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Health and Nutrition Examination Survey of 1971–75: Part I. Ear and Race Effects in Hearing

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Abstract

The Health and Nutrition Examination Survey of 1971–75 contains unique hearing data because its design permits generalization to noninstitutionalized civilians in the continental United States. Air-conduction thresholds and their relationships to age, ear, gender, frequency, and race were examined in unscreened 25- to 74-year-olds. Although the observed effects of age, gender, and frequency were expected, three aspects of the results were remarkable. First, there was support for previous observations that older females have poorer low-frequency hearing. Second, there was an ear effect among white* males who had poorer 2 and 4 kHz mean thresholds on the left at all ages. Third, there was a pattern of poorer mean thresholds for blacks that was particularly evident in comparisons between black and white females.

* Though inconsistent, terms used to denote race are those used in the original federal government reports.

Key Words: Hearing and ear differences, hearing and race, low-frequency hearing loss

Hearing surveys may be categorized in two ways: (1) those using screened data and (2) those using unscreened data. Screening involves the exclusion of subjects so that a particular effect may be isolated with a minimum of contamination by extraneous factors. For example, noise-exposed individuals would be excluded from a study describing presbyacusis. In contrast, the goal of studies using unscreened data is the investigation of hearing without regard to the etiology of any hearing losses. Such studies might be used to plan health services for the population.

In either case, investigators face two major problems: (1) designing a sampling technique appropriate to the population in question; and (2) finding the resources to collect the data. Robinson's (1988) review of data from unscreened populations is a case in point. Of eight studies describing hearing as a function of age and gender, two involved data from noise-exposed populations, two were limited to data from those under 18 years of age, two had sample sizes less than 1000, and one was the report by Glorig et al (1957) of the Wisconsin State Fair survey. The eighth was based on the federal government's 1960–62 survey (Glorig and Roberts, 1965). From a sampling point of view, and assuming the studies' goals were to describe the general population, five of the eight are unremarkable, at best, and, at worst, could be considered unacceptably biased. This example was not selected to denigrate Robinson's (1988) excellent analyses. Rather, it was selected because it emphasizes the scarcity of samples that provide accurate insights into what hearing is like in the general population. Few investigators have the resources to generate such samples. The federal government is one agency capable of such effort and followed its 1960–62 survey with the Health and Nutrition Examination Survey of 1971–75 (HANES).

HANES contains unique hearing data because, by design, its results can be generalized to 25- to 74-year-old, noninstitutionalized civilians in the continental United States. It was a

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multistage, stratified probability sample generated by selecting 65 geographic areas from 1900 (Miller, 1973; Anonymous, 1977; Engel et al, 1978). Each area was made up of census enumeration districts, which were made up of clusters of six households. Individuals within clusters were selected based on a systematic random sample of age-gender groups using rates specified in the design. Certain segments of the population were oversampled (e.g., individuals below the poverty level, women of child-bearing age, and the aged), and race was classified as "Black", "White" (including those of Hispanic heritage), or other (including Oriental, Native American, etc.). (The inconsistency of using black and white in the context of race is understood. Since black, white, and race are the terms used in the several governmental publications relating to the study, they will be used in this report.) As part of the design, audiograms were obtained from 6913 25- to 74-year-olds (a subset of the entire sample).

Two aspects of the data that require special consideration in the evaluation results should be pointed out. First, the data should not be analyzed with conventional statistical routines. Procedures that explicitly take into account the levels of stratification and the sampling biases must be used to maintain the generality of results. One such set of procedures is Super Carp (Hidiroglou et al, 1980), which was used in the analyses described below. It also compensates for missing data, such as those excluded for the reasons described below, while maintaining the generality of the descriptive parameters it generates. The precision of the parameters is reflected in their associated standard errors. Second, Super Carp was used to generate *population* parameters; the regression coefficients and means presented in the tables *do not* represent the coefficients or means of the data associated with the tables' cells. The values are estimates of what would have been obtained had all 25- to 74-year-old, noninstitutionalized civilians in the continental United States been tested. Thus, although dated and containing thresholds from only 0.5 to 4 kHz, the database is valuable, because it is the most recent, least biased sample of an unscreened population. The only published analysis of the hearing data (Rowland, 1980) was limited to percentage distributions of hearing thresholds by age for all subjects and for partitions by gender or race. This is unfortunate, because the data include information on three major parameters known to vary with hearing thresholds (age, gender, and frequency [Hz]), as well as two that are occasionally reported to do so (ear and race).

There is consensus about the influence of the first three factors. The pattern of hearing loss associated with age, gender, and frequency involves poorer hearing with increasing age and frequency. The pattern is similar for both males and females, although females have better hearing in most cells of an age-by-gender-by-frequency matrix. The exceptions generally occur at 0.25 and 0.5 kHz in older women. For example, Robinson's (1988) table of age-related hearing loss at 0.5 kHz shows a 14 dB poorer hearing threshold level among 70-year-old females. Differences decrease with decreasing age down to about 1 dB in 20-year-olds. Similar patterns were observed in a cross-sectional examination of 64- to 94-year-old females in the Framingham heart study cohort (Gates et al, 1990, 1993). The rate of increase in low-frequency hearing loss across time was also greater in women (Gates and Cooper, 1991). In a predominantly clinical sample, Jerger et al (1993) have also demonstrated that older females have poorer low-frequency hearing.

There have been suggestions that ear and race are factors in hearing, although no consensus exists regarding their influence. For example, Chung et al (1983) observed that mean right ear thresholds were better than those from the left in over 50,000 noise-exposed subjects and that the differences were present in those with thresholds of 0 to 10 dB HL. A variety of reviews of data from unscreened subjects (e.g., Robinson, 1988), however, fail to mention such differences. With respect to race, some investigators (e.g., Royster et al, 1980) have observed better mean thresholds among blacks than among whites. Conversely, Rowland (1980) reported a greater prevalence of hearing loss (thresholds "21 dB or more") among blacks. Such conflicting data may be why Kryter (1983) concluded that there were insufficient data to support "any significant inherent difference" between races.

METHOD

Procedure

The following data were extracted from the HANES database: parameters associated with the sampling design, age, gender, race, audiometer function, and air- and bone-conduction thresholds with associated masking levels. Air- and bone-conduction thresholds at 0.5, 1, 2, and

4 kHz were obtained by trained technicians using calibrated (ANSI, 1969) audiometers (Rowland, 1980). Rowland (1980) did not detail the training procedures, test environment requirements, etc. The advisory board that set training and testing protocols, however, included John W. Black, Hallowell Davis, Leo Doerfler, and Hayes Newby (Miller, 1973).

For each ear, air-conduction thresholds were established for the four frequencies and then reestablished at 1 kHz. Masking was used when the poorer air-conduction threshold was 35 dB greater than the better. The nontest ear was routinely masked at 30, 40, and 50 dB above its threshold during bone-conduction testing. No response at audiometric limits was recorded as 99 dB. An examination of the 6913 records led to the exclusion of 414 because of audiometer failure, missing thresholds, or other missing data. Computer routines searched the remaining records for test–retest (> 10 dB), air-bone gap (> 10 dB), and right–left air-conduction threshold (> 40 dB) inconsistencies. Two certified audiologists examined the inconsistencies and excluded an additional 157 records.

Analyses

Super Carp does not implement analysis of covariance, and because thresholds are known to vary with age, gender, and frequency, multiple regression was chosen to provide an overview of the inter-relationships among those factors, as well as ear and race. Then, population mean thresholds were examined along the dimensions of ear, gender, and race in the decade age ranges used by Rowland (1980). To evaluate differences between means, confidence intervals about one of the two means to be compared were created using a value equal to twice the smaller standard error of the mean (SEM). If the interval excluded the second mean, then it was assumed that the two were significantly different ($p < .046$). (2 SEMs were used, rather than the conventional 1.96 SEMs, to allow the reader to quickly explore other comparisons of interest in the same probability context.) The technique is sufficient for elucidating interactions and discerning patterns in the data and avoids the pitfalls of multiple comparisons. It is open to legitimate criticism when the significance of a single comparison is at issue. Any consistent pattern of differences, however, should reflect real trends in the data. Note that the terms "poorer" and "better" are used below to denote statistically significant differences as defined by the 2 SEMs criterion. The phrase "absolutely poorer" is occasionally used below in its literal sense, is numerically greater, and does not imply statistical significance.

RESULTS

Table 1 presents the multiple regression coefficients for age, gender, and race for the four thresholds from each ear. Positive coefficients mean greater loss with increasing age, in males and in nonwhites. As expected, age was significant at all ear–frequency combinations. From 1 to 4 kHz, gender was consistently significant (5 of 6 coefficients) and race intermittently so (3 of 6). Ear effects were reflected in the dissimilar left–right patterns for gender. For example, the gender coefficient for 1 kHz on the left was three times that on the right and well outside the confidence interval about the right coefficient. Similarly, the gender coefficients at 2 and 4 kHz were different for each ear. Note the sign of the gender coefficients at 0.5 kHz. Both were negative (poorer female hearing), though neither was significant. Note also the significant negative coefficients for race at 4 kHz. These aspects of Table 1 are discussed below.

The pattern of regression coefficients led to three decisions. First, unlike earlier studies, right and left ear identity would be preserved. Second, differences between black and white mean thresholds would be examined. The "other" racial group was excluded because of its heterogeneity. Third, means for all individuals or for

Table 1 Population Multiple Regression Coefficients/Standard Errors for Air-Conduction Thresholds (dB HL) as a Function of Age, Gender, and Race by Ear and Frequency, Based on Unscreened 25- to 74-Year-Olds

	Frequency (Hz)			
Ear	*500*	*1000*	*2000*	*4000*
Right				
Age	0.28/0.01*	0.34/0.01*	0.52/0.02*	0.78/0.02*
Gender	−0.52/0.28	0.41/0.30	3.22/0.39*	14.97/0.53*
Race	0.79/0.44	0.98/0.40*	0.61/0.48	−2.02/0.64*
Left				
Age	0.28/0.01*	0.34/0.01*	0.53/0.02*	0.80/0.02*
Gender	−0.21/0.30	1.22/0.30*	5.27/0.41*	16.76/0.64*
Race	0.69/0.39	0.75/0.41	0.23/0.50	−3.14/0.65*

* $p < .05$.

Table 2 Population Means/Standard Errors of Air-Conduction Thresholds (dB HL) for Gender-Race Combinations by Age, Ear, and Frequency, Based on Unscreened 25- to 74-Year-Olds.

Ear	*Frequency (Hz)* 500	1000	2000	4000	*Age*
Black Females					
Right	9.76/1.00	7.91/0.85	8.26/1.04	8.27/0.85	25–34
	11.53/1.23	8.82/0.90	9.53/1.11	10.64/1.29	35–44
	13.59/1.49	12.73/1.54*	14.11/1.49	17.43/1.85	45–54
	18.59/3.06	17.72/3.21	22.86/3.65	27.07/4.18	55–64
	22.10/2.21	22.43/1.90*	27.92/2.36	29.57/2.43	65–74
Left	10.79/1.38	8.24/1.09	9.18/1.01	8.91/1.15	25–34
	10.42/0.90	7.88/0.66	9.58/0.94	8.82/1.02	35–44
	13.08/1.03	10.45/0.95	13.40/1.23	16.22/1.37	45–54
	18.73/2.75	18.62/3.12	23.34/3.11	27.11/3.72	55–64
	19.09/1.79	18.14/1.93	25.09/2.32	28.35/2.46	65–74
Black Males					
Right	9.66/1.61	8.31/1.30	6.84/1.15	9.52/1.36	25–34
	10.31/1.03	12.02/1.75	14.67/1.81	16.02/2.01	35–44
	9.96/1.62	9.95/1.46	16.62/2.44	27.46/2.69	45–54
	14.10/1.92	17.24/2.00	23.06/2.09	35.57/2.33	55–64
	18.10/2.49	20.87/2.29	33.93/2.20	42.34/2.88	65–74
Left	9.08/1.73	7.48/1.65	7.96/1.74	11.49/2.11	25–34
	11.24/1.23	11.39/1.31	14.89/1.85	15.11/1.93	35–44
	10.67/1.45	10.46/1.48	16.25/2.64	27.12/3.79	45–54
	15.13/2.09	14.77/2.33	25.30/2.73	35.39/2.84	55–64
	18.29/1.50	21.37/2.36	34.54/2.75	44.39/2.71	65–74
White Females					
Right	8.08/0.43	6.05/0.38	6.58/0.41	5.70/0.41	25–34
	8.66/0.45	7.51/0.41	8.52/0.52	9.61/0.62	35–44
	12.28/0.62	11.12/0.59	12.79/0.69	14.95/0.71	45–54
	15.37/0.51	14.85/0.65	18.25/0.73	22.94/0.84	55–64
	20.92/0.88	20.49/0.94	25.64/1.12	33.29/1.19	65–74
Left	7.91/0.37	5.43/0.37	6.39/0.42	6.25/0.44	25–34
	8.66/0.43	7.06/0.44	8.90/0.53	10.65/0.67	35–44
	12.01/0.55	10.30/0.53	12.15/0.66	15.79/0.76	45–54
	15.46/0.51	14.09/0.64	18.11/0.78	24.18/0.80	55–64
	20.56/0.85	19.84/0.89	25.87/0.94	35.39/1.07	65–74
White Males					
Right	7.59/0.36	6.02/0.38	6.56/0.48	14.55/0.95	25–34
	9.56/0.47	8.67/0.48	11.67/0.76	24.31/1.30	35–44
	11.74/0.47	11.75/0.48	17.32/0.87	35.84/1.13	45–54
	16.08/0.71	16.40/0.81	24.40/1.18	43.55/1.19	55–64
	17.63/0.70	19.18/0.80	31.03/1.14	51.31/1.08	65–74
Left	8.02/0.37	5.90/0.39	8.24/0.60*	16.71/1.25*	25–34
	10.53/0.67*	9.30/0.55	13.28/0.76*	27.07/1.31*	35–44
	12.74/0.49*	11.95/0.57	20.42/0.78*	39.77/1.00*	45–54
	16.16/0.79	16.58/0.77	26.35/1.12	45.93/1.23	55–64
	18.08/0.68	19.20/0.78	33.32/1.22*	54.41/0.98*	65–74

* = poorer ear, based on mean differences > 2 SEMs.

partitions by gender or race alone would not be considered, since they would ignore the interactions implied in Table 1. Thus, the following examinations of the data were applied to four distinct groups: female and male blacks and female and male whites.

Population mean thresholds and SEMs are presented in Table 2. The expected age and frequency effects were seen within each ear-gender-race grouping. With few exceptions, thresholds became poorer as age or frequency increased. Evaluation of possible ear differences clarifies earlier comments about multiple comparisons. There are 80 possible comparisons (right versus left ear in five decade ranges for four frequencies, gender, and two races). Assuming a significance level of .05, 4 of the 80 possible comparisons would be significant if, in fact, there were no significant ear differences. There were 12 (tagged by an asterisk in Table 2), based on confidence intervals equal to twice the smaller SEM. Ten were in white males and eight of those were poorer left ears at 2 and 4 kHz. The two other differences involved black females at 1 kHz, where the right ear was poorer for 45- to 54- and 65- to 74-year-olds. It would be difficult to argue that black females had poorer right-ear thresholds. It is reasonable to conclude that white males had poorer 2 and 4 kHz thresholds on the left.

Because of the complexity of the pattern of regression coefficients in Table 1 and the mass of data in Table 2, Tables 3 and 4 were designed to highlight gender and racial differences. Table 3 displays gender differences. Race within gender is shown by an asterisk (*) in those cells where white means are poorer and by an octothorp (#) where black means are poorer. Similarly, racial differences are displayed in Table 4 with an asterisk, used to show poorer male thresholds, and an octothorp for poorer female thresholds.

A quick appreciation of gender effects can be had by noting the density of symbols Table 3's upper right-hand quadrant, compared to the upper left-hand quadrant. Males had poorer hearing. Overall, male thresholds were poorer in 41 of 80 comparisons and were poorer more often at higher frequencies (poorer at 1 of 20 comparisons at 0.5 kHz versus 19 of 20 at 4 kHz). Turning to the issue of poorer low-frequency hearing in females, there were four cells in which females had poorer hearing, all at 0.5 kHz. Both ears of 65- to 74-year-old white females were poorer than comparable male ears as were the right ears of black females in the 45- to 64-year-old groupings. There was no underlying trend for poorer female mean thresholds among whites (absolutely poorer in only 3 of 10 comparisons in Table 2), but black females were absolutely poorer than black males in 9 of the 10 cells.

Table 4 addresses racial differences. Overall, blacks were poorer in 34 of 80 comparisons and better in 19 without any obvious pattern related to age, ear, or frequency. Among fe-

Table 3 Significant Mean Air-Conduction Differences for Gender by Race, Based on Unscreened 25- to 74-Year-Olds. Comparisons are Between Genders in the Same Ear and at the Same Frequency and Age

	Females				*Males*				*Age*
	0.5	*1*	*2*	*4 kHz*	*0.5*	*1*	*2*	*4 kHz*	
Ear									
Right									
								*	25–34
						*#	*#	*#	35–44
	#						*	*#	45–54
	#					*	*	*#	54–64
	*						*#	*#	65–74
Left									
							*	*#	25–34
					*	*#	*#	*#	35–44
						*	*#	*#	45–54
						*	*	*#	54–64
	*						*#	*#	65–74

* = poorer white ear; and # = poorer black ear, both based on mean differences > 2 SEMs.

Table 4 Significant Mean Air-Conduction Differences for Race by Gender, Based on Unscreened 25- to 74-Year-Olds. Comparisons Are Between Races in the Same Ear and at the Same Frequency and Age

	Blacks				Whites				Age
	0.5	*1*	*2*	*4 kHz*	*0.5*	*1*	*2*	*4 kHz*	
Ear									
Right									
	*#	*#	#	#				*	25-34
	#	*#	*					*	35-44
	#	#		#	*	*		*	45-54
	#	#	#	#	*			*	55-64
		#	*#					*#	65-74
Left									
	*#	*#	#					*	25-34
	#	*	*	#				*	35-44
					*	*	*	*	45-54
	#	#	#	#		*		*	55-64
		*						*#	65-74

* = poorer male ear; and # = poorer female ear, both based on mean differences > 2 SEMs.

males, the pattern of generally poorer black hearing was more definite: black females were poorer in 24 of 40 comparisons; white females were poorer in only 2. Among males, the differences appeared to be random through 2 kHz. Blacks were poorer in 10 of the 30 and better in 7 comparisons. Both ears of white males, however, were uniformly poorer at 4 kHz.

DISCUSSION

Since previous reports of population parameters have not used similar sampling techniques or partitioned their data by ear and race, no detailed comparisons to these data were undertaken. Nonetheless, the expected relationships of thresholds to age, gender, and frequency were observed. Among whites and after appropriate interpolations from the data in Table 2 and the tables in Rowland's (1980) report, the HANES data often approximate Robinson's (1988) summary from unscreened populations and, occasionally, indicate better hearing.

There is scant information about black hearing but the mean thresholds in Table 2 are consistently poorer than those reported by Royster et al (1980), with the largest differences being about 15 dB for 4 kHz among 55- to 64-year-olds of either gender. Factors that could account for the magnitude of these differences are sampling technique and those implied by the differences in geography (continental United States versus North Carolina).

Although the regression coefficients for gender were negative at 0.5 kHz, there was no pattern of absolutely poorer female mean thresholds among whites at that frequency. However, two of the three absolute differences were significantly poorer (both ears of 65- to 74-year-olds). Conversely, black females reflected the trend implied by the coefficients in terms of absolute differences, though only two right ear means were significantly poorer than male values. Gates et al (1993) have proposed that "endogenous and exogenous estrogen use may be inversely related to metabolic presbyacusis" and, therefore, to low-frequency hearing loss. Their hypothesis was based on data collected from 60- to 94-year-olds, and, where the age groupings overlap and for whites, these data support their observation of poorer low-frequency hearing among females. Other reports describe a trend to poorer low-frequency hearing across a broad age range. That trend was only evident among the black females examined here. Previous reports of significantly poorer left ear thresholds were substantiated for only one portion of the four partitions used in these analyses: 2 and 4 kHz thresholds in white males.

Considering that one in eight Americans is black (U.S. Bureau of the Census, 1990), and if patterns of hearing loss (versus degree of loss) have remained stable since the early 1970s, it would appear that descriptions of hearing thresholds in unscreened populations should be partitioned by race. Furthermore, when dealing with white males, it would seem appropriate to partition data by ear. (Note that both of these suggestions address the future treatment of data from hearing surveys. They do not imply inherent differences between, for example, black and white hearing. Isolation of the factors responsible for the patterns is not possible with this database.) Last, these data support the recommendation by Gates et al (1993) that the extent of and the pathophysiology behind poorer low-frequency hearing in older females should continue to be investigated.

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