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Original Article

Lifelong occupational exposures and hearing loss among elderly Latino Americans aged 65–75 years

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Abstract

Objective: The purpose of this study is to determine the relationship between occupational exposures and hearing among elderly Latino Americans. *Design:* A descriptive, correlational design used for this secondary analysis with the data from the Sacramento Area Latino Study of Aging (SALSA). *Study sample:* A total of 547 older adults were included. *Results:* A majority of participants (58%) reported occupational exposures to loud noise and/or ototoxic chemicals. About 65% and over 90% showed hearing loss at low and high frequencies, respectively. Participants with occupational exposure to loud noise and/or ototoxic chemicals were, significantly, two times more likely to have hearing loss at high frequencies compared to those without exposure (OR = 2.29; 95% CI: 1.17–4.51, $p = .016$), after controlling for other risk factors of hearing loss such as age, gender, household income, current smoking, and diabetes. However, lifelong occupational exposure was not significantly associated with hearing loss at low frequencies (OR = 1.43; 95% CI: 0.94–2.18, $p = .094$). *Conclusion:* Lifelong occupational exposure to loud noise and/or ototoxic chemicals was significantly associated with hearing loss among elderly Latino Americans. Healthy work life through protection from harmful auditory effects of occupational exposures to noise and chemicals will have a positive impact on better hearing in later life.

Key Words: Occupational exposure; noise; ototoxicants; hearing loss; risk factors; Latino Americans

Latino Americans are the fastest growing segment of the U.S. population. According to the 2010 U.S. Census, 50.5 million Latinos resided in the USA, representing approximately 16% of the total population. Between 2000 and 2010, the Latino population increased by 43% (15.2 million), rising from 35.3 million in 2000. Approximately 28% (14.0 million) of the total Latino population lived in California, and Mexican origin was the most highly ranked Latino subgroup (63%) among the total Latino population (U.S. Census Bureau, 2011). This rapid increase in the Latino population in the U.S. has been due, in part, to immigration.

Latino immigrants tend to work in specific occupations with more hazards, such as agriculture, construction, and cleaning (Schenker, 2010). According to the National Agricultural Workers Survey (NAWS), the U.S. agricultural work force was predominantly born outside the U.S.; 75% in Mexico and 2% in Central American Countries (U.S. Department of Labor, 2005). In California, over 90% of agricultural workers were Latino immigrants (Aguirre International, 2005). Furthermore, 30% of blue-collar workers in construction were Latino workers; the majority (82%) of foreign-born workers in construction were born in Latin American countries, including 54% born in Mexico (Center for Construction Research and Training, 2013). Also, among building and grounds cleaning and maintenance occupations, 35.9% are Hispanic or Latino (U.S. Bureau of Labor Statistics, 2014). Specifically, cleaning occupations such as housekeeping/maintenance jobs are dominated by female immigrants (Schenker, 2010).

Numerous studies have documented the occupational health hazards and unsafe work conditions of agricultural work (Xiao et al, 2013), construction (Weeks, 2011), and cleaning jobs (European Agency for Safety and Health at Work, 2009). Thus, Latino immigrant workers, who tend to work in these high-risk industries, may have a higher risk of exposure to occupational hazards such as noise and toxic chemicals, and higher rates of occupational injuries and illnesses, including occupational hearing loss.

Noise is a well-known occupational and environmental health hazard. Exposure to excessive noise causes permanent sensorineural hearing loss (National Institute for Occupational Safety and Health, 1996). In the United States, approximately 10% (22 million) of adults between 20 and 69 years old have irreversible hearing loss due to exposure to loud noise at work or during leisure activities (National Institute on Deafness and Other Communication Disorders, 2011). Furthermore, research conducted over the last two

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Abbreviations

ACGIH	American Conference of Governmental Industrial Hygienists
ACOEM	American College of Occupational and Environmental Medicine
ANSI	American National Standards Institute
CI	Confidence interval
dB	Decibel
HTL	Hearing threshold level
NAWS	National Agricultural Workers Survey
NHANES	National Health and Nutrition Examination Survey
NSAIDS	Non-steroidal anti-inflammatory drug
OR	Odds ratio
PCB	Polychlorinated biphenyl
PTA	Pure-tone average
SALSA	Sacramento Area Latino Study on Aging

decades has brought attention to the ototoxicity (toxic effects on hearing) of chemicals in occupational settings and their interaction with noise (Campo et al, 2013; Johnson & Morata, 2010). Chemicals that have been specifically studied for their potential ototoxicity include solvents (styrene, toluene), heavy metals (lead, mercury), polychlorinated biphenyls (PCBs), and pesticides. It has been established that these chemical exposures can impact the peripheral (i.e. cochlea) and central auditory systems (Campo et al, 2013; Johnson & Morata, 2010).

Presbycusis, hearing loss due to aging, is the most common chronic health problem among older adults (Bielefeld et al, 2010). While aging is, no doubt, the leading cause of hearing loss among older adults, it is not the only cause of hearing loss (Pyykko et al, 2007). Other factors, particularly exposure to loud noise and ototoxic substances, also cause auditory damage. Exposure to ototoxic agents (noise and ototoxic chemicals) during the earlier working period may contribute to the extent of presbycusis at later stages in life. An animal study conducted by Kujawa and Lieberman (2009) has demonstrated that noise damage early in life made mice more susceptible to age-related hearing loss.

Most human studies that investigated the harmful auditory effects of noise and chemical exposures were conducted with working populations in occupational settings. There is no study investigating the effect of occupational exposure to ototoxic agents, specifically, loud noise and ototoxic chemicals, during one's work life on hearing loss in later life. The purpose of this study is to investigate the relationship between lifelong occupational exposures and hearing loss among elderly Latino Americans.

Methods

Study design and participants

This study used secondary cross-sectional data from the Sacramento Area Latino Study of Aging (SALSA), a longitudinal cohort study of 1789 Latino American older adults, aged 60 or above, residing in rural and urban areas of Sacramento County, California, between 1998 and 1999. Once the baseline data collection was completed, follow-up home visits were conducted every 12–15 months for seven years through late 2007. Among the 1789 participants, this study included 547 who were between 65 and 75 years old and completed the audiometric test that was offered from years four through seven of the study. Details of the recruitment process and data collection procedure for the original study can be found in Haan et al (2003) and Hong et al (2009), respectively. This study was approved by the institutional review boards of the University of California, Davis and the University of Michigan.

Measures

Baseline data (e.g. the majority of demographic characteristics except for age and lifelong occupation and exposures) were collected at the beginning of the study. All other variables were collected by interview in the participant's preferred language during a home visit at the time of the hearing test.

Dependent variable

Hearing ability

Hearing ability was measured by conventional pure-tone audiometric thresholds testing in both ears at frequencies of 0.25 through 8 kHz. Hearing threshold level (HTL) data from 0.25 kHz was not utilized for this study. Participants with hearing aids were asked to remove the device(s) before the audiometric testing. The audiometric tests were conducted using the Pocket HEARO LE Testing Device with Pocket PC (Otovation LLC, King of Prussia, USA). This device includes the use of noise-attenuating head phones to permit testing in the presence of noisy surroundings. The audiometer was calibrated by Otovation in accordance with American National Standards Institute (ANSI) standard Specification for Audiometers (ANSI S3.6-1996) (ANSI, 1996). We made our best efforts to minimize the influence of high ambient noise, including selecting a quiet room, using noise-attenuating headphones, and testing only as low as 25 dB HTL. Hearing threshold levels were obtained between 25 decible (dB) and 90 dB and recorded in 5-dB increments. An HTL of 90 dB was recorded if the participant's HTL at a particular frequency exceeded the upper limit of the test protocol.

Hearing loss was defined as pure-tone average (PTA) greater than 25 dB in the better ear at both lower (0.5, 1, 2, and 3 kHz) and higher (4, 6, and 8 kHz) frequencies. Also, the status of hearing loss was categorized as slight (26–40 dB), moderate (41–60 dB), severe (61–80 dB), and profound (above 80 dB), using the classification suggested by the World Health Organization (Mathers et al, 2000).

Independent variables

Demographics characteristics

Demographics characteristics included age, sex, education, marital status, household income per month, primary language, nativity, and job categories. Household monthly income was categorized as $<$\$1000, \$1000–1999, and $\geq$\$2000. Primary language was categorized as English or Spanish. Nativity was categorized into three: being born in the USA, Mexico, or another Latin American country.

Lifelong occupational exposure

Occupational exposure was assessed by a single question followed by a checklist: "On your main job, were you exposed to any of the following?" A checklist of nine hazards followed: pesticides, lead, cadmium, solvents, other heavy metal, loud noise, dust, fumes, and high level of heat. Main job was defined as the major occupation participants held for most of their lives. For each occupational hazard, the participant was asked to check "yes" or "no". For the purpose of this study, we used data for exposure to loud noise and potential ototoxicants (pesticides, lead, cadmium, solvents, and other heavy metal).

Several covariates of hearing loss such as smoking, hypertension, type 2 diabetes, and use of ototoxic medications were also measured.

Smoking status was categorized as current, former, and never smokers.

Hypertension was measured by self-report of physician diagnosis and/or the use of antihypertensive medication. Hypertension was dichotomized as yes/no.

Type 2 diabetes was also dichotomized as yes/no and was determined at the time of the hearing test by fasting glucose > 125 mg/dL, HbA1c $> 6.5\%$, self-report of physician diagnosis, or the use of any medication for diabetes.

Ototoxic medication use was assessed by asking the participants to show the data collector their medication bottles and recording the names of the medication from the bottles at the time of the hearing test. For the purpose of the study, we used data on taking a loop diuretic, non-steroidal anti-inflammatory drugs (NSAIDS), and/or other drugs with known ototoxicity, at the time of the hearing test.

Data analyses

Data were analysed using SPSS version 20 (SPSS Inc., Chicago, USA). Descriptive statistics were used to analyse all study variables and characteristics of study participants, using means and standard deviations for continuous variables, and frequencies and percentages for categorical variables. A t-test was used to compare the means of continuous variables. A chi-square test was used to compare categorical variables. Odds ratios with 95% confidence intervals and p-values were calculated to analyse the association of occupational exposures and hearing loss, using logistic regression analyses. Variables for adjustment in the multivariable logistic regression analyses were selected, based on their significance in bivariate analyses ($p < 0.05$). We also checked multi-collinearity among independent variables before running the logistic regression analyses and found no high intercorrelations among independent variables. A p-value of < 0.05 was set for statistical significance.

Results

Characteristics of the study participants

Table 1 shows the characteristics of the study participants. The mean age of the participants was 71.2 years, 56.5% were women, the average education level was ninth grade, and 59.7% were married. Slightly over one-half of the participants (52.0%) were born in the United States, 41.2% in Mexico, and 6.8% in another Latin American country. A majority of participants (53%) reported speaking primarily Spanish. The majority of the participants (73.3%) had household incomes under $2000 per month. The most commonly reported types of work were homemaker (15.9%), followed by farming/forestry/fishing (13.8%), and machine operators/assemblers/inspectors (10.5%).

A large number of participants reported having hypertension (66.5%) and 43.0% reported having type 2 diabetes. Approximately 12% of the participants were classified as current smokers, 41.3% former smokers, and 47.1% never smokers. The majority of participants (62.0%) used a loop diuretic, NSAIDs, or other ototoxic drugs.

Table 1. Characteristics of study participants (N = 547).

Characteristics	*Mean (SD)*
Age (years)	71.2 (2.9)
Education (years)	8.7 (5.4)
	n (%)
Sex	
Male	238 (43.5)
Female	309 (56.5)
Marital status	
Married	325 (59.7)
Widowed	118 (21.7)
Divorced	61 (11.2)
Separated	22 (4.0)
Never married	11 (2.0)
Living with someone as spouse	7 (1.3)
Nativity	
US born	283 (52.0)
Mexico	224 (41.2)
Other	37 (6.8)
Primary language	
English	259 (47.3)
Spanish	288 (52.7)
Household income (per month)	
<$1000	152 (28.7)
$1000–$1999	236 (44.6)
≥$2000	141 (26.7)
Hypertension	364 (66.5)
Diabetes	235 (43.0)
Smoking status	
Never smoked	256 (47.1)
Former smoker	224 (41.3)
Current smoker	63 (11.6)
Ototoxic medication use[a]	
Yes	339 (62.0)
No	208 (38.0)
Occupational exposures[b]	
Yes	307 (57.6)
No	226 (42.4)
Job categories	
Housewives	86 (15.9)
Farming, forestry, fishing	75 (13.8)
Machine operators, Assemblers, Inspectors	57 (10.5)
Service, except private HH or protective	51 (9.4)
Admin support, including clerical	48 (8.9)
Precision production, Craft, Repair	48 (8.9)
Professional specialty	45 (8.3)
Handlers, Equip cleaners, Helpers, Laborers	31 (5.7)
Sales	28 (5.2)
Exec., Admin, Managerial	27 (5.0)
Transportation, Material moving	18 (3.3)
Protective services	15 (2.8)
Technicians and related support	5 (0.9)
Military	3 (0.6)
Insufficient information	5 (0.9)

Totals may differ due to missing data. [a]Loop diuretic medication use, NSAIDs use, other ototoxic medication use. [b]Occupational exposures: Loud noise and/or ototoxic chemicals (pesticides, lead, cadmium, solvents, and other

A majority of participants (58%) reported occupational exposure to loud noise and/or ototoxic chemicals in their main job. The most commonly reported exposure was loud noise (52.7%), followed by solvents (21.9%), pesticides (21.4%), other heavy metals (13.5%), lead (11.5%), and cadmium (4.8%).

Prevalence of hearing loss at low and high frequencies

Table 2 presents the distribution of the extent of hearing loss at low (0.5, 1, 2, and 3 kHz) and high frequencies (4, 6, and 8 kHz). The mean PTAs at low frequencies and high frequencies were 33 dB and 49 dB HTL, respectively. About 65% of participants showed hearing loss at low frequency (0.5 to 3 kHz); 47.2% slight, 14.4% moderate, 3.1% severe, and 0.4% profound loss. The vast majority of the participants (90.9%) showed hearing loss at high frequency (4 to 8 kHz); 31.6% slight, 32.4% moderate, 21.8% severe, and 5.1% profound loss.

Comparison of characteristics between hearing loss and normal hearing at low and high frequencies

A comparison of characteristics between the study participants who had hearing loss and those who had normal hearing at low (0.5 to 3 kHz) and high frequencies (4 to 8 kHz) is presented in Table 3. At low frequencies (0.5 to 3 kHz), the participants who showed hearing loss were significantly older (71.6 years vs. 70.4 years, $p < .001$), were more likely to be male (54.8% vs. 22.5%, $p < .001$), were more likely to be born in the United States (55.0% vs. 46.6%, $p = .042$), were more likely to have type 2 diabetes (46.9% vs. 35.6%, $p = .014$), and were more likely to report occupational exposures (64.1% vs. 45.7%, $p < .001$), than those with normal hearing. Also, the study participants with hearing loss were less likely to have household incomes ≥ $2000 per month (22.7% vs. 33.9%, $p = .013$), and to never smoke (39.2% vs. 61.8%, $p < .001$) compared to those with normal hearing.

At high frequencies (4 to 8 kHz), the participants who showed hearing loss were significantly older (71.4 years vs. 69.4 years, $p < .001$), were more likely to be male (46.9% vs. 10.0%, $p < .001$), were more likely to be born in the United States (53.8% vs. 34.0%, $p = .020$), were more likely to have type 2 diabetes (44.7% vs. 26.0%, $p = .017$), and were more likely to report occupational exposures (60.0% vs. 34.0%, $p = .001$) than those with normal hearing.

Comparison of characteristics between exposure and non-exposure groups

When comparing the characteristics between the study participants who reported occupational exposures and those who did not (the data are not shown), the occupational exposure group reported significantly lower education grade (7.7 vs. 9.9, $p < .001$), were more likely to be male (56.7% vs. 25.2%, $p < .001$), were more likely to be born in Mexico (48.5% vs. 32.3%, $p = .001$), were more likely to speak in Spanish (57.7% vs. 44.7%, $p = .004$), were less likely to have household incomes ≥ $2000 per month (22.3% vs. 32.9%, $p = .022$), and were less likely to never be smokers (40.7% vs. 56.6%, $p < .001$), compared to those who did not report occupational exposures.

Relationship between hearing loss and occupational exposures

When hearing loss at low (0.5 to 3 kHz) and high (4 to 8 kHz) frequencies were compared between the occupational exposure group and the non-exposure group, the exposure group was significantly more likely to show hearing loss than the non-exposure group: 72.0% vs. 54.6% ($p < .001$) at the low frequency (0.5 to 3 kHz); 94.5% vs. 85.4% ($p < .001$) at the high frequency (4 to 8 kHz).

Logistic regression models for hearing loss at low and high frequencies

We included independent variables in the logistic regression model that were significantly associated with hearing loss in bivariate analyses ($p < 0.05$). Those significant covariates of hearing loss at low and/or high frequencies were age, gender, nativity, income, smoking, type 2 diabetes, and occupational exposure.

The summary of multiple logistic regressions is presented in Table 4. Variables for adjustment in the logistic regression analyses were selected, based on their significance in bivariate analyses. Prior to the logistic regression analyses, multicollinearity among independent variables was assessed. We detected no high intercorrelations among independent variables. The result demonstrated that the participants who reported occupational exposure to loud noise and/or ototoxic chemicals were, significantly, two times more likely to have hearing loss at high frequencies (4 to 8 kHz) compared to all others (OR = 2.29; 95% CI: 1.17–4.51, $p = .016$). However, the association between occupational exposure to loud noise and/or ototoxic chemicals and hearing loss at low frequencies (0.5 to 3 kHz) was not significant (OR = 1.43; 95% CI: 0.94-2.18, $p = .094$), but marginal. The study also found other factors such as age, sex, household income, current smoking, and diabetes were significantly related to hearing loss at low and/or high frequencies.

Discussion

We performed a cross-sectional secondary data analysis to assess the prevalence of hearing loss and the factors associated with

Table 2. Distribution of hearing status at low and high frequencies (N = 547).

Extent of hearing loss	*Low frequencies PTA (0.5, 1, 2, and 3 kHz) N (%)*	*High frequencies PTA (4, 6, and 8 kHz) N (%)*
Normal (≤ 25 dB HTLs)	191 (34.9)	50 (9.1)
Hearing loss (> 25 dB HTLs)	356 (65.1)	497 (90.9)
Slight (26–40 dB HTLs)	258 (47.2)	173 (31.6)
Moderate (41–60 dB HTLs)	79 (14.4)	177 (32.4)
Severe (61–80 dB HTLs)	17 (3.1)	119 (21.8)
Profound (> 80 dB HTLs)	2 (0.4)	28 (5.1)
Mean (SD) PTAs in dB HTLs	32.8 (11.0)	49.2 (17.8)

PTA: Pure tone average. HTL: Hearing threshold level

Table 3. Comparison characteristics between hearing loss and normal hearing at low and high frequencies.

	Low frequencies PTA (0.5, 1, 2, and 3 kHz)			*High frequencies PTA (4, 6, and 8 kHz)*		
	Hearing loss (n = 356, 65.1%)	Normal (n = 191, 34.9%)		Hearing loss (n = 497, 90.9%)	Normal (n = 50, 9.1%)	
Characteristics	Mean (SD)	Mean (SD)	*p*	Mean (SD)	Mean (SD)	*p*
Age (years)	71.6 (2.7)	70.4 (2.9)	<.001	71.4 (2.8)	69.4 (2.7)	<.001
Education (years)	8.7 (5.6)	8.7 (5.1)	.907	8.8 (5.4)	7.5 (4.9)	.096
	n (%)	*n (%)*	*p*	*n (%)*	*n (%)*	*p*
Sex			<.001			<.001
Male	195 (54.8)	43 (22.5)		233 (46.9)	5 (10.0)	
Female	161 (45.2)	148 (77.5)		264 (53.1)	45 (90.0)	
Marital status			.181			.160
Never married	7 (2.0)	4 (2.1)		8 (1.6)	3 (6.0)	
Married	223 (63.2)	102 (53.4)		298 (60.3)	27 (54.0)	
Widowed	74 (21.0)	44 (23.0)		109 (22.1)	9 (18.0)	
Divorced	35 (9.9)	26 (13.6)		52 (10.5)	9 (18.0)	
Separated	10 (2.8)	12 (6.3)		20 (4.0)	2 (4.0)	
Living with someone as spouse	4 (1.1)	3 (1.6)		7 (1.4)	0 (0.0)	
Nativity			.042			.020
Mexico	141 (39.9)	83 (43.5)		197 (39.9)	27 (54.0)	
US born	194 (55.0)	89 (46.6)		266 (53.8)	17 (34.0)	
Other	18 (5.1)	19 (9.9)		31 (6.3)	6 (12.0)	
Primary language			.598			.092
English	172 (48.3)	87 (45.5)		241 (48.5)	18 (36.0)	
Spanish	184 (51.7)	104 (54.5)		256 (51.5)	32 (64.0)	
Household income			.013			.099
<$1000	99 (28.9)	53 (28.5)		132 (27.4)	20 (41.7)	
$1000–$1999	166 (48.4)	70 (37.6)		220 (45.7)	16 (33.3)	
≥$2000	78 (22.7)	63 (33.9)		129 (26.8)	12 (25.0)	
Hypertension			.382			1.000
Yes	242 (68.0)	122 (63.9)		331 (66.6)	33 (66.0)	
No	114 (32.0)	69 (36.1)		166 (33.4)	17 (34.0)	
Diabetes			.014			.017
Yes	167 (46.9)	68 (35.6)		222 (44.7)	13 (26.0)	
No	189 (53.1)	123 (64.4)		275 (55.3)	37 (74.0)	
Smoking status			<.001			.119
Never smoked	138 (39.2)	118 (61.8)		227 (46.0)	29 (58.0)	
Former smoker	161 (45.7)	63 (33.0)		205 (41.6)	19 (38.0)	
Current smoker	53 (15.1)	10 (5.2)		61 (12.4)	2 (4.0)	
Ototoxic medication use[a]			.563			.447
Yes	217 (61.0)	122 (63.9)		311 (62.6)	28 (56.0)	
No	139 (39.0)	69 (36.1)		186 (37.4)	22 (44.0)	
Occupational Exposure [b]			<.001			.001
Yes	221 (64.1)	86 (45.7)		290 (60.0)	17 (34.0)	
None	124 (35.9)	102 (54.3)		193 (40.0)	33 (66.0)	

[a]Loop diuretic medication use, NSAIDS use, other ototoxic medication use. [b]Occupational exposure: Loud noise and ototoxic chemicals (pesticides, lead, cadmium, solvents, and other heavy metal). PTA: Pure -tone average. *P*-value for t-test or χ^2 test

hearing loss by using existing data from a large longitudinal cohort study with Latino-American adults. In particular, this study focused on the relationship between lifelong occupational exposure and hearing loss.

As expected for older adults, the study found a high prevalence of hearing loss among the study participants. While the definitions of hearing loss and age groups are slightly different, our findings are comparable to prevalence rates of 63% at speech frequencies (0.5, 1, 2, and 4 kHz) derived from the 2005–2006 cycle of the National Health and Nutrition Examination Survey (NHANES) using the better ear HTLs of adults aged 70 and over (Lin et al, 2011). However, the NHANES study assessed the prevalence of high frequency hearing loss with the worse ear HTLs defined by the mean HTLs at 3, 4, 6, 8 kHz of 15 dB and above. Using this definition, the prevalence of hearing loss in adults aged 70 years and older was 99.7%, which was greater than our finding (91%) with a cutoff of 25 dB. Lin's study also estimated the prevalence of hearing loss in the better ear, using the same definition (a 25-dB cutoff with HTLs from the high frequencies (3–8 kHz)), and reported that 90.9% showed hearing loss. This finding closely aligns with the prevalence showed in our study.

Table 4. Logistic regression model for hearing loss at low and high frequencies.

	Low frequencies PTA (0.5, 1, 2, and 3 kHz)		*High frequency PTA (4, 6, and 8 kHz)*	
	OR (95% C.I.)	*p*	*OR (95% C.I.)*	*p*
Age	1.14 (1.06–1.22)	<.001	1.26 (1.13–1.42)	<.001
Sex (ref. Female)				
Male	3.29 (2.05–5.29)	<.001	5.48 (2.06–14.58)	.001
Nativity (ref. Mexico)				
US born	1.38 (0.86–2.19)	.179	1.92 (0.96–3.85)	.064
Other	0.70 (0.32–1.55)	.376	1.11 (0.39–3.20)	.846
Income (ref: <$1000)			–	
$1000–$1999	0.96 (0.58–1.58)	.863		
≥$2000	0.47 (0.26–0.86)	.014		
Smoking (ref. never smoking)			–	
Former smoking	1.36 (0.87–2.12)	.181		
Current smoking	2.45 (1.11–5.41)	.026		
Diabetes (ref. No)				
Yes	1.42 (0.94–2.14)	.096	2.20 (1.09–4.45)	.028
Occupational exposure[a] (ref. No)				
Yes	1.43 (0.94–2.18)	.094	2.29 (1.17–4.51)	.016

PTA: Pure-tone average. [a]Loud noise, pesticides, lead, cadmium, solvents, Other heavy metal.

The study found exposures to ototoxic hazards, specifically noise and ototoxic chemicals at work, demonstrated a positive relationship to Latino American older adults' hearing loss (i.e. people with lifelong exposure to occupational ototoxic hazards were more likely to have hearing loss at high frequencies (4–8 kHz)). This finding is more or less consistent with earlier studies (Lee et al, 2005; Fransen et al, 2008; Lin et al, 2011). A European population-based multicenter study demonstrated a significant association between noise exposure (for more than one year) and hearing loss at frequencies of 1 kHz and above (Fransen et al, 2008). The NHANES study found a significant relationship between leisure exposure (not occupational exposure) and high-frequency hearing loss in the multivariate analysis (Lin et al, 2011). A longitudinal study conducted by Lee et al (2005) with older adults aged 60–81 years revealed an interesting result, a combination of significant effect of noise exposure history on the initial HTLs and no effect on the rate of longitudinal changes in HTLs. They found older adults with a positive history of noise exposure showed significantly higher HTLs at frequencies of 2 kHz and above, compared to those with no history of noise exposure. When Lee et al (2005) analysed longitudinal hearing data collected for 3–11.5 years however, they did not find significant differences in the longitudinal rates of HTL changes after baseline at any of the tested frequencies between the participants with and without the history of noise exposure.

Several studies have reported that occupational noise history was not significantly related to hearing loss among older adults (Albera et al, 2010; Cruickshanks et al, 2010). For example, the Beaver Dam Study (Cruickshanks et al, 2010) with over 3700 participants ages 48–92 years old found that noise exposure was not significantly correlated with the 10-year cumulative incidence of hearing loss (defined as greater than 25 dB HL in either 0.5, 1, 2, & 4 kHz). Since this study examined incidence (not prevalence) of hearing loss, as the authors noted, the effects of noise exposure may have already been manifested in the baseline hearing thresholds among the elderly study participants (Cruickshanks et al, 2010). Albera et al (2010) examined the effects of noise exposure with 568 subjects affected by noise-induced hearing loss who had been exposed to noise for at least 10 years and reported that hearing loss was more likely related to aging than to noise exposure.

One unique aspect of the current study is that ototototoxic chemical exposure history was included in 'occupational exposure.' This might have contributed to the strong association between occupational exposure and hearing loss. Recognizing the risk of occupational chemical exposure on hearing is timely. Both the European noise legislation (2003/10 EC noise) (European Union, 2003) and the U.S. Army Hearing Conservation guidelines (U.S. Army, 2003) have included ototoxic chemical exposure as a risk factor to be considered in risk assessment and prevention strategies for individuals' hearing who are exposed to such chemicals. The American College of Occupational and Environmental Medicine (ACOEM) guidance statement also states that exposure to ototoxicants should be considered when health professionals evaluate sensorineural hearing loss (Kirchner et al, 2012). The American Conference of Governmental Industrial Hygienists (ACGIH) stated in its Threshold Limited Values® and Biological Exposure Indices® publications that periodic audiograms are advised and should be carefully reviewed in occupational settings where exposure to toluene, lead, manganese, or n-butyl alcohol occurs (ACGIH, 2014). Health professionals should pay attention to possible additive or synergistic effects of ototoxic chemical exposure in the audiometric test data for populations who are exposed to both noise and ototoxicants.

The present study also found several other factors (e.g. age, sex, type 2 diabetes) that were significantly associated with hearing loss. Consistent with findings from earlier studies (Davanipour et al, 2000; Torre et al, 2006; Bainbridge et al, 2008; Lin et al, 2011), this study found that age and sex were significant risk factors for hearing loss. An increase in age was significantly associated with hearing loss at both low and high frequencies. Male sex had significantly higher odds of hearing loss at both low and high frequencies. These corroborate with reports from earlier studies (Helzner et al, 2005; Lee et al, 2005; Lin et al, 2011). In addition to sex-specific pathophysiologic mechanisms, occupational exposure has been considered as an attributed factor to sex differences in hearing loss (Helzner et al, 2005). Males tend to have jobs with higher exposure to loud noise and thus more hearing loss during their active working years. However, we found sex differences (greater hearing loss in men) even after controlling for occupational exposures in the multivariate analysis.

Among the medical covariates (e.g. cigarette smoking, use of ototoxic medication, type 2 diabetes, hypertension) considered in this study, diabetes was the only factor significantly associated with hearing loss at high frequencies. The association between diabetes and risk of hearing loss corroborates with many previous findings (Helzner et al, 2005; Ologe & Okoro, 2005; Vaughan et al, 2006; Sakuta et al, 2007; Bainbridge et al, 2008; Agrawal et al, 2009). A number of plausible physiological mechanisms have been proposed to explain the link between diabetes and hearing loss. These include vascular and neurological etiologies including central nervous system effects of diabetes, mitochondrial abnormalities, and genetic causes (Sataloff & Sataloff, 2006). It is also noted that diabetes may be an independent risk factor for hearing loss, because hyperglycemia may damage the cochlea both anatomically and physiologically (Vaughan et al, 2006; Bainbridge et al, 2008; Agrawal et al, 2009).

Presbycusis has always been considered an inevitable part of the aging process, but more and more research suggests that it is not a simple age-related health problem (Campo et al 2013, Helzner et al, 2005; Pyykkö et al, 2007; Fransen et al, 2008). It can be worse or better, depending on various factors including non-modifiable characteristics (e.g. age, sex, race), other medical conditions (e.g. diabetes, hypertension), lifestyle factors (e.g. smoking, alcohol use, nutrition), and environmental and occupational exposures (e.g. noise, ototoxic chemicals) (Helzner et al, 2005; Pyykkö et al, 2007; Fransen et al, 2008).

The present study's findings suggest relationships between lifelong occupational exposures and hearing loss. Hearing loss due to loud noise exposure remains a major public health problem and creates enormous economic burden and human suffering. Occupational noise exposure has long been recognized globally as one of the most prevalent causes of adult onset hearing loss (Nelson et al, 2005). However, ototoxicants have been a lesser-known risk to hearing. It is only in recent decades that investigators have drawn attention to the ototoxicity of chemicals in occupational settings and their interaction with noise. Interventions are needed to improve our understanding of the combined hazards of noise and ototoxic chemicals, as well as to improve and maintain the environmental and behavioral influences that can protect hearing health.

The study findings have implications for occupational health, primary care, and public health. An occupational health approach would be to identify effective occupational hearing conservation programs and disseminate them broadly to all workers throughout the lifespan. A primary care approach would be to establish a standardized hearing assessment for adults and to develop intervention protocols for those exposed to noise and/or ototoxic chemicals. A public health approach would involve work and community environmental surveillance on noise or chemical pollutants. For example, The City of San Francisco's Noise Enforcement Program run by the city's Department of Public Health conducts environmental noise exposure assessments and maintains the city's background noise map for the residents and educates them to reduce and prevent a variety of health problems associated with noise exposure, including hearing loss (http://www.sfdph.org/dph/EH/Noise/default.asp) (San Francisco Department of Public Health, 2014). Innovative methods such as use of personal or environmental health sensors and geographic information systems could identify populations at risk. Public health campaigns could be developed to educate the public on the combined effects of noise and chemicals on hearing loss and prevention strategies. Also, it is important to assess the history of occupational and non-occupational exposures to these ototoxic agents in order to improve hearing health in the public.

This study has several strengths. First, it is one of the first studies to examine the relationship between lifelong occupational exposures and hearing loss among elderly Latino Americans. Furthermore, this study considered exposure to ototoxicants as a potential risk factor of hearing loss by including it in the variable of 'occupational exposure'. Finally, this study performed the gold standard measurement of hearing status using pure-tone audiometry and the use of extensive self-report survey data from a large sample of elderly Latino Americans.

There are several limitations to this study using secondary analysis of existing data. It is a cross-sectional study, therefore conclusions cannot be made about causal relationships between hearing loss and the identified risk factors such as lifelong occupational exposure. While we included nine common types of exposures under the question of occupational exposures, this single question with dichotomous (yes/no) response data on exposures does not allow conclusions about dose-response relationships. The wording 'main job' may have caused confusion when participants were faced with a lifetime review of their various jobs. There were no data on military and non-occupational exposure including noisy hobbies and exposures at home, therefore total exposures were likely under-reported. Because the survey relied upon self-report of lifetime exposure, there may have been a recall bias among these older adults, resulting in either the direction of under-reporting or over-reporting exposures. Furthermore, we did not assess levels of noise, the duration of exposure, and the type of noise (impulse noise or steady noise). While systematic surveillance of work environment or personal exposure monitoring are ideal measures to assess occupational exposure, self-report is the only practically possible measure for epidemiological study with a non-working older adult population.

In conclusion, we found that lifelong occupational exposure to ototoxic hazards (loud noise and ototoxicants), after controlling for aging effect, was significantly associated with hearing loss among elderly Latino Americans. Healthy work life, through protection from the harmful auditory effects of occupational exposures to noise and chemicals, will have a positive impact on better hearing in later life.

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