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To determine whether functional and psychosocial outcomes associated with hearing impairment are a direct result or stem from prevalent comorbidity, we analyzed the impact of two levels of reported hearing impairment on health and psychosocial functioning one year later with adjustments for baseline chronic conditions. Physical functioning, mental health, and social functioning decreased in a dose-response pattern for those with progressive levels of hearing impairment compared with those reporting no impairment. Our results demonstrate an independent impact of hearing impairment on functional outcomes, reveal increasing problems with higher levels of impairment, and support the importance of preventing and treating this highly prevalent condition.

Key Words: Cohort study, Hearing loss, Mental health, Social functioning

Negative Consequences of Hearing Impairment in Old Age: A Longitudinal Analysis

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Hearing impairment is a commonly reported problem in old age that has shown a near doubling in prevalence over the past 30 years in the United States based upon self-reported data on trouble hearing (Benson & Marano, 1994; Jackson, 1968; Ries, 1994; Wallhagen, Strawbridge, Cohen, & Kaplan, 1997). These same studies indicate that the prevalence of hearing impairment is higher at all adult ages for men than for women. Recent clinical testing in one community-based study using greater than a 25 dB loss in one ear as a threshold for hearing loss has confirmed the high prevalence of hearing impairment among older persons, the sharp increase with age, and the higher prevalence for men (Cruickshanks et al., 1998). The most common loss occurs at higher frequencies, making speech especially difficult to understand when there is background noise (Weinstein, 1994).

Causes of the apparent increase in prevalence over the last three decades are unclear. Environmental noise may be increasing, but this type of noise may not be at a decibel level ($\sim\geq$85 dB) that damages hearing and thus probably creates stress rather than hearing impairment (Godlee, 1992; Gulya, 1995).

Occupational noise, on the other hand, is loud enough to cause damage, and there are data supporting an association between hearing impairment and service/blue-collar occupations (Godlee, 1992; Marvel, Pratt, Marvel, Regan, & May, 1991; Ries, 1994; Wallhagen et al., 1997). Other causes may involve pharmaco-therapeutic agents, industrial chemicals, rapid changes in ambient pressure, and a number of medical conditions, such as diabetes, ear infections, and cardiovascular disease (Chiodo & Alberti, 1994; Clark et al., 1995; Gatland, Tucker, Chalstrey, Keene, & Baker, 1991; Hariri, Lakshmi, Larner, & Connolly, 1994; Lim & Stephens, 1991; Shusterman & Sheedy, 1992; Vasquez, Maddux, Sanchez, & Pollak, 1993). Other than avoiding exposure to known causes, the only identified prevention strategy is exercise, which may be beneficial because of its relationship to lower incidence of certain cardiovascular and pulmonary conditions that may in turn affect hearing impairment (Wallhagen et al., 1997).

Hearing impairment alters a person's ability to communicate with others and thus can seriously affect interpersonal relationships (Slawinski, Hartel, & Kline, 1993). Previous studies of the consequences of hearing impairment in old age have shown that it is also associated with multiple negative outcomes, including depression, loneliness, altered self-esteem, and diminished functional status (Chen, 1994; Dugan & Kivett, 1994; Jerger, Chmiel, Wilson, & Luchi, 1995; Mulrow et al., 1990; Wallhagen, Strawbridge, & Kaplan, 1996). However, most studies on the consequences of hearing impairment have either involved cross-sectional analyses or analyzed sample sizes too small for adequate control of suspected confounders. It is plausible that both hearing impairment and the observed negative outcomes could result from associated comorbid conditions, such as cardiovascular disease or diabetes, rather than being linked in a causal relationship. Only longitudinal analyses with adequate controls for suspected confounders can clarify the relationships observed.

There have been two longitudinal studies of the

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impact of reported hearing impairment on subsequent physical disability as measured by either activities of daily living (ADL) or instrumental activities of daily living (IADL). The ADL analysis indicated that an initially increased relative risk for subsequent disability associated with baseline hearing impairment was reduced to nonsignificance when adjustments were made for baseline chronic conditions (Rudberg, Furner, Dunn, & Cassel, 1993). The IADL analysis indicated a statistically significant impact of baseline hearing impairment on subsequent IADL disability; adjustments included self-reported health rather than chronic conditions (Furner, Rudberg, & Cassel, 1995). Both studies used a dichotomous measure of hearing impairment and included reports of tinnitus in their definitions of hearing impairment.

The argument linking hearing impairment with functional outcomes would be strengthened if results indicated a dose-response pattern such that negative results became more severe as levels of hearing impairment increased. Unfortunately, many community-based studies rely on a single question (such as asking subjects whether they have trouble hearing) or combine several individual questions (such as prevalence of tinnitus and trouble hearing in one or both ears) to assess hearing impairment rather than trying to assess various degrees of such loss.

The aim of this study was to address the above issues by analyzing the longitudinal impact of two levels of self-reported hearing impairment on a number of subsequent physical health, functioning, mental health, and social functioning outcomes. Adjustments for comorbid conditions and other baseline factors that might confound any observed relationships were included in the analyses as were adjustments for baseline values of each outcome examined so as to remove any cross-sectional baseline associations.

Methods

Study Population

A longitudinal study of factors related to health and mortality, the Alameda County Study began in 1965 by enrolling 6,928 persons aged 16 to 94 (Berkman & Breslow, 1983). Subjects were originally selected by means of a random household survey in Alameda County, California, an area that includes the cities of Oakland and Berkeley. The county was selected for the study partly because residents were similar in age and ethnic status to the United States as a whole. Participants remain in the study regardless of where they subsequently move, although a majority has remained in the county and nearly 75% still live in the San Francisco Bay area. Data collection is by means of a mailed questionnaire supplemented by telephone and in-person interviews for participants unable to complete the questionnaires by themselves due to health reasons. Survivors were resurveyed in 1974, 1983, 1994, and 1995. Response rates for these four follow-up surveys were 85%, 87%, 93%, and 97%, respectively. More than 2,000 participants have died since the study began. Older participants in the Alameda County Study remain representative of the older population of the United States on demographic variables with two exceptions: a higher proportion of study participants have 12 years of education or more and a higher proportion are married (Strawbridge, Kaplan, Camacho, & Cohen, 1992).

Eligibility for the analyses of hearing impairment reported in this paper included the 2,504 participants aged 50 and older in 1994 who completed both the 1994 and 1995 questionnaires; 43 of them were subsequently excluded because they were missing one or more responses to the hearing assessment questions or to any of the adjustment variables asked in 1994. The total remaining was 2,461. A few more participants with missing data on individual outcome measures were omitted from individual statistical models where the missing values occurred; such deletions ranged from 2–27 individuals depending upon the model.

Measures

The 1994 questionnaire was designed to assess a wide variety of behavioral, medical, and social factors, whereas the shorter 1995 questionnaire emphasized physical functioning and mental health with only a few questions on morale and social relationships. Outcomes analyzed in the analyses that follow are necessarily limited to those included in both questionnaires.

Hearing Impairment.—Participants were asked in 1994 how much difficulty they had (even with a hearing aid) hearing and understanding words in a normal conversation, hearing words clearly over the telephone, and hearing well enough to carry on a conversation in a noisy room. Such self-reports of difficulty hearing can reasonably be used to identify older persons with hearing impairment (Reuben, Walsh, Moore, Damesyn, & Greendale, 1998). Several studies have included tinnitus in their measures of hearing impairment (Furner et al., 1995; Rudberg et al., 1993). We did not include tinnitus because in our data set the concordance between tinnitus and hearing impairment is poor.

We scored responses to all three questions according to level of difficulty: a great deal (3), some (2), a little (1), or none (0). Scores were summed. The resulting scale was then divided into three categories as follows: no hearing impairment (score of 0), a little hearing impairment (score of 1–3), and moderate or more hearing impairment (score of 4 or higher). To score 4 or more, participants had to report a minimum of some difficulty in two settings or a great deal of difficulty in one setting *and* at least a little difficulty in another setting.

Functioning Outcomes.—All 1995 outcomes were dichotomized for use with logistic regression analysis. These same variables had been assessed in 1994 and were scored the same as below.

Physical health was measured by *self-rated physical health.* Those reporting it as fair or poor were compared with those reporting it as good or excellent.

Physical functioning included disability in ADL, IADL, and physical performance. *ADL disability* was defined as reporting any trouble or needing help with walking across a small room, bathing, grooming, eating, dressing, transferring from bed to chair, or using the toilet. *IADL disability* was defined as reporting any trouble with cooking, heavy housework, shopping, using the telephone, or managing money. In order to preclude the IADL results being driven by the inclusion of the hearing-related telephone item, a model was also fit excluding that item from the IADL list. *Physical performance disability* was defined as having a lot of difficulty or needing help with pulling or pushing large objects, writing or handling small objects, standing up after sitting in a chair, getting up from stooping or kneeling, reaching or extending arms above the shoulder, lifting or carrying weights over 10 pounds, and stooping, crouching or kneeling. The more severe category of a lot of difficulty was used for the physical performance items because many functional middle-aged adults report a little or some difficulty with one or more of these items (Strawbridge, Cohen, Shema, & Kaplan, 1996).

Mental health and morale included five variables. *Depression* was measured using the 12 items and scoring algorithm from the DSM-III-R major depressive episodes scale (American Psychiatric Association, 1987). Persons scored as depressed were compared with those not depressed. *Self-rated mental health* was measured with a question asking participants to evaluate their own mental health and was scored in the same way as self-rated physical health. *Little enjoyment of free time* compared those people who said they got only some or not very much enjoyment out of their free time with those who said they got a lot. *Not pleased with accomplishments* compared persons who said they were pleased with their accomplishments only sometimes or never with those who were often pleased. *Difficulty paying attention* compared participants who said they had difficulty sometimes or often with those who said they never had difficulty.

Social functioning included three variables. *Not feeling close to others* and *feeling left out even in a group* involved simple true/false responses. For each, those who said the statement was true were compared with those who said it was false. The third item (*feeling lonely or remote*) compared persons answering sometimes or often with those answering never.

Baseline Chronic Conditions and Other Adjustment Variables.—Chronic conditions from the 1994 survey included presence in the last 12 months of heart disease, high blood pressure, stroke, transient ischemic attack, diabetes, cancer, circulatory problems, bronchitis, and emphysema. Scoring was the number of conditions reported. Age was measured in years. Education was coded as 12 years or more versus less.

Statistical analysis

Hearing impairment prevalence rates were calculated by 10-year age periods for each gender; the hearing impairment scale was divided into the three categories of no hearing impairment, a little hearing impairment, and moderate or more hearing impairment.

Separate logistic regression models were run for each of the functional outcomes rather than combining sets of the items into scales because we felt there were important differences even between similar-appearing items. For example, "not pleased with accomplishments" may entail looking back in time more than "difficulty paying attention." In a similar vein, "feeling left out even in a group" may involve more interaction with others than does "feeling lonely or remote." Results are also difficult to interpret when scales are composed of only a small number of items because the results may be driven by the impact of a strong association with only one item. Each 1995 outcome was regressed on age, gender, education, chronic conditions, and hearing impairment with the two levels of 1994 hearing impairment coded as indicator variables; the reference category was no hearing impairment. Further, the 1994 measure for the same 1995 outcome under study was included in each model to remove any cross-sectional association at baseline between hearing impairment and the outcome under investigation.

All statistical analyses were performed with the use of SAS software, version 6.12 (SAS Institute, 1996).

Results

The 2,461 participants ranged in age from 50 to 102; their mean age was 65. Women constituted 57% of the sample, men 43%. Ethnic minorities (Blacks, Asian Americans, Hispanics, and American Indians) constituted 17% of the sample, with Whites representing 83%.

Prevalence rates of the two levels of hearing impairment by 10-year age categories are shown in Table 1 for men and women separately. Prevalence rates for moderate or more hearing impairment are higher for men than for women and increase with age for both genders. When one combines prevalance rates for a little and moderate or more hearing impairment and looks at age, a majority of participants evidenced at least a little hearing impairment by their 60s (for men) or their 70s (for women).

Results of the seven logistic regression models examining the impact of 1994 hearing impairment on 1995 physical health, functioning, and mental health are shown in Table 2. For each outcome, adjusted odds ratios compare the occurrence of outcomes for participants at each level of hearing impairment with those reporting no impairment. For example, the odds ratio of 2.05 for depression indicates that individuals reporting moderate or more hearing impairment in 1995 were twice as likely to be depressed as persons reporting no hearing impairment after adjustment for the indicated variables, including depression in 1994. Similar results were obtained for the association be-

Table 1. Prevalence of Hearing Impairment in 1994 by Age and Gender for 2,461 Alameda County Study Participants Aged 50 to 102 Years

Group	Level of Hearing Impairment		
	None	A little	Moderate or more
Women			
Age Group			
50–59 years	334 (65.1%)	146 (28.5%)	33 (6.4%)
60–69 years	253 (62.8%)	110 (27.3%)	40 9.9%
70–79 years	170 (50.8%)	113 (33.7%)	52 (15.5%)
80 years and older	55 (38.5%)	44 (30.8%)	44 (30.8%)
All women	812 (58.2%)	413 (29.6%)	169 (12.1%)
Men			
Age Group			
50–59 years	211 (54.8%)	118 (30.7%)	56 (14.6%)
60–69 years	139 (44.4%)	107 (34.2%)	67 (21.4%)
70–79 years	82 (29.6%)	103 (37.2%)	92 (33.2%)
80 years and older	25 (27.2%)	30 (32.6%)	37 (40.2%)
All men	457 (42.8%)	358 (33.6%)	252 (23.6%)

tween moderate or more hearing impairment and self-reported mental health. Having moderate or more hearing impairment was also associated with ADL, IADL, and physical performance disabilities. Results for IADL disability were similar when the hearing-related telephone item was included and when it was not. For fair or poor self-rated physical health, the resulting odds ratio comparing moderate or more hearing impairment with impairment was 1.39 with a 95% confidence interval of 0.97 to 2.00.

Examining the results for a little hearing impairment, the magnitude of the resulting odds ratio for every outcome was consistent with a dose-response pattern by being greater than 1.0 but less than that reported for moderate or more hearing impairment.

Table 3 presents the results of the six regression models examining the impact of 1994 hearing impairment on 1995 morale and social functioning. The strongest impact of moderate or more hearing loss appears to be on the outcomes that involve interacting (difficulty paying attention, not feeling close to others, and feeling left out even in a group), which is consistent with the likely effects of hearing impairment. The weakest impact involved little enjoyment of free time, which could involve solitary as well as interactive pursuits. The variable assessing being pleased with accomplishments involves looking back at one's life and so may be less affected by present hearing impairment. As in the results presented in Table 2, the magnitude of the resulting odds ratios for every outcome in Table 3 associated with a little hearing impairment was greater than 1.0 but less than that reported for moderate or more hearing impairment.

Discussion

The high prevalence of hearing impairment presented in these data is consistent with results based upon single-item reports of trouble hearing, which is how the condition is often measured in surveys (Benson & Marano, 1994; Jackson, 1968; Wallhagen et al., 1997). The advantage of asking the three self-report assessments of difficulty hearing in different settings is that more subtle forms of hearing impairment can be identified that relate directly to common but important situations in everyday life. Hearing impairment was strongly associated with age, and men reported higher levels of hearing impairment than did women; these results are consistent with findings from the Beaver Dam study, which utilized audiometric testing, although our age and gender-specific prevalence outcomes are all somewhat lower than those reported for

Table 2. Adjusted Odds Ratios and 95% Confidence Intervals (CIs) for Impact of Two Levels of 1994 Hearing Impairment on 1995 Self-Reported Health, Physical Functioning, and Mental Health for 2,461 Alameda County Study Participants Aged 50 to 102

1995 Outcome	Level of Hearing Impairment[a]	
	A little	Moderate or more
Self-Rated Health		
Fair or poor self-rated physical health	1.20(0.87–1.65)	1.39*(0.97–2.00)
Physical Functioning		
ADL disability	1.71***(1.22–2.39)	1.85***(1.26–2.71)
IADL disability	1.24*(0.97–1.58)	1.37**(1.01–1.86)
IADL disability omitting telephone	1.22(0.95–1.56)	1.32*(0.98–1.80)
Physical performance disability	1.19 (0.87–1.63)	1.98***(1.38–2.84)
Mental Health		
Depression	1.22(0.85–1.77)	2.05***(1.37–3.06)
Fair or poor self-rated mental health	1.37*(0.97–1.93)	1.90***(1.30–2.78)

[a]Data are odds ratio (95% CI). Odds ratios and confidence intervals are based upon logistic regression models with adjustments for age, gender, chronic conditions, education, and prior measure of the indicated 1995 outcome in 1994. For each outcome, the odds ratios compare occurrence of the outcome for participants at two levels of hearing impairment compared with those reporting no impairment.
*$p < .10$; **$p < .05$; ***$p < .01$.

Table 3. Adjusted Odds Ratios and 95% Confidence Intervals (CIs) for Impact of Two Levels of 1994 Hearing Impairment on 1995 Morale and Social Functioning for 2,461 Alameda County Study Participants Aged 50 to 102

1995 Outcome	Level of Hearing Impairment[a]	
	A little	Moderate or more
Morale		
Difficulty paying attention	1.56***(1.27–1.91)	1.99***(1.52–2.60)
Little enjoyment of free time	1.10(0.88–1.37)	1.26*(0.96–1.66)
Not pleased with accomplishments	1.05(0.86–1.29)	1.34**(1.03–1.74)
Social Functioning		
Feeling lonely or remote	1.30**(1.05–1.60)	1.44***(1.10–1.88)
Not feeling close to others	1.23(0.95–1.59)	1.82*** (1.33–2.50)
Feeling left out even in a group	1.65***(1.24–2.19)	1.96***(1.39–2.75)

[a]Data are odds ratio (95% CI). Odds ratios and confidence intervals are based upon logistic regression models with adjustments for age, gender, chronic conditions, education, and prior measure of the indicated 1995 outcome in 1994. For each outcome, the odds ratios compare occurrence of the outcome for participants at two levels of hearing impairment compared with those reporting no impairment.
*$p < .10$; **$p < .05$; ***$p < .01$.

Beaver Dam residents even when combining our two levels of reported hearing impairment (Cruickshanks et al., 1998). It is possible that the Beaver Dam standard of assessing loss at 25 dB or more is more sensitive than the level at which some persons would begin to experience problems in everyday life. No doubt this level varies by lifestyle—musicians, psychiatrists, and birdwatchers probably notice losses sooner than factory workers, statisticians, or golfers.

These data document increased problems in physical, mental, and social health over one year for older persons reporting hearing impairment at baseline compared with those reporting no impairment. There appears to be a dose-response pattern: for each negative outcome the adjusted odds ratios for a little impairment are above 1.0, whereas the adjusted odds ratios for each of the comparisons involving moderate or more hearing impairment are higher than for the comparisons involving a little hearing impairment. Because chronic conditions are included as controls in the statistical models, these negative outcomes are unlikely to be caused by the conditions we included. Further, adjusting for the baseline measure of the year-later outcome lends additional support to the argument that hearing impairment is independently associated with subsequent decline in a wide variety of functional outcomes. Given the relatively short follow-up period of only one year, the magnitude of the observed impacts appears strong and lends support to the value of self-assessed hearing impairment.

Our findings indicate that moderate or more hearing impairment is longitudinally associated with three types of commonly measured disabilities for older persons: IADL, ADL, and physical performance. All three types of disability have serious implications for future health outcomes and the need for supportive services. Our results for IADL disability are consistent with those reported by Furner and colleagues (1995) although we adjusted for chronic conditions while they adjusted for self-rated health. For ADL disability we found an association even with adjustments for chronic conditions, while Rudberg and colleagues (1993) reported that their observed association for hearing impairment and ADL disability disappeared when adjustments were added for chronic conditions. Both of these other studies included tinnitus in their measure of hearing impairment; we did not.

The relationship we observed between moderate or more hearing impairment and self-rated health was not as strong as for the disability outcomes; however, self-rated health is a strong predictor of subsequent mortality independent of other specific conditions (Bjorner et al., 1996; Strawbridge & Wallhagen, 1999). The outcomes of mental health and social functioning included in our analyses also have health implications. Depression is a serious problem in old age that is also associated with negative sequellae (Wells et al., 1989). Social connections are important for good health at any age (Berkman & Syme, 1979; House, Landis, & Umberson, 1988). It is also difficult to conduct normal business, such as shopping, interacting with friends and family, or discussing symptoms with physicians, when one has a hearing impairment.

In order to help individuals remain socially engaged and to experience positive health, we need to identify those factors that facilitate or hinder these processes. The results of this study suggest that hearing impairment is one such factor and that more attention should be paid to its prevention, early identification, and treatment. This suggests that more attention should be paid to the types of hearing impairment and factors that may cause hearing impairment as well as strategies that maximize hearing capacity once impairment occurs.

Hearing impairment or loss can be classified as conductive, sensorineural, or a central auditory processing disorder (Heath & Waters, 1997; Reuben, Yoshikawa, & Besdine, 1996). Although mutually exclusive, identification of the type of problem is important to the development of preventive or therapeutic approaches. A conductive disorder implies an impairment in the transmission of sound to the inner ear and includes both cerumen (wax) impaction and otosclerosis. Because cerumen impaction is a common cause of conductive loss that is frequently overlooked but relatively

easy to correct, it should be included in any evaluation. Sensorineural problems involve the inner ear and include age related presbycusis as well as damage caused by noise and certain medications, such as antibiotics, loop diuretics, and some chemotherapeutic agents. Endocrine disturbances can also result in sensorineural losses. Finally, central auditory processing disorders are associated with problems at the level of the brain and result in speech discrimination problems.

Clinicians can play an important role in reducing the prevalence of hearing impairment caused by environmental or health-related factors. Persons need to be taught that repeated exposure to loud noise can damage hearing, which will not only inhibit social interaction but also prevent them from hearing warning sounds such as smoke alarms and oncoming traffic. Control of risk factors for cardiovascular problems may minimize vascular changes that contribute to diminished aural function. In addition, although hearing impairment is generally permanent once damage is done to the inner ear itself (Rees, Duckert, & Milczuk, 1994), multiple modalities are currently available that can facilitate continued function and maximize hearing potential.

Approaches to the treatment of hearing impairment have expanded dramatically over the past several decades. Hearing aids are becoming increasingly sophisticated with use of technology that can be programmed to individual deficits. However, these can only partially compensate for most losses and require that the user be motivated and have the support of family as well as an audiologist. Cochlear implants are increasingly common, although generally offered only to individuals with severe to profound hearing loss in both ears who meet specific criteria (Syms & House, 1997). A conductive loss such as otosclerosis is often also amendable to surgical correction or medical management (Fetterman & Luxford, 1997).

Multiple assistive devices are now available to facilitate hearing in different environments. These include special microphones, telephones or telephone attachments, telecommunicating devices (TDD), and special warning devices (Loovis, Schall, & Teter, 1997). Finally, in addition to specific modalities that enhance sound transmission or reception, behavioral treatment may also be important in maximizing hearing potential (Andersson, Melin, Scott, & Lindberg, 1995). Unfortunately, if the problem is central, amelioration of the problems experienced are more difficult.

For future research on measures of hearing impairment, it would be helpful to compare results of self-reported hearing impairment with clinical assessments on the same subjects to understand how much overlap there is and to better understand the tradeoffs when only one type of assessment can be made. This is particularly important because evidence for the rapid increase in prevalence of hearing impairment over the past three decades is based upon self-report.

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