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Main Articles

Diabetes and hearing impairment in Mexican American adults: a population-based study

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Abstract
Reports on the relationship between diabetes and hearing loss have been controversial. The present study examined this relationship in 1,740 Mexican American adults using data from the Hispanic Health and Nutrition Examination Survey. Hearing threshold levels were obtained for each participant at the following frequencies: 500, 1000, 2000, and 4000 Hertz (Hz). The thresholds from the worse hearing ear were used in the analyses. Diabetes and insulin use were assessed by self-report. The mean crude hearing thresholds in diabetics were significantly higher than in non-diabetics at each of the four frequencies. However, after adjustment for age, gender, and socioeconomic status, diabetics had a significantly higher mean threshold than non-diabetics only at 500 Hz (mean difference ± SE: 2.8 ± 1.2, $p = 0.04$). Diabetics who were not using insulin had significantly higher thresholds than those who were using insulin at 2000 (mean difference ± SE: 5.6 ± 2.6, $p = 0.03$) and 4000 Hz (7.7 ± 3.3, $p = 0.02$). Also, at 4000 Hz, insulin users had a significantly lower mean threshold than non-diabetics (mean difference ± SE: –4.9 ± 1.6, $p = 0.02$). Our data suggest that associations between diabetes and decreased hearing acuity in the higher frequencies are present only amongst diabetic Mexican-Americans who do not use insulin.

Key words: Hearing loss, sensorineural; Diabetes mellitus; Mexico; Hispanic Americans

Introduction

Hearing loss is one of the most common health problems of the elderly. The major risk factors for hearing loss are age, noise exposure, and vascular disease. Since both Type I (insulin dependent diabetes mellitus, IDDM) and Type II (non-insulin dependent diabetes mellitus, NIDDM) diabetes are known for their widespread microvascular lesions, their relationship with hearing loss has been widely studied, but findings are contradictory. While several studies have reported a positive correlation between diabetes and hearing loss (Taylor and Irwin, 1978; Ishii *et al.*, 1992; Cullen and Cinnamond, 1993), others have failed to confirm such an association (Harner, 1981; Hodgson *et al.*, 1987). Some investigators have shown that only diabetics with severe peripheral neuropathy or retinopathy are at increased risk of hearing loss (Friedman *et al.*, 1975; Miller *et al.*, 1983), but two other studies reported that duration or severity of diabetes was not associated with hearing impairment (Axellson and Fagerberg, 1968; Osterhammel and Christau, 1980). The positive findings are consistent with the theory that diabetics are at increased risk of hearing loss due to metabolic disorders such as microvascular lesions which impair blood flow to the cochlea (i.e. angiography); or neuropathic damage along the auditory pathway (i.e. neuropathy) (Jorgensen and Buch, 1961; Cullen and Cinnamond, 1993).

Most of the previous studies on diabetes and hearing loss have been hospital-based, and investigators have tended to select severe cases or Type I diabetes for their studies. There have been very few studies that have examined the association between diabetes and hearing loss in general populations and, particularly, in minority populations. Since both diabetics and hearing loss are among major public health problems and have great impact on quality of life, it is important to investigate their relationship at the population level.

Mexican Americans have been reported to have a two to five times greater diabetes prevalence and diabetes-specific mortality than the general U.S. population (Hanis *et al.*, 1983; Hamman *et al.*, 1989). Mexican Americans are also more likely to experience diabetic complications (Raymond, 1988).

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No study to date, however, has investigated the association between diabetes and hearing loss in this population. The present study examined this relationship in Mexican American adults using data from the Hispanic Health and Nutrition Examination Survey (HHANES, 1982–1984).

Materials and methods

Design and study population

The HHANES was conducted between July 1982 and December 1984 by the National Center for Health Statistics (NCHS). A stratified probability sample of the civilian, non-institutionalized population was selected from three sub-populations: Mexican origin or ancestry in the southwestern United States (California, Arizona, New Mexico, Colorado and Texas); Puerto Rican origin or ancestry in selected counties in New York, New Jersey, and Connecticut; and Cuban origin or ancestry in Dade County, Florida (Gonzalez *et al.*, 1985; Delgado *et al.*, 1990).

In the HHANES, half of the adult participants aged 20 to 74 years were randomly assigned to a fasting glucose tolerance test, and the remaining half to an audiometry test. The present study included those participants who were assigned to the audiometry test. Due to small sample sizes and the different sampling weights used in HHANES, data for Cuban Americans and Puerto Ricans could not be analysed together with Mexican Americans. Therefore, analyses for the present study were restricted to a total of 1,754 Mexican Americans, 20–74 years of age, who completed the audiometric test. Due to missing values, the final analyses were based on 1,740 Mexican American adults.

Measures

Audiometric testing was conducted in sound-treated booths using Beltone model 200-C audiometers (National Center for Health Statistics, 1988). Air conduction thresholds were obtained at the following frequencies: 500, 1000, 2000, and 4000 Hertz (Hz), with the 1000 Hz frequency repeated a second time in order to assess the reliability of the procedures. Hearing threshold was defined as the lowest intensity of a pure tone that was just audible to the subject. The threshold recorded for each frequency was the lowest decibel (dB) level at which 50 per cent or more positive responses were obtained. Masking for the non-test ear was done only during re-test which was performed when there was a 40 dB difference or more in the thresholds for the two ears. The effective range of audiometric testing was –15 to +105 dB. The standard audiometers used in the survey were calibrated in accordance with the 1969 American National Standards Institute (ANSI) specifications (American National Standards Institute, 1970).

Diabetes was defined based on results of a personal interview. People who reported during the interview that a doctor had told them they had diabetes were classified as diabetics. Insulin users were those who reported either injecting insulin or taking insulin pills at the time of the interview. Information on other variables such as gender, age, and marital and employment status was also collected through interview.

Statistical analyses

Simple linear regression analysis was performed first with hearing threshold as the dependent variable and diabetic status as the independent variable. Then, to determine whether diabetes had an independent effect on hearing impairment, multivariate regression analysis was used with inclusion in the model of potential confounders such as age, gender, and marital and employment status. These last two covariates have been shown to be associated with hearing impairment in Hispanic adults (Lee *et al.*, 1996). We also conducted multivariate regression analyses to examine the effect of length of time since diagnosis of diabetes and of insulin use on hearing threshold levels. Interaction between diabetic status and each of the covariates mentioned above was examined before selecting the final model. Since there is no evidence indicating that diabetic hearing loss is unilateral, the thresholds in the worst ear were used in all the analyses. Prior to any analyses, we examined the distribution of the continuous variables to be used in the different models. Because slight right skewness was found not only for the original hearing threshold levels but also for their logarithmic and square root transformations, and because of the known robustness of regression against slight departures from normality, all analyses were performed using the original values. Due to the multistage sampling design (Gonzalez *et al.*, 1985; Delgado *et al.*, 1990), we performed all analyses with adjustments for sample weights and design effects using the SUDAAN statistical package for the analysis of complex sample surveys (Software for Survey Data Analysis, 1995).

The REGRESS procedure in SUDAAN was used for the regression analyses. Since diabetic status was coded using dummy (or indicator) variables, the intercept and the regression coefficients (or appropriate combinations thereof) of these indicator variables are equivalent to crude (in simple regression) or adjusted (in multivariate regression) hearing threshold means or mean differences. Therefore, means and/or mean differences, instead of regression coefficients, are presented in the results.

Results

Among the 1,740 participants included in the present analyses, there were 118 self-reported diabetics (6.8 per cent). The length of time since diagnosis of diabetes ranged from one to 34 years, with a mean (± SE) of 7.8 (± 0.6) and a median of five. The average age at diagnosis of diabetes was 45.3 (± 1.5) years. About two-thirds of diabetics (72/118) reported either injecting insulin or taking insulin pills at the time of the interview. As shown in Table I, the overall mean age (± SE) was 36.9 (± 0.3) years; 50.7 per cent of the participants were

TABLE I

SOCIO-DEMOGRAPHIC CHARACTERISTICS† OF DIABETIC (N = 118) AND NON-DIABETIC (N = 1622) MEXICAN AMERICAN ADULTS: DATA FROM THE HISPANIC HEALTH AND NUTRITION EXAMINATION SURVEY (HHANES), 1982–1984

Variable	Overall	Diabetics	Non-diabetics	t or χ^2 statistic
Age (Mean ± SE)	36.9 ± 0.3	53.0 ± 1.3	36.0 ± 0.4	13.1**
Gender (% male)	50.7	42.5	51.2	10.3*
Marital status (% married)	74.7	74.7	74.7	0.0
Employment status (% employed)	62.2	37.0	63.7	24.5**

† Adjusted for sample weights and design effects
* p<0.05
** p<0.01

males, 74.7 per cent were married, and 62.2 per cent were employed. Diabetic participants were significantly older than the non-diabetic participants (53.0 ± 1.3 *vs* 36.0 ± 0.4, $p < 0.001$). The proportions of males and employed participants were lower in diabetics than in non-diabetics (42.5 *vs* 51.2 per cent, $p = 0.01$; and 37 *vs* 63.7 per cent, $p = 0.001$, respectively). The proportions of married participants in the two groups were almost identical (74.7 *vs* 74.7 per cent, $p = 0.95$).

Linear regression analyses were used to obtain unadjusted (simple regression) and adjusted (multivariate regression) means as well as mean differences in threshold levels between the subgroups of interest. In multivariate analyses, no interactions were found between diabetic status and any of the covariates including age, gender, marital status, and employment status. Means and mean differences in hearing thresholds are presented in Table II. After controlling only for sample weights and design effects, the mean hearing thresholds for diabetics was significantly higher than for non-diabetics at each of the four frequencies. After further controlling for age, gender, marital status, and employment status, the differences in hearing thresholds at 1000, 2000, and 4000 Hz were no longer significant. At 500 Hz, however, the difference remained significant, with a 2.8 dB (SE = 1.2, $p = 0.04$) higher mean threshold in diabetics than in non-diabetics.

To further investigate the association between hearing impairment and diabetes, duration of diabetes and insulin use were examined in multivariate regression analyses. Duration was not associated with hearing acuity at any of the frequencies in our analyses (results not shown), but insulin use was at some of the frequencies. Mean hearing thresholds and mean differences by diabetic status and insulin use are given in Table III. Regardless of frequency level, diabetics not using insulin had higher, but not statistically significant, crude mean thresholds than diabetics using insulin; and non-diabetics had significantly lower crude mean thresholds than either diabetic group. After adjustment for age, gender, and marital and employment status, the differences between diabetics with insulin use versus without insulin use were statistically significant at 2000 and 4000 Hz (mean difference ± SE: 5.6 ± 2.6, $p = 0.02$; and 7.7 ± 3.3, $p = 0.03$, respectively); and, surprisingly, except at 500 Hz, non-diabetics had higher thresholds than did diabetics taking insulin. This relationship was more apparent at 2000 and 4000 Hz, and for the latter frequency, the difference was statistically significant (mean difference ± SE: –4.9 ± 1.6, $p = 0.02$).

Discussion

In the present analysis, relative to non-diabetics, Mexican-American diabetics were shown to have increased hearing threshold level only at the 500 Hz frequency after adjustment for covariates. When

TABLE II

MEANS AND MEAN DIFFERENCES (± SE) IN HEARING THRESHOLDS (DB) FOR MEXICAN AMERICAN ADULTS BY DIABETIC STATUS: DATA FROM THE HISPANIC HEALTH AND NUTRITION EXAMINATION SURVEY (HHANES), 1982–1984

Frequency	Group or Group difference	Mean (± SE)†	Adjusted Mean (± SE)‡
500 Hz	Non-diabetics	13.3 ± 0.4	3.1 ± 1.3
	Diabetics	21.2 ± 1.3	5.9 ± 2.0
	Diabetics–Non-diabetics	7.9 ± 1.3**	2.8 ± 1.2*
1000 Hz	Non-diabetics	11.3 ± 0.5	–1.1 ± 1.6
	Diabetics	19.1 ± 1.7	0.8 ± 1.9
	Diabetics–Non-diabetics	7.8 ± 1.6**	1.9 ± 1.6
2000 Hz	Non-diabetics	13.9 ± 0.6	–4.8 ± 1.5
	Diabetics	21.6 ± 2.0	–5.5 ± 2.3
	Diabetics–Non-diabetics	7.7 ± 1.8**	–0.7 ± 1.4
4000 Hz	Non-diabetics	18.2 ± 0.8	–14.9 ± 1.2
	Diabetics	28.7 ± 2.1	–16.4 ± 2.3
	Diabetics–Non-diabetics	10.5 ± 1.9**	–1.5 ± 1.6

† Adjusted only for sample weights and design effects
‡ Further adjusted for age, gender, marital status, and employment status
* p-value<0.05
** p-value<0.01

TABLE III

MEANS AND MEAN DIFFERENCES (± SE) IN HEARING THRESHOLDS (DB) FOR MEXICAN AMERICAN ADULTS BY DIABETIC STATUS AND INSULIN USE: DATA FROM THE HISPANIC HEALTH AND NUTRITION EXAMINATION SURVEY (HHANES), 1982–1984

Frequency	Group or Group difference	Mean (± SE)†	Adjusted Mean (± SE)‡
500 Hz	Non-diabetics (Group 1)	13.3 ± 0.4	3.1 ± 1.3
	Diabetics w/ insulin use (Group 2)	20.6 ± 0.9	4.1 ± 1.5
	Diabetics w/o insulin use (Group 3)	22.0 ± 2.8	8.0 ± 3.4
	Group 3 – Group 1	8.7 ± 2.8**	5.0 ± 2.7
	Group 3 – Group 2	1.4 ± 2.8	3.9 ± 2.9
	Group 2 – Group 1	7.3 ± 1.0**	1.1 ± 0.9
1000 Hz	Non-diabetics (Group 1)	11.3 ± 0.5	–1.1 ± 1.6
	Diabetics w/ insulin use (Group 2)	18.2 ± 1.6	–1.4 ± 2.4
	Diabetics w/o insulin use (Group 3)	20.3 ± 2.8	3.5 ± 3.8
	Group 3 – Group 1	9.0 ± 2.7**	4.6 ± 2.9
	Group 3 – Group 2	2.1 ± 2.7	4.8 ± 2.7
	Group 2 – Group 1	6.9 ± 1.5**	–0.2 ± 1.4
2000 Hz	Non-diabetics (Group 1)	13.9 ± 0.6	–4.8 ± 1.5
	Diabetics w/ insulin use (Group 2)	20.8 ± 2.2	–8.0 ± 2.2
	Diabetics w/o insulin use (Group 3)	22.7 ± 2.9	–2.4 ± 3.3
	Group 3 – Group 1	8.8 ± 2.8**	2.5 ± 2.5
	Group 3 – Group 2	1.9 ± 3.0	5.6 ± 2.6*
	Group 2 – Group 1	6.9 ± 2.0**	–3.1 ± 1.6
4000 Hz	Non-diabetics (Group 1)	18.2 ± 0.8	–14.9 ± 1.2
	Diabetics w/ insulin use (Group 2)	27.2 ± 2.8	–19.9 ± 2.5
	Diabetics w/o insulin use (Group 3)	30.7 ± 3.2	–12.2 ± 3.4
	Group 3 – Group 1	12.5 ± 3.2**	2.8 ± 3.1
	Group 3 – Group 2	3.5 ± 2.4	7.7 ± 3.3*
	Group 2 – Group 1	9.1 ± 2.5**	–4.9 ± 1.6**

† Adjusted only for sample weights and design effects
‡ Further adjusted for age, gender, marital status, and employment status
* *p*-value<0.05
** *p*-value<0.01

insulin use was considered, this increase was no longer statistically significant; however, diabetics not using insulin were shown to have significantly higher mean thresholds, than diabetics using insulin, at 2000 and 4000 Hz.

In a review of the recent literature, five studies have supported the hypothesis that there is a possible association between diabetes and hearing loss (Jorgensen and Buch, 1961; Friedman *et al.*, 1975; Taylor and Irwin, 1978; Ishii *et al.*, 1992; Cullen and Cinnamond, 1993), while five studies have failed to support this hypothesis (Axellson and Fagerberg, 1968; Gibbon and Davis, 1981; Miller *et al.*, 1983; Sieger *et al.*, 1983; Hodgson *et al.*, 1987). Most authors in the former group noted that the diabetic hearing impairment was predominantly present at higher pure tone frequencies. In the present analysis, however, the strongest association was observed at the lowest frequency, 500 Hz. This discrepancy from the literature could not be explained, but a similar finding has been reported by Friedman *et al.* (1975).

Several studies have investigated the relationship between insulin use and hearing loss. Taylor and Irwin (1978) found that the dosage of insulin was not related to the degree of hearing loss, but Kurien *et al.* (1989) showed that poorly controlled diabetics had worse thresholds than those who were well controlled. It should be noted that all of these studies were conducted among diabetics. Our data suggest that in Mexican American diabetics, insulin use might limit the progression of hearing impairment, especially at higher frequencies. Also unexpected was the finding that, on average, diabetics taking insulin had significantly lower thresholds than non-diabetics at 4000 Hz. Unfortunately the HHANES did not obtain additional information on other diabetic management techniques such as administration of oral hypoglycaemics and diet. Furthermore, the cross-sectional nature of this study prevents us from concluding that insulin use might protect hearing. Future longitudinal studies with more reliable measures of diabetic management such as haemoglobin A1C (HbA1C) are needed to investigate the relationship between diabetic control, insulin use, and hearing impairment.

Several strengths of the present analyses should be noted. Firstly, this study used data from HHANES, a well-conducted national survey in which a multistage probability sampling scheme was used. This gave us the opportunity to investigate the relationship between diabetes and hearing loss at the population level. Secondly, the hearing measures used in HHANES were standard clinical procedures, leading to accurate assessent of hearing thresholds.

One of the limitations of this study is the potential misclassification bias possibly due to the use of self-reported data on diabetic status. Flegal *et al.* (1991) examined the fasting subsample data in the HHANES and reported that among self-reported non-diabetics, 11 out of 566 (1.9 per cent) in the age group 20–44, and 35 out of 337 (10.4 per cent) in the age group 45–74, were identified as having diabetes by the oral glucose tolerance test. Since the audiometry subsample shared similar characteristics with the fasting subsample in the HHANES, it is possible that there was a similar percentage of undiagnosed

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diabetic cases misclassified as non-diabetics in our analyses. This differential misclassification would underestimate the effect of diabetes on hearing loss (Rothman, 1986). Another limitation is that information on some important confounders such as noise exposure and deafness resulting from injuries or infection was not available in HHANES. Lack of control for these confounders in our analyses might have biased our results.

Conclusion

After controlling for age, gender, and marital and employment status, diabetics had a higher mean hearing threshold at a frequency of 500 Hz than non-diabetic Mexican American adults. Insulin use was shown to be protective of diabetic hearing impairment at 2000 and 4000 Hz. Furthermore, insulin users had a significantly lower mean threshold at 4000 Hz relative to non-diabetics. Future studies of the relationship between diabetic control and hearing loss in this population are needed.

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