train, bus, and ferry) addressed in the study were included in the questionnaire to provide visual reference. Similarly, images of earplugs and earmuffs were also provided. To reduce recall bias, the questionnaire was constructed to address current exposures (e.g., ridership activity within the past 7 days). A draft version of the questionnaire was reviewed by audiologists, transportation specialists, industrial hygienists, and other experts to provide face and content validity. A final version was pilot tested by ten volunteers to ascertain completion time (mean = 10 min) and readability. A paper version was prepared in the English language.

Several modes of subject recruitment were pilot tested for feasibility. Distribution at transit locations was determined to be infeasible due to the fact that most potential subjects were rushing to or from their destinations and, therefore, had limited availability. After several feasibility trials at various sites, a decision was made to collect data at neighborhood street fairs, typically held throughout NYC between the months of May to September. These well-attended events are generally several blocks long, with various booths offering clothing, household goods, foods, and other items. Many health care institutions and city agencies also sponsor booths at these fairs to publicize their services.

From a census list of several dozen street fairs held in the spring, summer, and fall of 2007, a random sample of five street fairs, stratified by borough, was drawn. An additional sample of five street fairs was also drawn as a backup for cancellations due to inclement weather. A small booth was rented at each selected fair. Booths were hosted for 6–8-h time periods by members of the research team, including trained graduate students. Using street intercept methodology, people attending the fair were encouraged by members of the team to complete the study questionnaire.[27]

Interested subjects were provided with a brief disclosure statement indicating the broad purpose of the study. If the potential participant met the eligibility criteria (18 years of age, ability to complete the questionnaire in English, and living and/or working in NYC), they underwent verbal consent procedures, followed by self-administration of the anonymous questionnaire. As an incentive, participants received a $1 NYC scratch-off lottery ticket. All procedures had the prior approval of the Columbia University Institutional Review Board (IRB-AAAD1614). Copies of the study questionnaire and coding information are available by contacting the corresponding author.

Measure

Predictor Variables

Demographics. Items on gender, age, race, ethnicity, and residence were included. Response options for these items were categorical and open-ended.

Mass Transportation Ridership. For each of four modes of transportation (underground subway, above ground train, bus, and ferry), participants were asked to indicate the average number of days per week wherein they used each type of transportation, the average length of time spent *waiting* for transportation (hours and minutes), and the average length of time spent *riding* (hours and minutes) each form of transportation. All items were structured for open-ended responses.

Occupational Characteristics. Participants were asked to indicate their current employment status, industry or field in which they worked, job title, number of hours worked per day, and number of weeks worked per year. One item queried participants on how frequently they were exposed to "high noise" at work (defined as louder than a noisy bar or restaurant), and another asked how often they had to "raise their voice at work in order to be heard by someone at arm's length away," using a five-point response scale ranging from "always/almost always" to "never/almost never." A third item asked participants to rate the noise level at work on a scale of 1 ("as loud as or quieter than normal speaking voice") to 5 ("as loud as or louder than a siren").[28] Respondents were also asked if they worked in a quiet office environment, with response categories of "yes" and "no." The questionnaire included one item asking if the noise on the subway, bus, train, bus, or ferry was louder than the noise levels at work, with four response categories, "yes," "no," "don't know," and "not sure." Participants were also asked about military service and volunteer service in a high noise setting (e.g., firefighting), with "yes" and "no" as the response choices.

Nonoccupational/Sociocusis Activities. Participants were asked to indicate the frequency in which they engaged in certain noisy leisure activities (i.e., "played music in a band," "attend concerts," "use power tools," "shoot guns," etc.).[29] Response choices included "weekly," "monthly," "yearly," and "rarely or never." Participants were also asked to indicate the number of hours per day spent using MP3 players or stereos and riding motorcycles and if they used MP3 players or stereos to indicate how loudly they were played ("quiet," "moderate," and "loud.") A composite risk variable was constructed to combine daily usage plus loudness of volume.

Hearing Protection. On five-point scales ranging from "always/almost always" to "never/almost never," participants were asked to report how frequently they used earplugs or earmuffs while riding mass transportation while at work and during high noise leisure time activities.

Outcome Variables Two subjective current assessment items on hearing health were included: "How would you rate your hearing?", with four response options ("good," "fair," "poor," and "don't know") and "Have family, friends, or coworkers complained to you about your hearing ability?", with "yes," and "no" as the response options. These questions were adapted from a previous study that evaluated the accuracy of self-reported hearing loss.[30]

Two items addressed current symptoms of hearing health: tinnitus symptoms ("How often do you hear ringing, whistling, or buzzing in your ears?") and symptoms of a transient change in audiometric thresholds and perception of sounds, referred to as a temporary threshold shift[31] ("How often does your hearing seem

muffled or distorted after riding the subways, trains, buses, or ferries?"). Both of these items used the same five-point response categories ranging from "never/almost never" to "always/almost always."

Finally, there were two medical-related items, as follows: "Have you ever been tested for hearing loss?" and "Have you ever been told by a doctor that you have a hearing loss?" Both questions used the following response choices: "yes," "no," and "not sure."

Statistical Analysis

A total of 1,045 questionnaires were collected; of these, 122 were excluded from data analysis due to incomplete or missing data or because respondent did not meet eligibility criteria (live or work in NYC). From the remaining 923 questionnaires, an additional 167 (18 %) were removed because the participant reported that they never used any form of mass transit, resulting in a final sample of 756 participants. All data were entered into a database and reviewed for inconsistencies and to ensure accuracy of data entry. To protect security and confidentiality of the data, all data storage was HIPAA compliant and password protected, and no data were stored on portable electronic devices. After data cleaning and editing procedures, basic descriptive analyses of the data (e.g., calculation of item response frequencies and measures of central tendency) were performed. The total time (minutes) spent riding and waiting for mass transportation per day was multiplied by days per week of ridership to estimate the amount of time spent riding and waiting for each mode of transportation per week. The median length of time (duration) is reported for time spent riding and waiting for mass transit in all cases, unless specified.

To ascertain the association between transit use and adverse outcomes, risk categories for the major potential sources of excessive noise were dichotomized as follows. For transit ridership, data were dichotomized into two groups: "heavy user" (1,100 min of exposure or more per week; $n=188$) and "non-heavy user" (350 min or less per week; $n=190$), representing the upper and lower quartiles of the sample's transit ridership duration. As noted, nontransit users were excluded from all analyses. Occupational exposure was categorized for the analysis into two categories: "high risk," vs. "low risk," based on the percentage of workers in each industry estimated to exceed recommended occupational exposure limits.[32] Sociocusis (leisure time) exposure was similarly categorized into two groups (i.e., "high risk" and "low risk") corresponding to above and below a composite score, which combined duration and frequency of activities. Similarly, two categories, "high risk" and "low risk," which corresponded to a composite score that combined duration and volume, were formed for MP3 and stereo use. Use of hearing protection was dichotomized into two groups, "rare/never" vs. "sometimes/frequent/always".

The data met the assumptions required by the intended statistical testing procedures, and level of significance was set at an alpha level of 0.05, two-tailed. For bivariate analysis, Pearson's chi-squared analysis was performed to assess relations between categorical items (e.g., ridership duration and hearing health outcome variables). Odds ratios (OR) and their 95 % confidence intervals (CI) were estimated, where appropriate.

To assess the relationship among predictor variables and the two major current outcome variables (i.e., tinnitus and symptoms of a temporary threshold shift), logistic regression analyses were performed. Additionally, tolerance tests were

performed to determine multicollinearity among the predictor variables. All analyses were conducted using SPSS 16.0.1.[33]

RESULTS

Predictor Variables

Demographics The majority of the sample was female (55 %), with an average age of 41 years old (range = 18–88 years, standard deviation = 15.1 years). A majority of the sample (72 %) was White, and 17 % reported that they were Hispanic or Latino. Employed participants worked an average of 40 h/week and 44 weeks/year.

Mass Transportation Ridership More than half of the sample (55 %) used more than one mode of mass transit on a regular basis, with either subway/bus or subway/train combinations most frequently reported (22 % and 19 %, respectively).

The average median length of time spent riding and waiting on platforms was 136 min/day or 950 min/week. Passengers exclusively using subways (41 %) reported 68 min of ridership per day or 475 min/week. Riders using the most common combination (subway and bus; 22 %) reported 94 min/day or 655 min/week of ridership. Riders using all forms of mass transit under consideration in this study, (i.e., subway, commuter train, bus, and ferry; 0.3 %) reported the lengthiest median ridership times, 242 min/day or 1,694 min/week. A complete list of the median durations of daily and weekly ridership times, by mode of transportation, is shown in Table 1.

Among the upper quartile of participants referred to as “heavy transit users,” the median length of time spent waiting and riding mass transit was 157 min or more per day or 1,100 min or more per week. In comparison, for the lower quartile of the sample, referred to as “light users,” the median length spent waiting or riding was 50 min or less per day or 348 min or less per week.

At the bivariate level, only gender and race were significantly associated with ridership duration. Males were more likely to be heavy transit users (OR = 1.6, 95 % CI = 1.04–2.37, $P<0.05$) compared to females, and non-White participants were over three times more likely to be heavy transit users (OR = 3.3, 95 % CI = 2.00–5.32, $P<0.001$), compared to White participants.

Occupational Characteristics Eighty-seven percent of the sample reported that they were currently employed. Of these, 20 % worked in “noisy” occupations (those with a high probability of noise exposure above the recommended limit of 85 dBA):[32] construction, manufacturing, food, sports/entertainment transportation/utilities, military, or agriculture. This group included a small proportion (3 %) who identified themselves as police officers, emergency medical service personnel, firefighters, and/or members of the National Guard. The remainder of the sample worked in fields with a low probability of excessive noise exposure: education and research, health services, professional or legal services, financial services, retail, information or computing, and design and art.

With respect to perceived noise in the work environment, half the sample (56 %) reported that they worked in a quiet office environment, while 30 % indicated that there was a “high level of noise,” at least half of the time, in their workplace. Roughly half of those working in a high noise risk occupation (43 %) also reported that they worked in a high noise setting. More than half of the sample (56 %) rated

TABLE 1 Length of time of ridership by mode of transportation, *N*=756

Mode of transportation	Number (valid %)	Daily		Weekly	
		(min/day[a])	(h:min)	(min/week[b])	(h:min)
Single					
Subway only	313 (41.4)	68	01:08	475	07:55
Bus only	21 (2.8)	34	00:34	240	04:00
Train only	9 (1.2)	63	01:03	441	07:21
Ferry only	–	–	–	–	–
Combination					
Subway and bus	167 (22.1)	94	01:34	655	10:55
Subway and train	147 (19.4)	123	02:03	863	14:23
Subway, train, and bus	74 (9.8)	186	03:06	1,300	21:40
Subway, bus, and ferry	8 (1.1)	139	02:19	970	16:10
Train and bus	8 (1.1)	217	03:37	1,520	25:20
Subway, train, and ferry	5 (0.7)	206	03:26	1,443	24:03
Subway, train, bus, and ferry	2 (0.3)	242	04:02	1,694	28:14
Subway and ferry	1 (0.1)	47	00:47	330	05:30
Bus and ferry	1 (0.1)	209	03:29	1,465	24:25
Total	756 (100.0)				

Length of time of ridership includes time waiting on the platform and time riding. Median length of time reported. All values rounded to nearest whole number

h:min hours:minutes

[a]Average median = 136 min/day (02:16 h:min); ferry only was not included in calculation due to no ridership

[b]Average median = 950 min/week (15:50 h:min); ferry only was not included in calculation due to no ridership

the noise level at their place of employment as relatively quiet, and 16 % compared the noise level at their workplace to that of a powered lawnmower or louder. Many participants (73 %) reported that the noise they experienced while using mass transit was louder than the noise levels at their workplace.

Males were more likely than females to work in high noise occupations (OR = 2.4, 95 % CI = 1.68–3.55, $P<0.001$). No other demographic variables were significantly associated with employment in a high noise occupation.

Nonoccupational/Leisure Activities Only a small portion of the sample (roughly 4 %) reported frequent exposure to noisy leisure activities, such as using power tools (e.g., drilling and carpentry), using lawn tools, playing in a band, attending loud concerts, and attending commercial sporting events (e.g., Yankee Stadium or car races), as shown in Table 2.

TABLE 2 Frequency of noisy leisure activities among participants, *N*=756 (valid %)

Activity	Weekly	Monthly	Yearly	Rarely or never
Play in a band	30 (4.4)	18 (2.6)	7 (1.0)	631 (92.0)
Attend loud concerts	22 (3.1)	114 (16.0)	246 (34.5)	331 (46.4)
Attend commercial sporting events	6 (0.8)	102 (14.3)	233 (32.8)	370 (52.0)
Use loud lawn tools	20 (2.8)	30 (4.2)	43 (6.0)	621 (87.0)
Use other loud power tools	30 (4.2)	41 (5.7)	85 (11.9)	558 (78.2)
Shoot guns	8 (1.1)	8 (1.1)	26 (3.7)	669 (94.1)

Numbers may vary because of missing values

Males were three times more likely to engage in noisy leisure activities compared to females (OR = 3.0, 95 % CI = 1.75–5.04, $P<0.001$). No other demographic variables were associated with leisure.

A large proportion of participants (69 %, $n=519$) reported use of MP3 players or stereos, with average daily use of 3.1 h. Almost one-quarter of those listening to these devices (22 %) reported that they typically played them at a "loud" volume. Younger participants (age >42 years) were more likely to report more frequent use of MP3 players or stereos than older participants (OR = 2.7, 95 % CI = 1.94–3.80, $P<0.001$). Very few participants ($n=23$) reported that they rode motorcycles, generally for 2 h or less per day.

Hearing Protection Usage Use of hearing protection was uncommon. Only a small percentage (14 %) of participants wore hearing protection, at least some of the time, during mass transit use. Similarly, only 9 % of participants reported that they wore hearing protection at work, even under high noise conditions, and 16 % wore hearing protection during noisy leisure time activities.

Compared to females, males were more likely to wear hearing protection while riding mass transportation (OR = 1.7, 95 % CI = 1.09–2.62, $P<0.05$), at work (OR = 2.1, 95 % CI = 1.20–3.72, $P<0.01$), and during noisy leisure activities (OR = 1.6, 95 % CI = 1.07–2.41, $P<0.05$).

Participants in the high risk groups were more likely to wear hearing protection during noise exposure. That is, heavy transit users were more likely to wear hearing protection while riding and waiting for transportation than light transit users (OR = 2.1, 95 % CI = 1.16–3.72, $P<0.05$). Workers in noisy occupations were more likely to wear hearing protection while on the job than workers in low noise occupations (OR = 2.2, 95 % CI = 1.23–3.88, $P<0.01$). Similarly, participants who engaged in more noisy leisure activities were more likely to wear hearing protection during these activities than participants who do not engage in such activities (OR = 3.85, 95 % CI = 2.38–6.23, $P<0.001$).

Outcome Variables

Self-Reported Hearing Health

Subjective Hearing Ability Items. Over half of the sample (58 %) rated their hearing as "good," 34 % rated it as "fair," 6 % rated it as "poor," and 2 % were unsure. Nearly a quarter of the sample (24 %) reported that others (e.g., family, friends, or coworkers) had complained to them about their lack of hearing ability. Subjective hearing ability items were associated with tinnitus and temporary threshold shifts, as shown in Table 3. Self-reported hearing ability was not associated with demographic variables and nontransit sources of noise exposure.

Hearing Loss Symptom Items. Thirteen percent of the sample reported that they experienced tinnitus symptoms on a frequent basis. At the bivariate level, tinnitus symptoms were significantly associated with heavy transit ridership and more frequent participation in noisy leisure activities, as shown in Table 3. Tinnitus was also associated with use of hearing protection, fair, or poor self-reported hearing ability, complaints about hearing ability, prior hearing testing, and physician diagnosed hearing loss, as shown in Table 3. Age, gender, race, occupation, and use of MP3 players or stereos were not associated with tinnitus symptoms.

TABLE 3 Factors significantly associated with tinnitus symptoms (ringing, whistling, or buzzing in ears) among NYC transit riders, $N=756$

Variable	More than half of the time to always	About half to never	OR (95 % CI)	*P* value
Transit use				
Heavy	11.3 % (20)	88.7 % (157)	2.5 (1.10–5.63)	0.024
Light	4.9 % (9)	95.1 % (176)		
Noisy leisure activities				
High risk	23.5 % (12)	76.5 % (39)	3.2 (1.59–6.43)	0.001
Low risk	8.8 % (59)	91.2 % (612)		
Hearing protection use				
Sometimes/frequent/always	16.8 % (16)	83.2 % (79)	3.4 (1.78–6.38)	<0.001
Rare/never	5.7 % (34)	94.3 % (565)		
Hearing rating				
Fair/poor	11.6 % (34)	88.4 % (258)	3.1 (1.71–5.69)	<0.001
Good	4.1 % (17)	95.9 % (402)		
Others complain about hearing				
Yes	20.7 % (35)	79.3 % (134)	7.7 (4.25–14.08)	<0.001
No	3.3 % (18)	96.7 % (533)		
Prior testing for hearing loss				
Yes	12.3 % (38)	87.7 % (272)	3.5 (1.84–6.54)	<0.001
No	3.9 % (14)	96.1 % (348)		
Physician diagnosed hearing loss				
Yes	31.3 % (21)	68.7 % (46)	9.0 (4.77–16.91)	<0.001
No	4.8 % (30)	95.2 % (590)		

Numbers may vary because of missing values

Approximately one-third of the sample (32 %) frequently experienced symptoms of a temporary threshold shift after riding the subways, trains, buses, or ferries (about half the time or more). A temporary threshold shift after riding mass transit was significantly associated at the bivariate level with several variables, as shown in Table 4, including heavy transit use, which had the strongest association as well as gender (male), race (non-White), age (>42 years), use of hearing protection, fair or poor self-reported hearing ability, and complaints about hearing ability. Occupation, leisure activities, MP3 or stereo use, hearing testing, and physician diagnosis were not associated with temporary threshold shifts after riding mass transit. Tinnitus symptoms and muffling after riding mass transit were significantly associated with each other (OR = 3.4, 95 % CI = 1.64–7.25, $P=0.001$).

Medically-Related Hearing Items. Almost half of the sample (43 %) had been previously tested for hearing loss and 9 % had been told by a doctor that they suffered from hearing loss. At the bivariate level, hearing testing was associated with age (>42 years) (OR = 1.6, 95 % CI = 1.18–2.18, $P<0.01$). Age (>42 years) was similarly associated with physician diagnosed hearing loss (OR = 2.1, 95 % CI = 1.26–3.58, $P<0.01$). No other predictor variables were associated with hearing testing or physician diagnosis.

Multiple Regression Analysis

None of the tolerance indices were below 0.82, indicating that tolerance was acceptable (i.e., multicollinearity among the predictors was not a statistical

TABLE 4 Factors significantly associated with symptoms of a temporary threshold shift (muffled or distorted hearing) after riding and waiting for mass transit among NYC transit riders, *N*=756

Variable	Less than half of the time or more	Never or almost never	OR (95 % CI)	*P* value
Transit use				
Heavy	72.5 % (121)	27.5 % (46)	2.6 (1.66–4.08)	<0.001
Nonheavy	50.3 % (89)	49.7 % (88)		
Gender				
Male	49.0 % (150)	51.0 % (156)		
Female	63.1 % (238)	36.9 % (139)	1.8 (1.31–2.42)	<0.001
Race				
White	54.0 % (247)	46.0 % (210)		
Non-white	63.1 % (101)	36.9 % (59)	1.5 (1.01–2.11)	0.046
Age				
<42 years	52.4 % (196)	47.6 % (178)		
>42 years	63.2 % (191)	36.8 % (111)	1.6 (1.15–2.13)	0.005
Hearing protection use				
Sometimes/frequent/always	17.5 % (68)	7.8 % (23)	2.5 (1.51–4.11)	<0.001
Rare/never	82.5 % (320)	92.2 % (270)		
Hearing rating				
Fair/poor	65.8 % (181)	34.2 % (94)	1.9 (1.35–2.55)	<0.001
Good	50.9 % (200)	49.1 % (193)		
Others complain about hearing				
Yes	74.2 % (118)	25.8 % (41)	2.7 (1.79–3.95)	<0.001
No	51.9 % (268)	48.1 % (248)		

Numbers may vary because of missing values

problem). To determine the unique contributions of each predictor variable with the two hearing symptom outcomes (i.e., tinnitus and muffling), while controlling for the other variables, we performed logistic regression analyses.

In step 1 of the first model, with tinnitus as the outcome, demographic variables (age, gender, and race), high risk groups (occupation, noisy leisure activities, and MP3 or stereo use), and use of hearing protection while riding mass transit were forced entered into the model. Use of hearing protection was the only significant predictor of tinnitus, determined by effect size ($P<0.05$). In step 2 of the model, it was found that ridership duration (heavy users vs. light users) did not enter the model. Thus, the use of hearing protection was the only significant predictor of tinnitus in the model after controlling for possible demographic risk factors (OR = 3.8, 95 % CI = 1.13–12.44, P=0.031).

To determine the significant predictors of a probable temporary threshold shift after mass transit use, logistic regression analysis was performed. In step 1 of the second model, demographic variables (age, gender, and race), high risk groups (occupation, noisy leisure activities, and MP3 or stereo use), and use of hearing protection while riding were forced entered. Gender (female) was the only variable that significantly predicted symptoms of a temporary threshold shift in the first step of the model. In step 2, ridership duration (heavy users vs. light users) entered the model, with gender remaining significant. Heavy transit use was the strongest predictor of hearing symptoms of a temporary threshold shift after riding (OR = 2.9,

95 % CI = 1.55–5.58, $P=0.001$), followed by female gender (OR = 2.7, 95 % CI = 1.41–5.33, $P=0.003$).

DISCUSSION

In this study's sample, at more than 2 h/day, median ridership duration was substantial, with more than half of the sample typically using more than one form of mass transit each day. In logistic regression models that adjusted for other possible risk factors, such as age and occupation, heavy transit users (i.e., upper quartile of ride duration, 157 min or 2 h and 37 min/day) was significantly and positively associated with symptoms of a temporary threshold shift, followed by gender. It should be noted that a large proportion, over a third of our sample, reported symptoms of a temporary threshold shift after riding mass transit. Use of hearing protection was the only variable significantly associated with tinnitus in the final model. This latter finding is understandable, since persons with tinnitus might be more proactive in protecting their hearing. Similar to the rate of 10 % in the general population citied by the National Institute on Deafness and Other Communication Disorders,[34] 13 % of our sample reported tinnitus.

To our knowledge, this is the first study to investigate the relation between length of time riding mass transit and hearing health outcomes. These findings suggest that extensive mass transit travel, at least in this older, high noise transportation system, may be deleterious to hearing health, possibly even exceeding the hearing health risks traditionally associated with some occupations with moderate noise exposures.

Given the high noise levels measured in previous mass transit studies, these findings are not unexpected, especially considering that only a very small proportion of transit users wore hearing protection while riding. In general, regardless of the noise source, the majority of our sample did not use hearing protection, a finding consistent with other studies. For example, in a large sample of US workers, 34 % employed in hazardous noise environments reported that they did not use hearing protection when indicated, while in our sample, 85 % of those working under similar conditions did not wear hearing protection.[35] A slightly larger proportion of our sample (39 %) wore hearing protection during noisy leisure time activities, and other studies have also found similar levels of hearing protection use during these activities.[12,36]

Use of MP3 players or stereos was very common in our sample, with nearly 70 % of subjects reporting their use. In comparison, a recent study of college students found that 67 % used these devices, with 58 % listening at high levels. [37] Using mannequins to measure the actual levels associated with these levels, the researchers recorded levels that typically exceeded 85 dBA.[37] We have anecdotal reports of MP3 music played at levels high enough to be heard by others several feet away. Some MP3 users may have a false sense of protection from their use, or they may simply be playing them at higher volumes in order to overcome the high ambient noise levels. Though standards exist for occupational exposures to hazardous noise levels, no similar standards exist for recreational noise exposure, including exposure to MP3s. The role of MP3 use in conjunction with frequent and lengthy mass transit ridership on hearing health needs additional study, preferably with a larger sample.

Although both EPA and WHO have community exposure recommendations for total daily noise exposure, data suggest that these recommended exposure limits are routinely exceeded, and NIHL rates continue to rise worldwide.[38,39] As demonstrated in our study and others, compliance with use of hearing protection is clearly suboptimal. The relative contribution of various sources, in addition to traditional occupational sources of noise exposure, requires additional research. In modern urban

populations, excessive noise exposure may not be related primarily to occupation but to other nonoccupational risk factors, including mass transit ridership. Our study findings raise the specter of harm arising from these other sources.

Beyond the hearing health implications, these findings also raise concern regarding the nonauditory impact on health and well-being, including stress levels. Evidence suggests that nonauditory effects of noise can begin at levels well below those associated with NIHL.[9] Our study was not designed to evaluate these other health concerns and additional studies focused on these other health outcomes are needed. Nor did our study assess the impact of long commutes on the well-being of the ridership. Again, this should be the focus of future research, especially given that mass transit commutes are getting longer and more complicated as cities continue to sprawl outwards. Urban planners may want to consider ways to keep durations as reasonably brief as possible.

Our findings must be considered in light of a number of potential study limitations. The most important of these is the cross-sectional design, which precludes the ascertainment of causality. If participation in the study was linked to either the predictor or outcome variables, there could be threats to validity and strength of association. However, this design is a useful, efficient, and cost-effective approach to glean preliminary data that can then serve as a foundation for future studies.

Another potential limitation is related to the generalizability of the findings, since only NYC mass transit riders participated in the study. Riders in our sample might not represent all mass transit riders in the US, and it is possible that they are not even representative of all NYC transit riders. However, we compared our sample to NYC census data (data not shown) and found that they were similar.[40]

Finally, the potential exists for self-report and recall bias. Frequency and duration of ridership patterns and other risk factors (e.g., occupation, noisy leisure time activities, etc.,) may not have been accurately reported or recalled. Future research involving personal dosimetry measurements over long periods of time and including a variety of occupational, nonoccupational, and transit activities can help corroborate the accuracy of self-reports and limit these potential biases. The accuracy of self-reported perceived hearing ability has been studied and shown to have valuable sensitivity and specificity, roughly 60–80 %, depending on the frequency and age group of subjects studied using audiometric testing. A recent paper by McCullagh et al. noted that 42 % of noise-exposed factory workers had hearing loss, while 76 % of workers rated their hearing as excellent or good.[41] However, only a single-item measuring hearing ability was used. In our study, we used several different measures for self-reported hearing health. Additional studies are needed to address self-report bias.

CONCLUSIONS

This study represents an important first step in clarifying the relationship between mass transit ridership and hearing health. The findings indicate that lengthy ridership is associated with important hearing health symptoms, such as symptoms of a temporary threshold shift. These results suggest the need for more intensive and definite experimental studies, including audiometric evaluations. In the interim, strategies are needed to reduce risk as much as reasonably possible. Risk management interventions should be guided by standard industrial hygiene and public health practice, including hazard mitigation (i.e., environmental noise abatement strategies) and the use of hearing protection devices by riders, especially for those with frequent and lengthy ridership. The health and well-being of the large and growing population of mass transit ridership should be an important public and urban health priority.

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