

Factors Associated With Longitudinal Patterns of Hearing Aid Use

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Abstract

Background and Objectives: The objectives of this study are to identify patterns of hearing aid usage among U.S. National Health & Aging Trends Study (NHATS) participants and to examine users' characteristics associated with each pattern.

Research Design and Methods: Using data from 666 adults ages 65 and above from NHATS, we analyzed individuals' self-reported hearing aid use from eight waves of data, 2011–2018, using group-based trajectory modeling to identify clusters of individuals with similar utilization patterns of use over time. Potential risk factors associated with membership to a specific group included baseline sociodemographic characteristics, problems with activities of daily living, presence of a caregiver, and experiencing problems with their hearing aid. We compute and analyze the odds ratios between individuals' baseline characteristics and group membership.

Results: We identified three utilization group patterns: continued use ($n = 510$, 76.6%), interrupted use ($n = 121$, 18.2%), and ceased use ($n = 35$, 5.2%). Individuals with an income under the poverty line had 2.9 (95% CI: 1.09, 7.75) and 2.7 times (95% CI: 1.38, 5.27) the odds of being in the interrupted and ceased use group, respectively, compared with the continued use group. Other risk factors for interrupted and ceased use included lower education and having a caregiver.

Discussion and Implications: Nearly a quarter of hearing aid users experience interrupted or ceased use of hearing aids. Socioeconomic factors, such as age, income, and education, may be relevant for how individuals use assistive medical devices over time and could inform policymakers to support maintained use of hearing aids.

Translational Significance: Discontinuation of hearing aid use is a common challenge, and it may hinder the effectiveness of the intervention. The exploration of risk factors associated with discontinued use of hearing aids provides a foundation for future research and translational efforts, such as enabling health care professionals to address potential barriers and develop strategies to enhance device adherence.

Keywords: Disability, Health outcomes, Observational studies

Hearing loss is a common chronic health condition among older adults, prevalent among half of adults over age 60 in the United States (Lin, Niparko, et al., 2011; National Institute on Deafness and Other Communication Disorders, 2018). Recent epidemiologic evidence suggests hearing loss is associated with important aging outcomes including dementia (Lin, Metter, et al., 2011), cognitive decline (Deal et al., 2015), and decreased physical activity (Deal et al., 2016). These associations may be mediated by hearing loss' impact on socioemotional consequences including depression (Shukla, Reed, et al., 2021), social isolation (Shukla, Cudjoe, et al., 2021), and loneliness (Sung et al., 2016) due to communication limitations and barriers.

Hearing aids are the most common treatment option for hearing loss (National Academies of Sciences Engineering

and Medicine, 2016). The devices amplify and manipulate sound to augment generally desired sounds (e.g., speech) in the immediate environment and have several integrated technologies to improve phone and broadcast media access. Trials demonstrate hearing aids improve hearing-specific outcomes and health-related quality of life (National Academies of Sciences Engineering and Medicine, 2016; Noffsinger et al., 2002), and some research suggests a protective effect of hearing aids on important aging outcomes including cognitive function (Sanders et al., 2021) and depressive symptoms (Acar et al., 2011). As such, understanding patterns of hearing aid use is important for clinical and public health planning and interventions.

Most research in hearing aid usage is concentrated on characterizing individuals who do or do not obtain hearing

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aids and factors associated with static ownership of hearing aids. Previous studies have cited patient-related factors such as race, ethnicity, socioeconomic status, encountering a social stigma, social support, information seeking, having a usual source of care, and prior fluency with technology as other factors associated with low uptake of hearing aid use among individuals with untreated hearing loss (Assi et al., 2021; Bainbridge & Ramachandran, 2014; McKee et al., 2019; Nieman et al., 2016; Tahden et al., 2018). A 2015 systematic review identified determinants of hearing aid adoption including the severity of hearing loss, self-perceived hearing problems, self-perceived benefit of hearing aid use, satisfaction with hearing aid use, socioeconomic status, and social support from significant others (Ng & Loke, 2015). Importantly, affordability is frequently cited as a barrier to hearing aid use (Aazh et al., 2015; Assi et al., 2021). In qualitative structured interviews conducted in 2019, low-income participants reported high out-of-pocket expenses as a major obstacle to obtaining hearing aids (McKee et al., 2019). This is coupled with the fact that Medicare, a common public insurance option for older adults, currently does not cover hearing aids (Jilla et al., 2020). While characteristics related to hearing aid uptake are well-documented, there is a paucity of longitudinal research on patterns of continued hearing aid usage.

In this study, we employ a group-based trajectory modeling (GBTM) approach in the United States using the 2011–2018 National Health Aging Trends Study (NHATS) to identify longitudinal patterns of hearing aid usage among participants who had hearing aids and to examine users' baseline characteristics associated with each pattern. Analysis of characteristics associated with patterns of hearing aid use over time may inform hearing care providers on strategies to encourage noninterrupted use of hearing aids.

Method

Study Design and Data Collection

We used data from the 2011 to 2018 waves of the National Health and Aging Trends Study (NHATS), a nationally representative longitudinal panel study of Medicare beneficiaries ages 65 and older that began in 2011 with an initial cohort of 8,245 participants (Kasper & Freedman, 2019). Interviews are collected annually on a broad array of health information, including hearing aid use. The interviews are completed by either the beneficiary themselves (i.e., self-report) or a proxy respondent. The interview contains mostly self-report questionnaires but also brief functional assessments (e.g., cognitive testing). The study collects demographic and aging-related health information, and the data is publicly available for use. Data collection protocols are approved by the Johns Hopkins University Institutional Review Board and all participants provided informed consent. The analytic sample was restricted to participants who first reported using a hearing aid during any of the first four waves of the study and who had participated for at least five waves of the study ($N = 672$). Our final analytic sample excluded observations without a full set of covariates ($N = 6$).

Hearing Aid Use

Hearing aid use was collected annually (“*In the last month, have you used a hearing aid or other hearing device?*”) and

was obtained during each follow-up. Hearing aid use was coded into a binary variable (“*Yes*”/“*No*”).

Participants' Characteristics

Analyses included baseline characteristics measured at the time hearing aid use was first reported: gender (self-reported men vs. self-reported women), age category (65–74, 75–84, and 85+ years), education (some college or above [including vocational/technical school] vs. high school completion or equivalent and below), marital status (married vs. single, divorced, widow, and never married), self-reported household income with respect to the poverty line for a two-person household of 65+ individuals (<100% poverty line vs. ≥100% poverty line), race and ethnicity (non-Hispanic White vs. Hispanic, Black, Asian, other racial or ethnic minorities [non-White]), dementia status (probable or possible dementia vs. no dementia), problems with at least one of the activities of daily living (ADLs), the presence of a caregiver (defined as a person who reported helping the older adult with eating, bathing, toileting, dressing, or with medications during the last month), and if any hearing problems were reported while using a hearing aid (whether or not participants reported hearing well enough to use the telephone, to carry a conversation with the TV or the radio on, or in a quiet room, while wearing a hearing aid). Dementia status (probable and possible) was defined based on a proxy report of an ADRD diagnosis, AD8 screener, and cognitive test scores in the domains of memory, orientation, and executive function according to previously defined criteria (Kasper et al., 2013). ADLs were defined based on participants' self-report for receiving help for an ADL, experiencing a little to a lot of difficulty while performing an ADL, or not performing an ADL because of lack of help or its difficulty. Due to small sample sizes, race/ethnicity was collapsed into a binary variable (non-Hispanic White and non-White).

Statistical Analysis

First, patterns of self-reported hearing aid use over time were determined using GBTM (Nagin, 1999, 2005). This approach has the benefit of allowing group membership and the identified trajectories to be driven by the data without the need for a priori investigator-based definitions. GBTM assumes that all participants, based on their baseline characteristics and hearing aid use over time, can be categorized into different groups defined by their behavior regarding their hearing aid use. Group number and their trajectories were chosen by comparing the performance of different models using Bayesian- and Akaike-Information Criteria and the researchers' ability to interpret the models. The number of groups was determined by comparing models with linear trajectories, while trajectory shapes were chosen after comparing all possible trajectory models. Once a particular model was selected, we reviewed individual patterns of hearing aid use vis à vis group assignment to ensure that group membership was reasonable (See [Supplementary Material](#) for a detailed description).

Second, once the number of groups is defined, the model uses maximum likelihood to estimate the shape of each group trajectory while assigning all individuals to one of the possible groups. During estimation, the model allows individuals' time-invariant covariates to be associated with the probability of group membership using a generalized multinomial logistic regression. The time-invariant baseline characteristics included in the model are: age, sex, race or

ethnicity, education, marital status, problems with a hearing aid, income, dementia, the presence of a caregiver, and problems with at least one ADL. Group trajectories, log odds ratios, and their corresponding 95% confidence intervals (CI) for the risk factors associated with group membership relative to one specific group were jointly estimated using GBTM. Sensitivity analysis was conducted using an available case approach to examine whether there were differences in risk factor associations from the primary analysis that restricted the sample to those contributing at least five survey waves to the analysis. The analysis employed the “traj” plug-in and Stata/SE 17.0.

Results

The full sample included $n = 666$ hearing aid users (Table 1). Participants were predominantly over the age of 75 ($n = 508$; 76.2%), White ($n = 583$; 87.5%), married ($n = 376$; 56.5%), and had at least a high school diploma ($n = 381$; 57.2%). Almost a 3rd of participants (32.7%) reported having problems with at least one ADL. The GBTM identified and categorized participants into three groups: 510 (76.6%) were assigned to the *continued-use* group (report using hearing aids at every cycle), 121 (18.2%) to the *interrupted-use* group (cease reporting use of hearing aids for at least one survey wave but report using them again at a later wave), and 35 (5.3%) were assigned to the *ceased-use* group (stopped using hearing aids and never reported using them again during follow-up), as shown in Figure 1.

Sociodemographic characteristics varied across the three groups (Table 1). The continued use users had the lowest percentage (9.2%) of non-White participants, in contrast with the interrupted use (20.7%), and ceased use (31.4%) groups. Compared to continued use (58%) and interrupted use (62%) group members, participants in the ceased use group were less likely to have some college or more (28.6%). Continued use users were less likely to report a household income below the poverty line (10.6%), compared to the ceased use (37.1%) and interrupted use (24%) groups.

Table 2 shows the estimates from the generalized multinomial logistic model for the odds of falling into the interrupted (vs. continued) and ceased (vs. continued) groups. Among sociodemographic measures, age was associated with interrupted hearing aid use patterns. Specifically, compared to adults 65–74 years old, adults ages 75–84 years had reduced odds (OR = 0.13, 95% CI: 0.04, 0.38) of ceasing hearing aid use. Race and ethnicity were not significantly associated with hearing aid use patterns. Last, self-reported males had 1.72 times (95% CI: 0.99, 2.96) times the odds of being in the ceased use group compared to self-reported women; however, the CI still included the null hypothesis and is not statistically significant. When compared to individuals with higher incomes, individuals with an income under the poverty line had 2.9 (95% CI: 1.09, 8.16) and 2.7 (95% CI: 1.38, 5.27) times the odds of ceased hearing aid use and interrupted hearing aid use instead of continued hearing aid use. Similarly, individuals with some college or higher education had diminished odds (OR = 0.33; 95% CI: 0.13, 0.83) of interrupted

Table 1. Baseline Characteristics as Percent (%) of Study Participants According to Hearing Aid Use Trajectories

Baseline characteristics	Full sample $N = 666$	Continued use $n = 510$ (76.6%)	Interrupted use $n = 121$ (18.2%)	Ceased use $n = 35$ (5.3%)	<i>p</i> Value
Age					.005
65–75 years	158 (23.7%)	108 (21.2%)	34 (28.1%)	16 (45.7%)	
75–85 years	304 (45.6%)	247 (48.4%)	49 (40.5%)	8 (22.9%)	
85+ years	204 (30.6%)	155 (30.4%)	38 (31.4%)	11 (31.4%)	
Gender					.14
Self-reported women	313 (47.0%)	242 (47.5%)	50 (41.3%)	21 (60.0%)	
Self-reported men	353 (53.0%)	268 (52.5%)	71 (58.7%)	14 (40.0%)	
Race					<.001
White	583 (87.5%)	463 (90.8%)	96 (79.3%)	24 (68.6%)	
Non-White	83 (12.5%)	47 (9.2%)	25 (20.7%)	11 (31.4%)	
Education					.002
At most high school education	285 (42.8%)	214 (42.0%)	46 (38.0%)	25 (71.4%)	
Some college or more	381 (57.2%)	296 (58.0%)	75 (62.0%)	10 (28.6%)	
Marital status					.14
Single/widowed/divorced	290 (43.5%)	213 (41.8%)	57 (47.1%)	20 (57.1%)	
Married	376 (56.5%)	297 (58.2%)	64 (52.9%)	15 (42.9%)	
Problem with hearing aid	186 (27.9%)	150 (29.4%)	27 (22.3%)	9 (25.7%)	.28
Income < 100% poverty line	96 (14.4%)	54 (10.6%)	29 (24.0%)	13 (37.1%)	<.001
Probable/possible dementia	121 (18.2%)	84 (16.5%)	29 (24.0%)	8 (22.9%)	.12
Has a caregiver	114 (17.1%)	73 (14.3%)	30 (24.8%)	11 (31.4%)	.002
Problem with ≥ 1 ADL	218 (32.7%)	150 (29.4%)	51 (42.1%)	17 (48.6%)	.003

Note: ADL = activities of daily living.

use when compared to individuals with at most a high school education. Finally, for participants in our study, having a caregiver is associated with higher odds of ceased use of a hearing aid (OR = 2.98; 95% CI: 1.09, 8.16), as opposed to continued use, when compared to participants without a caregiver.

In sensitivity analyses including all available observations regardless of a number of survey waves contributed, the GBTM also yielded three groups with trajectories very similar to the ones of our main analyses. In addition, the characteristics associated with ceased use and interrupted use group membership, compared to continued use, were mostly similar to the ones from above (See [Supplementary Material](#)). In the sensitivity analysis, we observed a qualitative change in the measure of association for probable dementia to indicate a stronger association between dementia and interrupted

or ceased hearing aid use. That is, in the sensitivity analysis, probable/possible dementia was significantly associated with ceasing hearing aid use (OR = 2.02; 95% CI: 1.09, 4.2) and interrupted hearing aid use (OR = 1.85; 95% CI: 1.17, 2.91).

Discussion

In a nationally representative sample of Medicare beneficiaries over age 65 years who reported hearing aid use from 2011 to 2018, we identified three major patterns of hearing aid use—continued use (76.6%), interrupted use (18.2%), and ceased use (5.3%). Nearly one-quarter (23.5%) of hearing aid users experienced interrupted or ceased use of hearing aids over the study duration. In addition to describing the trajectories, the multinomial logistic model revealed that relatively younger age, lower education, lower income, and having a caregiver were associated with interrupted use. Having lower income was also associated with ceasing the use of hearing aids during the 8-year study period. To our knowledge, this is one of the only, if not the first, study to use GBTM to detect patterns of hearing aid use in a longitudinal United States cohort of older adults. Although preliminary, our findings lay the foundation for future research on public health interventions and clinical strategies to support the maintained use of hearing aids.

There is minimal research on the sustained use of hearing aids despite the importance for an individual to continue and maintain their selected hearing care. A survival analysis of 355 older adults fitted with hearing aids at a public hospital in Chile found approximately one in five participants discontinued use of their hearing aids, a similar estimate to the 23.5% of participants in the current study who experienced interrupted or ceased use of hearing aids ([Fuentes-López et al., 2019](#)). In an analysis of nearly 300,000 hearing aid users, [Naylor et al \(2022\)](#) found prevalent dementia was a

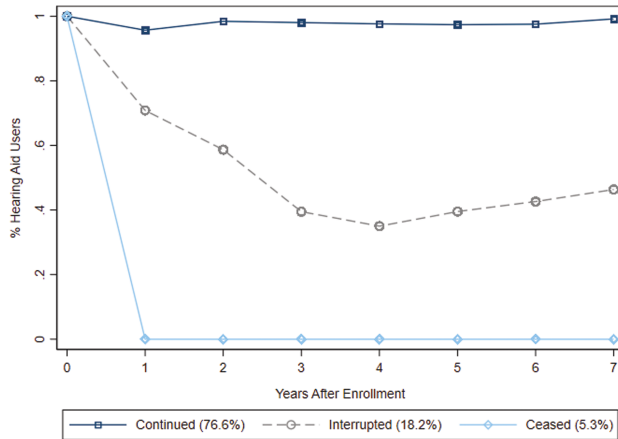


Figure 1. Group trajectories of hearing aid use from years after enrollment.

Table 2. Associations Between Study Participants' Baseline Characteristics and Hearing Aid Use Patterns Compared with the Continued Use Trajectory

Baseline characteristics	Interrupted use		Ceased use	
	Odds ratios [95% CI]	<i>p</i> Value	Odds ratios [95% CI]	<i>p</i> Value
Age				
65–75 years	1 (ref.)		1 (ref.)	
75–85 years	0.13 [0.04, 0.38]	<.001	0.62 [0.35, 1.08]	.093
85 + years	0.21 [0.07, 0.58]	.003	0.71 [0.38, 1.32]	.282
Self-reported men	0.56 [0.21, 1.47]	.239	1.72 [0.99, 2.96]	.053
Race				
White	1 (ref.)		1 (ref.)	
Non-White	2.5 [0.93, 6.70]	.069	1.6 [0.81, 3.17]	.179
Education				
At most high school education	1 (ref.)		1 (ref.)	
Some college or more	0.33 [0.13, 0.83]	.018	1.56 [0.95, 2.56]	.078
Married	0.77 [0.29, 2.04]	.594	0.7 [0.40, 1.23]	.215
Problems with hearing aid	0.49 [0.19, 1.27]	.141	0.6 [0.35, 1.03]	.063
Income under poverty line	2.9 [1.09, 7.75]	.033	2.7 [1.38, 5.27]	.004
Probable/possible dementia	0.71 [0.24, 2.09]	.538	1.12 [0.62, 2.03]	.702
Has a caregiver	2.98 [1.09, 8.16]	.034	1.6 [0.87, 2.93]	.129
Problem with ≥ 1 ADL	1.34 [0.55, 3.27]	.514	1.56 [0.93, 2.60]	.093

Note: ADL = activities of daily living; 95% CI = confidence interval; ref. = reference.

risk factor for nonpersistent hearing aid use. In a separate analysis in the same publication, the authors found nonpersistent use of hearing aids was also associated with incident dementia (Naylor et al., 2022), which is consistent with the results of our sensitivity analysis. However, the Naylor et al (2022) analyses were conducted among individuals in the U.S. Veterans Affairs health care system, which offers free hearing aid services, and consequently, the results may not be generalizable to most Americans in the United States where hearing aids are not covered by most insurances. The majority of the work on discontinued use of hearing aids is from the international literature, perhaps because hearing aids are more likely to be covered by public insurance in some capacity outside the United States. However, despite some financial assistance often available in these countries, lower income is consistently associated with discontinued use of hearing aids (Fuentes-López et al., 2019; Lupsakko et al., 2005). Our study corroborates prior findings in that we found income under the poverty line to be associated with interrupted or ceased hearing aid use. Several studies on clinical populations identified several auditory-specific reasons for nonuse of hearing aids including physical fit, cost, and maintenance of the device following the purchase of hearing aids (Garstecki & Erler, 1998; McCormack & Fortnum, 2013). Although we did not explore device-related characteristics such as fit or maintenance requirements, we hypothesize maintenance costs play a role in the association found between income under the poverty line and interrupted and ceased hearing aid use. Furthermore, one study found difficulty with activities of daily life and cognitive capacity to be associated with discontinuation of hearing aids (Lupsakko et al., 2005). Although this study did not find a significant association between activities of daily life and hearing aid use patterns, we did find that the presence of a caregiver, often linked with a disability, was associated with interrupted hearing aid use.

Consistent with previous work on barriers to entry to hearing aid use, our study identified low income as a risk factor for both interrupted and ceased use. Participants with income under the poverty line had 2.9 times the odds of interrupted use and 2.7 times the odds of ceasing hearing aid use. Hearing aids are indeed costly devices, costing up to \$4,000 per set (National Academies of Sciences Engineering and Medicine, 2016). Although most researchers focus on the initial barriers to purchasing hearing aids due to high costs (Nassiri et al., 2021), few also note that hearing aids are electronic devices with a limited lifespan and require regular maintenance and replacement of parts, and full replacement every 3–7 years (National Academies of Sciences Engineering and Medicine, 2016). In fact, prior market researchers have estimated 87% of total hearing aid sales in 2015 to be attributed to device replacement (Nassiri et al., 2021). Moreover, many benefit from regular device adjustments and counseling from a professional which is often bundled into the initial cost of the hearing aids, but there are some fee-for-service models that exist that would necessitate continued regular payments (National Academies of Sciences Engineering and Medicine, 2016). Notably, hearing aids and related services are a statutory exclusion under Medicare (Cohen-Mansfield & Taylor, 2004; Whitson & Lin, 2014). Additional private insurance may include hearing aid benefits but can still be costly. For example, many Medicare Advantage hearing aid benefits still require enrollees to contribute out-of-pocket for nearly 80% of total hearing care spending (Willink et al., 2020). Although

unmeasured in the current analysis due to limitations in insurance details, previous literature suggests that insurance status (among those not enrolled in the Veterans Affairs insurance program) is not associated with hearing aid use, while low income appears to be a consistent risk factor for the nonuse of hearing aids (Laplante-Lévesque et al., 2012; McKee et al., 2019; Simpson et al., 2019).

The combination of high device costs, regular needs for professional services, maintenance and replacements, and lack of insurance coverage renders the continued use of hearing aids expensive, even for those who are able to make the initial purchase. Additional expenses beyond the initial investment in the device include purchasing batteries, new connecting tubes, cleaning accessories, and electronic maintenance. These costs can be excessive for low-income individuals, which is consistent with prior research noting maintenance cost as a significant barrier to continued use (Fuentes-López et al., 2019; Garstecki & Erler, 1998; Lupsakko et al., 2005). Adults living below the poverty line may be vulnerable due to continued costs but also because individuals with lower incomes tend to face other barriers to continued access to care, including inflexible employment arrangements that do not allow time for medical visits (Lamsal et al., 2021), restrictive transportation options (Syed et al., 2013), or limited health literacy skills (Lazar & Davenport, 2018). Especially concerning is that while those in our study population were able to make the initial investment in hearing aids, low-income status was ultimately associated with the inability to maintain continued use of their hearing aids over time—and the cost of the initial device investment is an expenditure that cannot be recovered.

Other risk factors were associated with hearing aid use continuity in the current study. Lower education was associated with increased odds of experiencing interrupted use of hearing aids. This may be collinear with income or independently represent lower health literacy resulting in barriers navigating the hearing care system for regular engagement. A novel finding from the analysis was that the presence of a caregiver who helps with at least one ADL was significantly associated with being in the interrupted use group. The presence of a caregiver may be a proxy for a health condition, such as chronic disease or disability, that requires a family caregiver, home health aide, or other assistive role. Hearing aids often require manual dexterity to handle, and disability or severe chronic disease can consequently affect an individuals' ability to operate the small device. Given that the association was found solely in the interrupted use group, it is possible that competing health care demands for conditions related to caregiving may deprioritize addressing hearing loss resulting in a lapse in hearing aid use. However, caregiver support may ultimately result in re-engaging with hearing aid use, especially given potential barriers of hearing loss on care partner communication which may affect quality of life for both the caregiver and care recipient.

Two risk factors included in our analysis differed from our expectations given prior literature on HA use. While previous literature has reported that men are less likely to adopt hearing aids despite a higher prevalence of hearing loss among men versus women (Lin, Thorpe, et al., 2011; Simpson et al., 2019), our study did not find a significant association between self-reported males and patterns of hearing aid use. Some have suggested different perceptions of stigma between men versus women may play a role in different levels of uptake. Because hearing aid use was an inclusion criterion in our study, our

findings might suggest sex plays a role during uptake, but not afterward. However, the CI only narrowly included the null hypothesis. Additional research should further investigate the relationship between gender and discontinued hearing aid use (Garstecki & Erler, 1998; Knudsen et al., 2010). Second, we did not find a significant association between the presence of difficulty with at least one ADL and hearing aid use patterns. Among a cohort of Finish older adults, Lupsakko et al (2005) found discontinuation of hearing aids to be associated with challenges with ADL. In concordance with our findings, Lupsakko et al (2005) reported cognitive capacity as a risk factor for discontinued use. In our sensitivity analysis which included individuals with missing follow-up time, we found probable dementia was associated with higher odds of interrupted and ceased hearing aid use. It is possible that probable dementia was associated with increased risk of study drop-out and therefore, the analysis excluding missing individuals did not capture the association.

Our findings should be considered in light of the study's limitations. First, we do not know how many of the participants in our study used traditional hearing aids versus other hearing amplifiers. It is possible different device types may have varying effects on the longitudinal patterns of use as the devices would be packaged with different support models that could affect these patterns. However, while the use of amplifiers or other direct-to-consumer hearing devices is possible, it is likely relatively rare. Hearing device market surveys have reported personal sound amplifier use to be less than 5% (Kochkin, 2010). Similarly, availability or frequency of hearing care services received by participants is not reported and could explain some of the results observed in our study, particularly with respect to use cessation. Second, our analysis relied on self-reported risk factors and use of hearing aids, which may be subject to recall bias. Third, self-reported reasons for discontinued use were also not recorded in the NHATS data, which would have added richer information to our study. It is possible worsening hearing may have resulted in ceasing use or moving on to different therapies (e.g., surgery for cochlear implants). Fourth, the temporal granularity of our longitudinal analysis was limited to an annual data collection. While the study was unique in its consideration of cessation of device use in the United States, questions related to time exposed to the device (i.e., device "dosage") measured by daily use, hours of use, or habitual use remained unanswered. We examined longitudinal patterns of hearing aid use related to participant characteristics at baseline, so we were unable to capture major changes in health and physical ability over time that may have been related to hearing aid use patterns. Furthermore, though the NHATS study oversamples by age and race to allow for appropriate statistical power for the analysis of underrepresented populations (Freedman & Kasper, 2019), the sample used for this analysis was mostly White. This may be because White individuals are more likely to own hearing aids in general (Simpson et al., 2019). We were unable to evaluate associations with racial/ethnic groups due to small sample sizes; however, future work should target these underrepresented hearing aid users. We lacked information on hearing aid providers, including hearing care provider characteristics or experiences of the patient with the provider. It is possible that provider-side characteristics play a role in individuals' pattern of hearing aid use (e.g., hearing aid provider closes down, raises prices, retires, etc.). Our analysis was confined to an analysis of individuals who completed at least

5 survey waves, which may introduce bias due to differential loss-to-follow-up. Our sensitivity analysis revealed similar results when comparing the primary analysis (participants who contributed at least 5 survey waves) to an available data analysis (all participants), but the measure of association for one risk factor—dementia—changed both qualitatively and in terms of statistical significance, suggesting dementia may be related to study drop-out, and the relationship between dementia and hearing aid use was not ultimately captured in the main analysis. Finally, our NHATS data set did not include relevant clinical data that would differentiate hearing loss severity, such as pure-tone average. We suspect the significant association between continued use and older age may be confounded by hearing loss severity.

On a policy level, the structure of hearing care is undergoing broad changes that may address the barriers to hearing aid adoption and continued use. In December 2016, the U.S. Food and Drug Administration announced the creation of over-the-counter hearing aids as a new category for hearing devices, which was officially proposed in November 2021 and was finalized by August 2022. The final rule allows consumers to purchase hearing aids for mild to moderate hearing loss directly in-store or online without a prescription or visit to a medical provider for a professional fitting (U.S. Food & Drug Administration, 2022). By lowering the barriers to entry for companies, the rule aims to enhance competition in the over-the-counter marketplace and drive costs lower for the consumer. Although the rule may not be the solution for all, over-the-counter hearing aids may expand access to those who face limited access to hearing providers. Understanding the use patterns of over-the-counter devices will be important to optimizing the hearing care delivery system. However, little is known at this time, and it is unknown how the availability of over-the-counter hearing aids will affect our findings, as the hearing care landscape is rapidly developing to accommodate the new devices in the market. Ambiguity remains on appropriate device selection, current device costs, and sustained support models. Moreover, our results could inform future research to support Medicare coverage that encourages continued hearing aid use such as hardware maintenance and repair expenses, batteries and tube replacements, and hearing-related examinations.

Some important conclusions can be noted from this study. In our sample of Medicare beneficiaries over the age of 65 years, we identified having an income below the poverty line and lower educational attainment as significant risk factors for interrupted or discontinued hearing aid use. Older age at baseline was strongly associated with persistent hearing aid use across the study period. Future work is needed at the intersection of clinical/audiologic data and a health services framework—one that combines clinical measurements with social and economic determinants to gain a broader understanding of true predictors of device use over time. Population-based prospective studies should consider investigating a dose-response relationship between hours of device use, clinical benefits, and impact on daily social life, as well as the role of hearing care-related costs in unsuccessful hearing aid use. Finally, additional research should focus on the possible repercussions of discontinuing hearing aid use entirely.

Supplementary Material

Supplementary data are available at *Innovation in Aging* online.

Author Notes

The gender item in the National Health and Aging Trends Study uses “men” and “women.”

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Conflict of Interest

N.S. Reed reported being a scientific advisory board member of Neosensory.

Author Contributions

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