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Time From Hearing-aid Candidacy to Hearing-aid Adoption: a Longitudinal Cohort Study

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Abstract

Objectives—Although many individuals with hearing loss could benefit from intervention with hearing aids, many do not seek or delay seeking timely treatment after the onset of hearing loss. There is limited data-based evidence estimating the delay in adoption of hearing aids with anecdotal estimates ranging from 5–20 years. The current longitudinal study is the first to assess time from hearing-aid candidacy to adoption in a 28-year ongoing prospective cohort of older adults, with the additional goal of determining factors influencing delays in hearing-aid adoption, and self-reported successful use of hearing aids.

Design—As part of a longitudinal study of age-related hearing loss, a wide range of demographic, biologic, and auditory measures are obtained yearly or every 2–3 years from a large sample of adults, along with family, medical, hearing, noise exposure, and hearing-aid use histories. From all eligible participants (age 18, N = 1,530), 857 participants were identified, using audiometric criteria, as hearing-aid candidates either at baseline or during their participation. Longitudinal data were used to track transition to hearing-aid candidacy and hearing-aid adoption. Demographic and hearing-related characteristics were compared between hearing-aid adopters and non-adopters. Unadjusted estimated overall time (in years) to hearing-aid adoption and estimated delay times were stratified by demographic and hearing-related factors and were determined using a time-to-event analysis (survival analysis). Factors influencing rate of adoption in any given time period were examined along with factors influencing successful hearing-aid adoption.

Results—Age, number of chronic health conditions, sex, retirement status and education level did not differ significantly between hearing-aid adopters and non-adopters. In contrast, adopters were more likely than non-adopters to be married, of white race, have higher socioeconomic status, have significantly poorer higher frequency (2.0, 3.0, 4.0, 6.0, 8.0 kHz) pure-tone averages, poorer word recognition in quiet and competing speech babble, and reported more hearing handicap on the Hearing Handicap for the Elderly/Adults (HHIE/A) emotional and social scales.

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Unadjusted estimation of time from hearing-aid candidacy to adoption in the full participant cohort was 8.9 years (standard error $\pm$ 0.37, interquartile range = 3.2–14.9 years) with statistically significant stratification for race, hearing as measured by low and high frequency pure-tone averages, keyword recognition in low-context sentences in babble, and the HHIE/A social score. In a subgroup analysis of the 213 individuals who adopted hearing aids and were assigned a success classification, 78.4% were successful. No significant predictors of success were found.

Conclusions—The average delay in adopting hearing aids following hearing-aid candidacy was 8.9 years. Non-white race and better speech recognition (in a more difficult task) significantly increased the delay to treatment. Poorer hearing and more self-assessed hearing handicap in social situations significantly decreased the delay to treatment. These results confirm the assumption that adults with hearing loss significantly delay seeking treatment with hearing aids.

INTRODUCTION

Hearing loss is one of the most common chronic health conditions, especially among older adults, affecting ~360 million people worldwide (World Health Organization 2017). Most individuals with hearing loss could benefit from intervention with services and technologies (including hearing aids and other devices). However, many people do not seek help or delay seeking timely treatment after onset of hearing loss. As a result, many middle-aged and older adults live for years and even decades with untreated hearing loss and the negative consequences of poorer communication abilities. Moreover, those who delay treatment cannot take advantage of any potential benefits of early intervention. In addition, delaying diagnosis and treatment may require more advanced interventions as hearing loss and age increase.

In order to understand help-seeking and treatment delays for both acute and chronic health conditions, health researchers have focused on a wide range of approaches to identify factors associated with these behaviors. For example, hearing healthcare researchers have focused on health behavior change models and other psychosocial factors to understand treatment-seeking delays (Saunders et al. 2012; Saunders et al. 2016; Amlani 2016) with the goal of changing behavior and increasing the uptake of hearing aids.

Although widely assumed and reported, there is little data-based evidence that estimates the length of treatment delay for hearing healthcare in general and for adoption of hearing aids in particular. Although anecdotal estimates range from 5–20 years, the few available studies have significant limitations, including lack of longitudinal, population-based samples; exclusion of middle-aged adults; and lack of consideration of contributions of age, sex, hearing, and health-related co-morbidities (Davis et al. 2007). Longitudinal data-based evidence is needed to estimate the duration of treatment delay, its contributing factors, and how delay varies among groups and individuals. The current longitudinal study will be the first to assess time from hearing-aid candidacy to adoption in a 28-year ongoing prospective cohort of older adults using Cox-Proportional hazards modeling, which allows all data to be used regardless of whether the subject adopted hearing aids. Cox-proportional hazards modeling is a type of time-to-event analysis or survival analysis, which is commonly used in medical and epidemiological research to determine time to treatment or to a specific

outcome, in this case hearing-aid adoption, and to identify factors related to the length of time to event. Hearing-aid candidacy was measured longitudinally by speech reception thresholds (SRT) or pure tone thresholds and adoption was determined from a self-report hearing health history questionnaire. With this information, the goal of the current study was to estimate delays in time from hearing-aid candidacy to hearing-aid adoption, compare demographic and hearing-related factors for hearing-aid candidates who did or did not adopt hearing aids and when, and determine factors that influence delays in adoption. Data were generated from the ongoing longitudinal study of age-related hearing loss at the Medical University of South Carolina (MUSC).

MATERIALS AND METHODS

Subject Sample

The protocols for this study were approved by the Institutional Review Board at MUSC. In the longitudinal study of age-related hearing loss that began in 1987 at MUSC, subjects 18 years and older, in good general health, were recruited through advertisements and subject referral. This cohort has been described previously in Lee et al. (2005), Matthews et al. (1997), and Dubno et al. (1995). Exclusion criteria included evidence of conductive hearing loss, active otologic/neurologic disease, or significant cognitive decline. Subjects were scheduled monthly for three to six visits to complete a test battery, which included conventional and extended high-frequency pure-tone air conduction thresholds, speech recognition measures in quiet and noise, middle ear measurements, otoacoustic emissions, auditory brainstem responses, clinical blood chemistries, and a cognitive test battery. Self-assessment questionnaires included medical and family histories, hearing health history (including noise history and hearing-aid use), and demographic history (ethnicity/race, sex, education level, marital status and occupation). For analysis, education level was categorized as education ≤ 12 years or education >12 years. Marital status was also categorized as married or not married (widowed, separated, divorced or single). Race was divided into white and non-white (98% African American). Conventional pure-tone thresholds were measured on each visit. After completion of the test battery, subjects were scheduled annually to obtain an updated medical and hearing health history, updated demographic information, and an audiogram. The entire test battery was repeated every 2 to 3 years.

Hearing-aid candidacy was defined as SRT ≤ 30 dB HL (either ear) or thresholds at 3.0 and 4.0 kHz ≤ 40 dB HL (either ear). If the SRT was missing, candidacy was determined by the pure-tone average (PTA; average thresholds at 0.5, 1.0, and 2.0 kHz) ≤ 30 dB HL (either ear). From all eligible participants (age ≥ 18 , $N = 1,530$), 857 participants were identified as hearing-aid candidates either at baseline or during their participation and 673 were identified as never being hearing-aid candidates throughout their participation (Figure 1). Of the 857 individuals identified as hearing-aid candidates, we determined who adopted hearing aids and eliminated those participants who had entered the study with hearing aids ($N = 125$) due to lack of time data (Figure 1). To calculate the time to adoption, year of hearing aid adoption was converted to a full date. December 31st was imputed in the date in order to calculate the time from candidacy to adoption. This resulted in two comparison groups of hearing-aid candidates, those who never adopted hearing aids ($N = 514$) and those who

adopted hearing aids while they were in the study (N = 218) (Figure 1). In addition, the individuals who adopted hearing aids during the study were classified as “successful” or “unsuccessful” users, based on self-report, that is, if they considered themselves successful users or if they wore their hearing aids at least twice a week

Socioeconomic status (SES) proxy was determined by classifying each subject’s occupation using the 2010 Standard Occupational Classification (SOC) system as described by the United States Department of Labor’s Bureau of Labor Statistics (BLS) (U.S. Department of Labor, Bureau of Labor Statistics 2013) and then placing these classifications into one of the ten Survey Job Categories of the U.S. Equal Employment Opportunity Commission (EEOC) (U.S. Equal Employment Opportunity Commission). To divide the EEOC’s categories into SES proxy groups for analysis, annual salaries for SOC and EEOC categories for 1122 job titles were obtained from the BLS (U.S. Department of Labor, Bureau of Labor Statistics 2015). The annual salaries were averaged per EEOC category to create the following SES proxy groupings: High (Executive/ Senior Officials and Managers; First/Mid-Level Officials and Managers; Professionals), Mid (Technicians; Sales Workers; Administrative Support Workers; Craft Workers) and Low (Operatives; Labors and Helpers; Service Workers). Students and those reporting being unemployed or unable to work were placed in the SES proxy group Low. Those who reported homemaker as their principal occupation were classified either as unknown occupation or by their spouse’s occupation if known. Retirees were classified by their former occupation or if occupation not known were classified as unknown along with others with unavailable occupation information.

As an indication of general health, percent “yes” responses were calculated for 55 questions from the participant’s self-reported health history questionnaire. The top eight chronic conditions were selected for analysis: arthritis and orthopedic issues (76%), hypertension (43%), heart disease (18%), shortness of breath (18%), diabetes (14%), thyroid disease (14%), asthma (13%), and chest pain or angina (13%). The arthritis and orthopedic issues variable included the following conditions; arthritis, back injury, backache or leg pain, foot troubles or bad arches, knee issues, shoulder issues, neck injury, swollen joints and chiropractic treatments. Although eye issues and osteoporosis ranked high, they were excluded as both questions did not differentiate between non-chronic (i.e., cataracts, blocked tear ducts) or pre-disease states (i.e., osteopenia). The total number of chronic health conditions (range 0 to 8) was then calculated for each participant (Simpson et al. 2015).

Procedures

All audiometric testing including conventional pure-tone thresholds and word recognition in quiet and noise were measured with either a Madsen OB822 or Madsen OB922 clinical audiometer (Otometrics A/S, Taastrup, Denmark) calibrated to appropriate ANSI standards (ANSI 1969, 1989, 1996, 2004) and equipped with TDH-39 headphones (Telephonics Corporation, Farmingdale, NY, USA) and a compact disc player. Pure-tone thresholds were measured using the guidelines recommended by the American Speech-Language-Hearing Association (ASHA 2005). Word recognition scores in quiet were obtain using Auditec recordings (Auditec, Incorporated, St. Louis, MO) of the Northwestern University Auditory Test Number 6 (NU-6) 25 item word lists presented at 30 to 40 dB sensation level (SL) re:

the SRT. A different NU-6 list was used for each ear. Word recognition scores in noise were obtained using one of 8 lists per ear of the Revised-Speech Perception in Noise (SPIN) Test (Bilger 1984). Each list consists of 25 high-context (semantic and syntactic information) and 25 low-context (syntactic information) sentences presented in multi-talker babble to measure recognition for the final key word in each sentence. The SPIN sentences were presented at 50 dB SL relative to the participant's calculated babble threshold, with babble presented at a +8 dB signal-to-noise ratio (Bilger 1984). If the initial presentation level of the SPIN sentences was uncomfortably loud, the level was reduced to a comfortable loudness level while maintaining the +8 dB signal-to-noise ratio. Percent correct scores were calculated for keywords for both high and low context sentences.

Depending on study participant's age, either the 25-item Hearing Handicap for the Elderly (HHIE; age ≥ 60 years) or the 25-item Hearing Handicap for Adults (HHIA; age < 60 years) was used to assess self-perceived hearing handicap (Ventry & Weinstein 1982; Newman, et al. 1990). The questionnaire was administered by paper and pencil and was obtained prior to any audiometric testing or discussions about hearing loss. Participants are asked to indicate the extent to which they agree with a question by answering "yes" indicating total agreement (score = 4), "sometimes" indicating partial agreement (score = 2) or "no" indicating either disagreement or "non-applicable" (score = 0). The responses for each item are summed to provide three scores, the total score (all questions), the emotional subscale score (13 questions), and the social/situational subscale score (12 questions). The Total score indicates the degree of self-perceived hearing handicap with higher scores indicating more handicap (0–16 no-self perceived handicap; 18–42 mild-to-moderate self-perceived handicap; 44–100 significant self-perceived handicap).

Following each visit, results were reviewed with the study participants and appropriate recommendations for amplification and assistive devices were provided. In addition, communication strategies were discussed and participants' questions were answered.

Data Analyses

First, we compared demographic and hearing-related characteristics of hearing-aid candidates who adopted and did not adopt hearing aids (χ^2 test for categorical variables and t test for continuous variables). Second, we estimated the unadjusted time to hearing-aid adoption (event) using a time-to-event analysis (survival analysis) and estimated the overall time (in years) to hearing-aid adoption and estimated delay times stratified by demographic and hearing-related groups. Third, we determined factors that influence rate of adoption in any given time period, with adjusted hazard ratios estimated using Cox-proportional hazards model (regression). Significance for covariate inclusion in the final parsimonious model was determined by a combination of model fit statistic, likelihood ratio tests, and statistical significance. Each of these criteria was examined after each iteration of manual covariate removal. The models satisfied proportional hazard assumptions and informative censoring is unlikely. Not all study participants had recorded values for all demographic and hearing-related characteristics. To handle missing data in the Cox-proportional hazards model, multiple imputation was used. In general, imputation refers to filling in missing data. In multiple imputation, by simultaneously analyzing multiple datasets that have different

estimated values, uncertainty in the estimation can be accounted for. In the imputation the missingness was assumed to be missing at random which means that differences between the missing values and the observed values can be explained by the other observed variables. For example, socioeconomic status was more likely to be missing for women than men. Auxiliary variables, variables that influence the likelihood of missingness in a variable (sex for socioeconomic status, in this example) as well as variables related to the incomplete variable itself (age for socioeconomic status, for example), were included to predict the missing values. A total of 25 imputation sets were generated. Finally, in a subgroup analysis of participants who adopted hearing aids during the study time period and were classified as successful or unsuccessful users ($n = 213$), we used logistic regression methods to examine factors that influenced the odds of successful hearing-aid use, including time to adoption. Analyses were performed using SAS (Version 9.4). Results were considered statistically significant if $p < 0.05$.

RESULTS

Sample Description

Study participants' average age, number of chronic health conditions, proportion in each sex category, proportion retired, and education level category did not differ significantly between those who adopted hearing aids and those who did not (Table 1a). In contrast, adopters were more likely to be married ($p = 0.0001$), of white race ($p < 0.0001$), and have higher socioeconomic status ($p = 0.01$) than non-adopters (Table 1a). With respect to hearing-related variables, compared to non-adopters, adopters had significantly poorer higher (57.8 vs. 51.7 dB HL, $p < 0.0001$) frequency thresholds, poorer word recognition in quiet (76.8% vs. 80.3%, $p = 0.005$), poorer recognition of keywords in low-context (48.1% vs. 59.3%, $p < 0.0001$) and high-context (89.3% vs. 94.1%, $p < 0.0001$) sentences in babble, and reported more hearing handicap as assessed by HHIE/A emotional scores (13.4 vs. 7.9, $p < 0.0001$) and HHIE/A social scores (14.5 vs. 8.7, $p < 0.0001$) (Table 1b).

Unadjusted Analyses

Unadjusted estimation, from survival analysis without covariate adjustment, of time from hearing-aid candidacy to adoption in this full participant cohort was 8.9 years (standard error ± 0.37 , interquartile range = 3.2–14.9 years). In stratified analysis of time to hearing-aid adoption, we observed a trend toward earlier adoption as age categories increased, with individuals aged 65 or younger averaging 9.2 years to adoption and those older than 76 years averaging 6.6 years to adoption (Figure 2); however, these age-related differences were not statistically significant. Females averaged 8.7 years to adoption compared to 9.0 years for males (ns). Individuals in the low SES category averaged 10.7 years to adoption compared to 8.7 years in the middle and 8.3 years in the high SES categories, these unadjusted comparisons were not statistically significant (Figure 2). In contrast, we found statistical significance for race in that non-white participants took an average of 15.2 years to adopt hearing aids after candidacy compared to 8.6 years for white participants ($p = 0.003$) (Figure 2).

When examining unadjusted analysis of time to hearing-aid adoption among categories of magnitude hearing loss, we observed large difference between stratified groups. As low-frequency PTA (0.25, 0.5, 1.0 kHz) increased from 10 dB HL to > 30 dB HL, we observed the average time to hearing-aid adoption decreasing from 11.2 years to 4.3 years ($p < 0.0001$) (Figure 3). An even more pronounced step function was observed in high-frequency PTA (2.0, 3.0, 4.0, 6.0, 8.0 kHz) stratified groups. For individuals with high-frequency PTAs 45 dB HL, the estimated time to hearing-aid adoption was 11.5 years, individuals with high-frequency PTAs between 45 and 55 dB HL averaged 9.7 years, those with high-frequency PTAs between 55 and 65 dB HL averaged 6.8 years, and for those with PTAs > 65 dB HL, estimated time to adoption was 5.9 years ($p < 0.0001$) (Figure 3). Similar stratified trends were observed with poorer keyword recognition in low-context sentences in babble (SPIN) ($p < 0.0001$) and as the HHIE/A social score increased, indicating more hearing handicap ($p < 0.0001$) (Figure 3).

Adjusted Analyses

In order to assess factors that influence the rate of adoption over time, a Cox proportional hazard regression was performed. The semiparametric Cox model is the most commonly used method to analyze survival time-to-event data in healthcare research (Bradburn et al. 2003). Cox models, a type of survival analysis, are used to estimate the time from a fixed starting point (e.g., cancer diagnosis) to a terminal event (e.g., death) in right-censored data and allows for covariate adjustment. One of the key features in this analysis that distinguishes it from other regression models is that the time from the starting point to the end of the study includes times for individuals who do not reach the terminal event (Clark et al. 2003a), which is referred to as censoring. Although it may not be known if and when the censored subjects will reach the terminal event, the time that they are event-free contributes to the final time estimate (Bradburn et al. 2003). In the current study, the fixed starting point is hearing-aid candidacy and the terminal event is hearing-aid adoption. The following covariates were tested to determine if they significantly influenced the rate of hearing-aid adoption: baseline (at candidacy) age, race, sex, education level, retired status, SES proxy (employment), marital status, number of chronic health conditions, word recognition in quiet (NU-6), keyword recognition in low- and high-context sentences in babble (SPIN high, SPIN low) [tested as both a continuous and categorical variable], and social and emotional scores on the HHIE/A (HHIE/A Social, HHIE/A Emotional). In addition, we examined low-frequency PTA and high-frequency PTA as time-varying covariates. Time-dependent or time-varying covariates may contribute more information than just the fixed value at baseline (Clark et al. 2003b). When available, these variables, which can contribute significant information by including multiple measurements over time, can be included in the multivariable model as a vector of values for each subject (Hosmer, Lemeshow, & May 2011). The effect size of a Cox model is reported as Hazard Ratios, each presented with a 95% confidence interval (CI), and is interpreted in a similar manner to Odds Ratios. The Hazard Ratio (HR) is the probability that an individual who is under observation at a given time has the terminal event at that time (Clark et al. 2003a).

White participants were 2.96 times (HR = 2.96, 95% CI 1.06–8.25) more likely to adopt hearing aids in any given time interval than non-white participants (Figure 4). Females were

78% more likely to adopt than males at any given time (HR = 1.78, 95% CI 1.20–2.63) (Figure 4). Participants with high SES were 2.48 times more likely to adopt when compared to those with low SES (HR = 2.48, 95% CI 1.43–4.29).

Similar to results for unadjusted time to hearing-aid adoption, adjusted Hazard Ratios for hearing-related factors were highly predictive of adoption. When examining the impact of each 10 dB increase in pure-tone thresholds (PTA) on likelihood of hearing-aid adoption, we found that each 10-dB increase in high-frequency PTA increases the likelihood of hearing-aid adoption at any given time by 24% (HR=1.024, 95% CI 1.0089–1.04; numeric values are for 1 unit change). With each 10-point increase in the HHIE social score (more hearing handicap), the likelihood of hearing-aid adoption increased by 58% (HR = 1.058, 95% CI 1.04–1.08; numeric values are for 1 unit change) (Figure 5).

Individuals with the poorest low-context SPIN scores (<42%) had 2.53 times higher probability (HR = 2.53, 95% CI 1.32–4.88) of adopting hearing aids at any given time than individuals with the best low-context SPIN scores (>70%). The low-middle category SPIN score group and the middle-high group were not significantly more likely to adopt hearing aids than the group with the highest scores (Figure 5).

Of the 218 individuals who adopted hearing aids, five participants did not answer either of the success questions. In this subgroup analysis of 213 hearing-aid adopters, 167 reported that they were successful users (78.4%). After an examination of demographic and hearing-related factors influencing successful hearing-aid adoption, we found no significant predictors of success. In addition, time to hearing-aid adoption did not differ significantly between successful and unsuccessful users. That is, no evidence was found that earlier adoption of hearing aids increases the likelihood of success.

DISCUSSION

Study participants' average age, number of chronic health conditions, sex, retirement status and education level did not differ significantly between those who adopted hearing aids and those who did not (Table 1a). In contrast, adopters were more likely to be married, of white race, and have higher socioeconomic status than non-adopters. With respect to hearing-related variables, compared to non-adopters, adopters had significantly poorer higher frequency thresholds, poorer word recognition in quiet, poorer recognition of keywords in low-context and high-sentences in babble, and reported more hearing handicap as assessed by HHIE/A emotional and social scores.

Our results are similar to those reported in a review by Knudsen et al. (2010), which examined factors that influence adults' help-seeking behavior, hearing-aid uptake, and hearing-aid use and satisfaction. In five peer-reviewed articles assessing hearing-aid uptake, no significant effects were found related to age, sex, or living arrangements, with mixed results related to SES and educational level, although differing definitions of SES and educational levels may have confounded result comparisons. Guessekloo et al. (2003), using the same sample categories of married and not married as in the current study, did not find an association between marital status and hearing-aid uptake. Similar to the current results,

those seeking help and adopting hearing aids had higher degrees of self-reported hearing loss and reported either greater self-assessed disability or handicap or reported being bothered by their hearing problems (Gussekloo et al. 2003). Also consistent with current results, a recent review by Meyer and Hickson (2012) reported that higher thresholds were associated with both hearing-aid uptake and help seeking and found those with a moderate-to-severe hearing loss and self-reported activity limitations were more likely to seek help and/or adopt hearing aids

With regard to race, Nieman et al. (2016), Bainbridge et al. (2014), and Tomita et al. (2001) examined hearing-aid use (not adoption) and found that whites were more likely than non-whites to use hearing aids. More research with larger sample sizes is needed to confirm these results and determine factors that may contribute to differences in hearing-aid adoption and use by white and non-white adults with hearing loss.

Concerning time to hearing-aid adoption, limited published data are available and the current study appears to be the first to determine the demographic and hearing-related factors that influence rate of adoption within a certain time period. Factors that contribute to adoption or non-adoption of hearing aids also tend to contribute to the time to adoption. In unadjusted time analyses, time to hearing-aid adoption was not significantly different between sexes, age groups, and SES proxy groups. However, unadjusted time to adoption shortened significantly with decreases in keyword recognition in low-context sentences (i.e., poorer word recognition in babble), increases in both low and high-frequency PTAs, and increases in self-assessed hearing handicap in social situations.

In unadjusted stratified estimates, non-white racial minorities (primarily African American participants) delayed adopting hearing aids significantly longer than non-Hispanic white participants (15.2 vs. 8.6 years). Because this finding is unadjusted, portions of the effect size may be related to better hearing for African-Americans than non-Hispanic white participants (e.g., Lin et al. 2011), however significant racial differences remained after fully adjusted Cox-modeling.

Similar to the unadjusted findings in the current study, adjusted models controlling for demographic and hearing-related variables indicated that faster rates of adoption occurred in participants with more high-frequency hearing loss, more self-assessed hearing handicap in social situations, poorer keyword recognition in babble in low-context sentences and in non-Hispanic whites. In addition, while controlling for changes in pure-tone thresholds over the same time period, those with higher SES proxy and females had faster rates of adoption. Consistent with the current study, and with results reported by Knudsen et al. (2010) and Meyer and Hickson (2012), sex does not contribute to the decision to adopt hearing aids. However, sex contributes significantly in the time domain, that is, females were 78% more likely to adopt hearing aids than males at any given time. Participants with high SES were 148% more likely to adopt and those with middle levels of SES were 85% more likely to adopt, when compared to those with low SES (Figure 4). Bainbridge and Ramachandran, using data from the National Health and Nutrition Examination Survey, examined income-to-poverty ratio quintile and hearing-aid use and found that the proportion of people in the

upper quintiles who were hearing-aid users was 28% to 66% greater than those in the lowest quintile.

Study strengths included a longitudinal design that follows participants over long periods of time, a diverse study sample for age and hearing loss, underrepresented minority participation, and a well-characterized study sample that included extensive audiologic and medical/biologic measures. The primary study limitation was its observational study design, which did not include randomized assignment to treatment and control groups. The average time to event (8.9 years) may be underestimated because the subject with the longest time point did not adopt hearing aids (as the study is ongoing). In addition, 46% of the participants began the study as hearing-aid candidates; for these participants, their study entry date served as their candidacy date, which likely underestimated time to adoption. Finally, the estimated delay to hearing-aid adoption may be shorter than the general population because participants in this study are counselled at multiple appointments about hearing aids, assistive devices, and communication strategies, have yearly hearing tests with counselling, and have the opportunity to ask questions and receive general hearing-aid information without concerns about financial commitments. Moreover, it is possible that individuals with hearing loss who are interested in participating in hearing-related research may also be more open to using hearing aids. Even taking these factors into account, hearing-aid uptake while in the study (25.4%) was still relatively low for hearing-aid candidates, although somewhat higher than population-based estimates (Lin et al. 2011) and delay to treatment was long (8.9 years, interquartile range = 3.2–14.9 years).

In summary, within an ongoing longitudinal study, we determined if and when participants adopted hearing aids following their transition to hearing-aid candidacy. Two groups of participants were compared who did or did not adopt hearing aids to estimate the delay (in years) from candidacy to hearing-aid adoption and determine the factors that influenced that delay. As expected, participants who adopted hearing aids had more hearing loss, more self-reported hearing handicap, and poorer speech recognition. Other significant factors related to hearing-aid adoption were white race, sex, and SES (employment income). Age, marital status, general health, retirement status and education were not significant factors. The average delay in adopting hearing aids following hearing-aid candidacy was 8.9 years. Non-white race and better speech recognition (in a more difficult task) significantly increased the delay to treatment. Poorer hearing and more self-assessed hearing handicap in social situations significantly decreased the delay to treatment. These results confirm the assumption that adults with hearing loss significantly delay seeking treatment. Near-decade delays are seen in most populations, with shorter delays with increasing hearing loss and communication difficulties in social situations. Minority populations may be especially vulnerable to effects of delayed treatment. More research is needed to identify health and economic benefits of identifying and treating adult hearing loss early, to better understand treatment-seeking delays to minimize delay, increase uptake, and improve communication abilities for adults with hearing loss.

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Figure 1. Cohort selection consort diagram showing the entry of subjects into the study and their assignment to the two comparison groups.

Figure 2. Unadjusted time to hearing-aid adoption stratified by demographic characteristics (baseline age, sex, race, socioeconomic status).

Figure 3. Unadjusted time to hearing-aid adoption stratified by hearing-related characteristics (low-frequency pure-tone average, high-frequency pure-tone average, sentence recognition scores in babble, Hearing Handicap Inventory for Adults/the Elderly (social score)).

Figure 4. Demographic factors influencing time to hearing-aid adoption as indicated by hazard ratios (race, sex, socioeconomic status).

Figure 5.

Top: Hearing-related factors influencing time to hearing-aid adoption as indicated by hazard ratios (high-frequency pure-tone average, low-frequency pure-tone average, Hearing Handicap Inventory for Adults/the Elderly – HHIA/HHIE Social Score). Bottom: Speech-recognition factors influencing time to hearing-aid adoption as indicated by hazard ratios (Speech Perception in Noise Test – Low Context Sentences).

Table 1a

Subject-Related Characteristics (N = 732)

Characteristic	Hearing Aids		
	Adopted Mean (SD) (N = 218)	Not Adopted Mean (SD) (N = 514)	<i>p</i>
Age (years)	69.1 (8.6)	70.2 (10.6)	0.14
Chronic health conditions (0–8)	1.6 (1.4)	1.8 (1.7)	0.12
	Adopted N (%)	Not Adopted N (%)	<i>p</i>
Sex			0.21
Male	120 (55.1)	257 (50.0)	
Female	98 (44.9)	257 (50.0)	
Race			< 0.0001
White	214 (98.2)	427 (83.1)	
Non-White	4 (1.8)	87 (16.9)	
Retired			0.13
Yes	147 (67.4)	316 (61.5)	
No	71 (32.6)	198 (38.5)	
Education (Years completed)			0.41
> 12	161 (73.9)	353 (68.7)	
12	35 (16.1)	92 (17.9)	
Unknown	22 (10.1)	69 (13.4)	
Socioeconomic Status (SES) (Proxy: Employment)			0.01
High	96 (44.0)	203 (39.5)	
Mid	87 (39.9)	172 (33.5)	
Low	25 (11.5)	105 (20.4)	
Unknown	10 (4.6)	34 (6.6)	
Marital Status			0.0001
Married	155 (71.1)	278 (54.1)	
Not Married	50 (22.9)	184 (35.8)	
Unknown	13 (6.0)	52 (10.1)	

Table 1b

Hearing-Related Characteristics (N = 732)

Characteristic	Hearing Aids		
	Adopted Mean (SD) (N = 218)	Not Adopted Mean (SD) (N = 514)	<i>p</i>
Low-frequency PTA (0.25, 0.5, 1.0 kHz) (dB HL)	21.7 (12.0)	20.2 (10.9)	0.09
High-frequency PTA (2.0, 3.0, 4.0, 6.0, 8.0 kHz) (dB HL)	57.8 (13.4)	51.7 (13.7)	< 0.0001
Word recognition in quiet (NU-6%) [*]	76.8 (15.4)	80.3 (13.7)	0.005
Low-context sentences in babble (SPIN Low%) [†]	48.1 (20.8)	59.3 (17.9)	< 0.0001
High-context sentences in babble (SPIN High%) [†]	89.3 (15.5)	94.1 (9.9)	< 0.0001
HHIE/A Emotional Score (Self-reported hearing handicap) [‡]	13.4 (11.0)	7.9 (9.2)	< 0.0001
HHIE/A Social Score (Self-reported hearing handicap) [‡]	14.5 (9.6)	8.7 (8.0)	< 0.0001
	Adopted N (%)	Not Adopted N (%)	<i>p</i>
Low-context sentences in babble (SPIN Low-Categorized, %)			< 0.0001
42	73 (33.5)	61 (11.9)	
43–58	49 (22.5)	90 (17.5)	
59–70	51 (23.4)	102 (19.8)	
> 70	25 (11.5)	107 (20.8)	
Unknown	20 (9.2)	154 (30.0)	

^{*} Word recognition in quiet missing for 6 participants (2 adopted and 4 not adopted).

[†] SPIN scores missing for 174 participants (20 adopted and 154 not adopted).

[‡] HHIE/A scores missing for 53 participants (10 adopted and 43 not adopted).