Published in final edited form as:
J Am Geriatr Soc. 2014 August ; 62(8): 1427–1433. doi:10.1111/jgs.12938.

Association of Hearing Impairment with Lower Levels of Physical Activity in Older Adults

Fiona E. Gispen, MS[1,2], **David S. Chen, BS**[1,2], **Dane J. Genther, MD**[2,3], and **Frank R. Lin, MD, PhD**[2,3,4]

[1]Johns Hopkins University School of Medicine, Baltimore, Maryland [2]Center on Aging and Health, Johns Hopkins Medical Institutions, Baltimore, Maryland [3]Department of Otolaryngology-Head & Neck Surgery, Johns Hopkins University School of Medicine, Baltimore, Maryland [4]Departments of Geriatric Medicine, Mental Health, and Epidemiology, Johns Hopkins University, Baltimore, Maryland

Abstract

Address correspondence, reprint requests, and proofs to: Fiona E. Gispen, Johns Hopkins Center on Aging & Health, 2024 Monument St, Suite 2-700, Baltimore, MD 21287, Telephone: (662) 801-6363, fgispen1@jhmi.edu. Alternate corresponding author: Fiona E. Gispen, 404 S. Ann St., Baltimore, MD 21231, Telephone: (662) 801-6363, fgispen1@jhmi.edu.

Conflict of Interest Disclosures:

Elements of Financial/Personal Conflicts	Gispen		Chen		Genther		Lin	
	Yes	No	Yes	No	Yes	No	Yes	No
Employment or Affiliation		X		X		X		X
Grants/Funds		X		X		X	X	
Honoraria		X		X		X	X	
Speaker Forum		X		X		X		X
Consultant		X		X		X	X	
Stocks		X		X		X		X
Royalties		X		X		X		X
Expert Testimony		X		X		X		X
Board Member		X		X		X	X	
Patents		X		X		X		X
Personal Relationship		X		X		X		X

For all "Yes" responses, provide a brief explanation here:
He also reports being a consultant to Cochlear Americas, on the scientific advisory board for Autifony and Pfizer and has been a speaker for Med El and Amplifon.

Author Contributions: Gispen: conception and design, analysis and interpretation of data, preparation of manuscript; Chen, Genther: analysis and interpretation of data; Lin: conception and design, analysis and interpretation of data, preparation of manuscript.

Sponsor's Role: The sponsors had no role in the design, methods, data analysis, or preparation of this article.

OBJECTIVES—Identifying modifiable risk factors for decreased physical activity in older adults is important given the impact of physical activity on health. Whether hearing impairment, highly prevalent in older adults, is associated with activity levels is unclear.

DESIGN—Cross-sectional analysis

SETTING—2005–2006 National Health and Nutritional Examination Survey

PARTICIPANTS—706 adults aged 70 years or greater who completed audiometric testing and whose physical activity was assessed subjectively with questionnaires and objectively with body-worn accelerometers

MEASUREMENTS—Hearing impairment was defined by the speech-frequency (0.5 – 4 kilohertz (kHz) pure tone average in the better-hearing ear (normal <25 decibel (dB), mild 25 to <40dB, moderate or greater ≥40dB). Main outcome measures were self-reported leisure time physical activity and accelerometer-measured physical activity. Both were quantified using minutes of moderate-intensity physical activity and categorized into three levels: inactive, insufficiently active, and sufficiently active. Ordinal logistic regression analyses were conducted and adjusted for demographic and cardiovascular risk factors.

RESULTS—Compared to those with normal hearing, individuals with moderate or greater hearing impairment had a greater odds of being in a lower category of physical activity as measured by self-report (OR=1.59, 95%CI: 1.11, 2.28) and accelerometry (OR=1.70, 95%CI: 0.99, 2.91). Mild hearing impairment was not associated with level of physical activity.

CONCLUSION—Moderate or greater hearing impairment in older adults is associated with decreased levels of physical activity independent of demographic and cardiovascular risk factors. Future research is needed to investigate the basis of this association and whether hearing rehabilitative interventions could affect physical activity in older adults.

Keywords

hearing impairment; physical activity; older adults; epidemiology

INTRODUCTION

The prevalence of hearing impairment doubles with every age decade such that nearly two-thirds of United States adults 70 years and older have a clinically-significant hearing impairment[1]. Recent studies have demonstrated that hearing impairment is independently associated with poorer physical functioning[2–4] and slower gait speed[5]. These associations may be mediated through the effects of hearing loss on cognitive load,[6, 7] social isolation[8, 9], and/or reduced awareness of the auditory environment. Alternatively, concomitant dysfunction of the cochlear and vestibular sense organs or a common pathologic cause (e.g., microvascular disease) could also underlie these observed associations.

The potential contribution of impaired hearing to slower gait speed and poorer physical functioning suggests that physical activity levels may also be reduced in those individuals with hearing loss[10]. With the aging of the population, investigating factors associated with physical activity levels in older adults is important given the importance of physical activity to health and functional outcomes in older adults[11, 12]. Importantly, mechanistic pathways that could potentially underlie an association between hearing and poorer physical activity (e.g., cognitive load, poorer social engagement, reduced awareness of the auditory environment) may be amenable to hearing rehabilitative treatments which remain grossly underutilized.

In this study, we investigated whether hearing impairment was associated with level of physical activity in a nationally representative sample of older adults. Hearing was objectively measured with audiometry, and physical activity levels were measured with self-report and accelerometer data. Amounts of physical activity were quantified using minutes of moderate-intensity physical activity and categorized based on the U.S. Department of Health and Human Services' *Physical Activity Guidelines for Americans*[13].

METHODS

Study Participants

The study included adults aged 70 and older in the 2005–2006 National Health and Nutrition Examination Survey (NHANES) who underwent audiometric assessment of hearing and had valid questionnaire and/or accelerometry data regarding their physical activity levels. The NHANES is an ongoing series of studies conducted by the National Center for Health Statistics to assess the health, functional, and nutritional status of representative cross-sectional samples of the civilian, non-institutionalized U.S. population[14]. Each 2-year cross-sectional study cycle uses a complex sampling design to survey a sample of the population, with selective oversampling of low-income individuals, racial minorities, and older adults. Sampling weights included in the dataset allow for analyses that account for the complex survey design and yield results that are generalizable to the U.S. population. We analyzed data from the 2005–2006 survey cycle, the only cycle that has included measurements of both audiometry and accelerometry in adults aged 70 and older.

Audiometry

Pure tone audiometry was performed by a trained examiner according to established NHANES protocols[15]. Air conduction hearing thresholds for each ear were obtained in a sound-isolating room in a mobile examination center. Testing was conducted according to a modified Hughson-Westlake procedure using the automated testing mode of the audiometer (Interacoustics Model AD226) and/or manually, as per testing protocol. Quality assurance and control were established through daily calibration of equipment and monitoring of ambient noise levels. All thresholds were measured in decibels of hearing loss (dB HL), and as an additional quality measure, thresholds were measured twice at 1 kilohertz (kHz) in both ears and audiometry repeated if a difference of more than 10 dB existed between measurements. Hearing was defined by a speech-frequency pure tone average (PTA) of thresholds at 0.5, 1, 2, and 4 kHz in the better hearing ear, as per the definition of hearing used by the World Health Organization[16]. Thresholds of hearing impairment severity defined by PTA were based on American Speech-Language Hearing Association guidelines[17]: normal hearing <25 dB, mild impairment ≥25 dB and <40 dB, moderate or greater impairment ≥40 dB.

Leisure-time Physical Activity

General information regarding participants' physical activity during the past thirty days was obtained by study personnel during the household interview portion of data collection through retrospective questions. If participants recalled that they had performed vigorous or moderate leisure-time activities in bouts of at least ten minutes during the past 30 days, they were further questioned on the level of exertion, frequency, and duration of each activity. Activities for which the reported duration was less than ten minutes were excluded.

Based on reports that health benefits from physical activity may be dependent on total energy expenditure rather than specific type of activity[18], we used minutes of self-reported moderate and vigorous activity as an overall measure of physical activity,. Both the US Department of Health and Human Services[13] and NHANES[19] recommend that one minute of vigorous activity be counted as two minutes of moderate activity, so we converted each minute of vigorous activity to two minutes of moderate-intensity activity and summed across activities to derive our final variable: self-reported leisure-time physical activity, measured in minutes of moderate-intensity physical activity (MPA).

This variable was categorized into three levels based on the *2008 Physical Activity Guidelines for Americans*[13]: inactive (0 minutes of MPA per week), insufficiently active (<150 minutes of MPA per week), and sufficiently active (≥ 150 minutes of MPA per week).

Accelerometer-measured Physical Activity

Physical activity was measured by Actigraph AM-7164 accelerometers programmed to record acceleration magnitude (intensity) data in 1-minute intervals. Participants were asked to wear the accelerometers for seven days following their examinations and to take them off only for sleep and water-based activities. Participants who used wheelchairs or had other limitations that prevented them from walking or wearing the device were not given accelerometers (n=112). After seven days, participants returned the accelerometers to NHANES study personnel, who determined whether the device was still correctly calibrated and downloaded the data. Other specific details of the accelerometer protocol have been described elsewhere[20].

Participants with fewer than four days of reliable accelerometer wear were excluded from analysis (n=72). Mean minutes of moderate and vigorous activity completed daily by participants were calculated using previously established thresholds of ≥2020 intensity counts per minute for moderate activity and ≥5999 per minute for vigorous activity, as per previous research[18, 21, 22]. SAS code developed and provided by the National Cancer Institute (http://riskfactor.cancer.gov/tools/nhanes_pam/) was modified and used for the analysis described above.

Accelerometer-measured physical activity was then quantified similarly to self-report data to derive a variable indicating accelerometer-measured physical activity per week. Weekly minutes of moderate-intensity physical activity (MPA) per participant were calculated by converting daily to weekly minutes and each minute of vigorous-intensity activity to two minutes of moderate-intensity activity. Similar to self-reported physical activity, accelerometer-measured physical activity was categorized into three levels based on the

2008 Physical Activity Guidelines for Americans[13]: inactive (0 minutes of MPA per week), insufficiently active (<150 minutes of MPA per week), and sufficiently active (≥ 150 minutes of MPA per week).

Other Study Variables

Other variables that could confound the association between hearing impairment and physical activity were included in analysis. Demographic and health data of participants were obtained from interviews and physical examination. For confidentiality purposes, NHANES truncates the age variable at 85 years, so all participants older than 85 are reported as "≥85". To account for this in our primary analysis, we defined age as a categorical variable with the following categories: 70–74, 75–79, 80–84, ≥85 years. We also performed a sensitivity analysis restricting our cohort to those 70–84 years to allow for the adjustment of age as a continuous covariate. Self-reported gender was included as a binary variable, and self-reported race/ethnicity data were grouped as: Mexican American, other Hispanic, non-Hispanic white, non-Hispanic black, or other. Education was defined as: <9th grade, 9–11th grade, high school graduate/passed General Educational Development test (GED), some college/associate degree, or college graduate, and household income was collapsed into a five-level variable: <$20k, ≥$20k and <$50k, ≥$50k and <$75k, ≥$75k, or refused/don't know. In order to reduce the possibility of shared pathologic factors confounding the relationship between hearing loss and physical activity, we included variables known to be associated with both hearing impairment and physical functioning such as hypertension, cardiovascular disease, stroke, smoking status (current/former/never), and body mass index (BMI). Hypertension was defined as having been diagnosed by a physician on at least two visits or taking antihypertensive medication. Cardiovascular disease was defined as any self-reported history of coronary artery disease, congestive heart failure, angina, or myocardial infarction. BMI as measured by trained health technicians was collapsed into a four-level variable: underweight ($<18.5 kg/m^2$), normal weight (≥18.5 and <25), overweight (≥25 and <30), and obese (≥30).

Statistical Methodology

We accounted for the complex sampling design in all analyses by using sample weights according to the National Center for Health Statistics guidelines[23]. Table 2 is unweighted, as its purpose is to give a description of the study cohort rather than nationally generalizable estimates. Baseline characteristics of study participants with self-reported physical activity data versus those with accelerometry data were compared using Pearson's chi-squared test. We then used multivariate ordinal logistic regression to examine the relationship between level of hearing impairment and level of self-reported physical activity, and between level of hearing impairment and level of accelerometer-measured physical activity. Ordinal logistic regression assumes that the coefficients describing the relationship between the lowest and all higher categories of the outcome variable are the same as those describing the relationship between the next lowest category and all higher categories. This assumption is called the proportional odds assumption, or parallel regression assumption, and it was met in both models. We adjusted for demographic factors, cardiovascular factors, and body mass index in all analyses by including them as covariates.

Sensitivity analyses included treating hearing as a continuous variable, restricting the cohort to individuals <85 to allow for the adjustment of age as a continuous covariate, and including hearing aid use as a covariate. To assess effect modification by gender, age and hearing aid use, we also conducted analyses with hearing loss-gender, hearing loss-age, and hearing loss-hearing aid use interaction terms. In all models, individuals with missing data accounted for <10% of the study population. All significance tests were conducted using two-sided tests with a type I error of 0.05.

Summary measures of accelerometer-measured physical activity were generated in SAS 9.4 (SAS Institute, Cary, NC) and subsequently analyzed using STATA 13 (Stata Corp, College Station, Texas). All other analyses were performed using STATA 13.

RESULTS

A total of 706 participants aged 70 and older were included in our analysis. 217 (31.1%) of these participants had normal hearing (Table 2). Of those with hearing loss (n=489), 257 (52.6%) had mild HL and 232 (47.4%) had moderate or worse HL. Participants with hearing loss were more likely to be male, older, white, non-hypertensive and less educated (Table 2). There were no differences in income, cardiovascular disease, smoking status, stroke, or BMI among the groups. Accelerometry data were available on a subset of these individuals (n=522) after excluding 112 individuals who used wheelchairs or were unable to wear an accelerometer and 72 individuals who did not have 4 days of reliable accelerometer wear. There were no significant differences in hearing ability or in covariates between the subgroup of individuals with accelerometry data and the larger group (data not shown). Activity levels measured by self-report and accelerometry were substantially different with self-report levels consistently higher than levels measured by accelerometry (Table 2).

We investigated whether hearing was associated with lower levels of self-reported and accelerometer-measured physical activity (categorized as inactive, insufficiently active, or sufficiently active). In stepwise ordinal logistic regression models adjusted for demographic factors, cardiovascular risk factors, and BMI, we observed that individuals with moderate or greater hearing impairment had a greater odds of less self-reported physical activity compared to individuals with normal hearing (OR = 1.59 per lower category of physical activity, 95% CI: 1.11, 2.28). There were no significant differences in activity levels between individuals with mild hearing impairment and those with normal hearing (Table 3). Similar results were observed for accelerometer-measured activity. Compared to normal hearing individuals, individuals with a moderate or greater hearing impairment had a greater odds of less accelerometer-measured activity (OR=1.70 per lower category of physical activity, 95% CI: 0.99, 2.91).

We conducted sensitivity analyses to investigate the robustness of these results. In analyses treating hearing as a continuous variable and adjusted for demographic factors, cardiovascular factors, and BMI, we observed that a 25dB shift in hearing (equivalent to going from normal hearing to a mild hearing impairment) was associated with a greater odds of having less self-reported physical activity (OR=1.55 of next lower physical activity category per 25 dB, 95% CI: 1.23, 1.98) and accelerometer-measured activity (OR=1.45 of next lower physical activity category per 25 dB, 95% CI: 0.95, 2.22). Restricting our analytic cohort to those individuals <85 years (to allow for adjustment of age as a continuous covariate) also did not substantively change our results compared to Table 3 (data not shown).

Finally, we also investigated whether factors such as gender, age, or self-reported hearing aid use moderated the association between hearing and physical activity. HL-gender and HL-age interaction terms were not statistically significant, indicating that neither gender nor age significantly moderated the relationships between HL and self-reported or accelerometer-measured physical activity (data not shown). Including self-reported hearing aid use as a covariate in our fully adjusted models also did not substantively change our results. Including an HL-hearing aid use interaction term in our fully adjusted model also did not significantly moderate the relationship between HL and physical activity: among those with moderate or worse hearing loss, self-reported use of hearing aids was not significantly associated with a lower odds of less self-reported (OR=1.14, 95% CI: 0.66, 1.97) or accelerometer-measured (OR=0.74, 95% CI: 0.28, 1.97) physical activity.

DISCUSSION

Our results demonstrate that moderate or greater hearing impairment in older adults is independently associated with reduced physical activity as measured both subjectively by self-report and objectively with accelerometry. Compared to those with normal hearing, individuals with moderate or greater hearing impairment had a 59% increased odds of having lower levels of self-reported physical activity and a 70% increased odds of having lower levels of accelerometer-measured physical activity. These observed results were robust to analyses treating hearing as both a continuous and categorical variable and after adjustment for multiple potential confounders. Importantly, the categories of physical activity used in these analyses are clinically meaningful. They are derived from the 2008 Physical Activity Guidelines for Americans[13] and are based on evidence that older adults will accrue health benefits from physical activity with energy expenditures of ≥150 minutes of MPA per week (sufficient category), some health benefits with expenditures of <150 minutes of MPA per week (insufficient category), and no health benefits when sedentary (inactive category)[24].

Our results contribute to the current literature. Previous studies have demonstrated associations between hearing and poorer physical functioning[2–4], decreased cardiorespiratory fitness[25], increased sedentary behavior[10], and decreased gait speed[5] in older adults. Recently published work also demonstrates an association between hearing and less physical activity in younger adults[26]. In contrast, other reports have indicated that there is no significant association between hearing and physical functioning and activity[27, 28]. Heterogeneity in study results may be explained by subjective measurement[26, 28] or varying definitions[27] of hearing. Strengths of our current study include results generalizable to the national population, standardized audiometric testing protocol by a definition of hearing adjudicated by the World Health Organization[16], and both subjective and objective measurements of physical activity.

An important finding in our study is that our results were consistent with both subjective and objectively measured physical activity. Participants tend to routinely overestimate the time they spend physically active compared to objective measurements[18] (perhaps due to participants' inaccuracy in retrospectively recalling bouts of activity and/or the perceived social desirability of exercise[18]), and this observation was consistent in our cohort where the levels of physical activity differed markedly according to the method of measurement (Table 2). Accelerometer-defined physical activity has generally been more strongly related to self-reported indicators of health[29] and measured cardiovascular risk factors[30] than self-report data, but objectively-measured accelerometry data are limited in not reflecting activities such as swimming, biking, upper body movement, or load carrying[21]. Though self-report measurements have previously resulted in underestimation of the strength of relationships between physical activity and risk factors as compared to accelerometer-based data[31], they remain strongly associated with many health outcomes[29, 30, 32]. Importantly, both self-report and accelerometry data should be used when possible[29, 30, 32].

Several mechanisms could explain the observed association between hearing and physical activity. Individuals with moderate or greater hearing impairment may perform less physical activity due to a greater likelihood of social isolation[9] (and thus a lesser likelihood of exercise in a social setting) than normal hearing individuals. Studies have also demonstrated that impaired hearing can contribute to cognitive load[7] and therefore affect attentional and cognitive resources[33, 34] that are important for maintaining posture and balance[35, 36]. Finally, impaired hearing could restrict an individual's ability to effectively monitor the auditory environment (e.g. hearing footfalls and other auditory cues that provide orientation to the physical environment) and thereby affect an individual's likelihood of performing physical activities.

Alternatively, common pathologic processes may underlie impairments in both hearing and physical activity. For example, microvascular disease could plausibly contribute to both hearing loss[37] and poorer health and physical activity. However, our results were robust to adjustment for multiple factors associated with cardiovascular disease (e.g., congestive heart failure, coronary artery disease, angina, myocardial infarction, hypertension, smoking status, BMI). Alternatively, common neural degeneration affecting both the cochlear and vestibular sense organs (which are important for balance) could also potentially explain the relationship between hearing loss and physical activity.

In the current study, self-reported hearing aid use was not associated with physical activity level. However, data on other key variables (hours hearing aid use per day, years used, etc) that may affect rehabilitative success were not available. Whether hearing rehabilitation could potentially affect levels of physical activity will therefore require further investigation.

A key limitation of our present study is that we cannot determine the mechanistic basis of the relationship between physical activity and hearing loss. Any current hypothesis is speculative and will require further investigation. Importantly, though, we note that these pathways (social isolation, poorer cognitive function, common pathology) are not mutually exclusive, and multiple pathways could likely synergistically contribute to poorer physical activity in individuals with hearing loss. Our study is also based on cross-sectional data, which may be subject to bias from inter-individual variability or cohort effects. Prospective studies will be required to determine whether hearing is associated longitudinally with reduced physical activity. It is also important to note the small number of participants who were sufficiently active according to accelerometer data (n=24), which may have affected estimates of effect size. We assessed this by using two separate strategies to increase the number of counts per cell: first, we collapsed mild and moderate or worse hearing impairment into one hearing impairment category, and second, we collapsed insufficient and sufficient physical activity in one physical activity category. In both iterations, the effect of hearing impairment on physical activity remained significant and effect size increased slightly.

In summary, our study strongly suggests that individuals with hearing impairment perform less physical activity than individuals with normal hearing. If our results are confirmed in other studies, these findings may be of clinical significance given that hearing impairment is highly prevalent but undertreated in older adults. Future research investigating the mechanistic basis of the observed associations and whether hearing rehabilitative therapies could potentially help mitigate reduced physical activity in those individuals with hearing impairment is critically important.

Acknowledgments

Funding

The NHANES is sponsored by the National Center for Health Statistics (NCHS), Centers for Disease Control and Prevention. Additional funding for the NHANES hearing data were generously provided by the National Institute on Deafness and Other Communication Disorders (including an interagency agreement with the National Institute for Occupational Safety and Health for training health technicians to perform audiometry), National Institute on Aging, and National Center for Health Statistics. Funding for the accelerometry data was provided by the National Cancer Institute. Dr. Lin is supported by NIH K23DC011279, the Eleanor Schwartz Charitable Foundation, and through a clinician scientist award from the Triological Society and American College of Surgeons. Ms. Gispen's work was supported by the Johns Hopkins University School of Medicine Dean's Fund for Summer Research.

REFERENCES

1. Lin FR, Niparko JK, Ferrucci L. Hearing loss prevalence in the United States. Arch Intern Med. 2011; 171:1851–1852. [PubMed: 22083573]
2. Reuben DB, Mui S, Damesyn M, Moore AA, Greendale GA. The prognostic value of sensory impairment in older persons. Journal of the American Geriatrics Society. 1999; 47:930–935. [PubMed: 10443852]
3. Strawbridge WJ, Wallhagen MI, Shema SJ, Kaplan GA. Negative consequences of hearing impairment in old age: a longitudinal analysis. The Gerontologist. 2000; 40:320–326. [PubMed: 10853526]
4. Viljanen A, Kaprio J, Pyykko I, Sorri M, Koskenvuo M, Rantanen T. Hearing acuity as a predictor of walking difficulties in older women. J Am Geriatr Soc. 2009; 57:2282–2286. [PubMed: 19874410]
5. Li L, Simonsick EM, Ferrucci L, Lin FR. Hearing loss and gait speed among older adults in the United States. Gait Posture. 2012
6. Tun PA, McCoy S, Wingfield A. Aging, hearing acuity, and the attentional costs of effortful listening. Psychol Aging. 2009; 24:761–766. [PubMed: 19739934]
7. Wingfield A, Tun PA, McCoy SL. Hearing loss in older adulthood - What it is and how it interacts with cognitive performance. Current directions in psychological science. 2005; 14:144–148.

8. Barnes LL, Mendes de Leon CF, Wilson RS, Bienias JL, Evans DA. Social resources and cognitive decline in a population of older African Americans and whites. Neurology. 2004; 63:2322–2326. [PubMed: 15623694]
9. Mulrow CD, Aguilar C, Endicott JE, et al. Association between hearing impairment and the quality of life of elderly individuals. J Am Geriatr Soc. 1990; 38:45–50. [PubMed: 2295767]
10. Loprinzi PD. Association between accelerometer-assessed sedentary behavior and objectively-measured hearing sensitivity in older US adults. Preventive medicine. 2013; 57:143–145. [PubMed: 23707813]
11. Drewnowski A, Evans WJ. Nutrition, physical activity, and quality of life in older adults: summary. The journals of gerontology Series A, Biological sciences and medical sciences. 2001; 56(Spec No 2):89–94.
12. Samitz G, Egger M, Zwahlen M. Domains of physical activity and all-cause mortality: systematic review and dose-response meta-analysis of cohort studies. International journal of epidemiology. 2011; 40:1382–1400. [PubMed: 22039197]
13. US Department of Health and Human Services. Physical Activity Guidelines for Americans: Appendix 1. Translating Scientific Evidence About Total Amount and Intensity of Physical Activity Into Guidelines. http://www.health.gov/PAGuidelines/guidelines/appendix1.aspx.
14. Centers for Disease Control and Prevention; National Centers for Health Statistics. The National Health and Nutrition Examination Survey Questionnaire and Exam Protocol. http://www.cdc.gov/nchs/nhanes/nhanes2005–2006/nhanes05_06.htm
15. Centers for Disease Control. [Accessed 6/15/2013] Audiometry/Tympanometry Procedures Manual. http://www.cdc.gov/nchs/data/nhanes/au.pdf.
16. World Health Organization. World Health Organization Prevention of Blindness and Deafness (PBD) Program. Prevention of Deafness and Hearing Impaired Grades of Hearing Impairment. http://www.who.int/pbd/deafness/hearing_impairment_grades/en/index.html
17. Clark JG. Uses and abuses of hearing loss classification. ASHA. 1981; 23:493–500. [PubMed: 7052898]
18. Tucker JM, Welk GJ, Beyler NK. Physical activity in U.S.: adults compliance with the Physical Activity Guidelines for Americans. American journal of preventive medicine. 2011; 40:454–461. [PubMed: 21406280]
19. Centers for Disease Control and Prevention; National Centers for Health Statistics. The National Health and Nutrition Examination Survey. Physical Activity Individual Activities File Data Documentation, Codebook, and Frequencies 2005–2006. http://www.cdc.gov/nchs/nhanes/nhanes2005-2006/PAQIAF_D.htm.
20. Centers for Disease Control and Prevention; National Centers for Health Statistics. The National Health and Nutrition Examination Survey. Anthropometry and physical activity monitor procedures manual. http://www.cdc.gov/nchs/data/nhanes/nhanes_05_06/BM.pdf.
21. Troiano RP, Berrigan D, Dodd KW, Masse LC, Tilert T, McDowell M. Physical activity in the United States measured by accelerometer. Medicine and science in sports and exercise. 2008; 40:181–188. [PubMed: 18091006]
22. Metzger JS, Catellier DJ, Evenson KR, Treuth MS, Rosamond WD, Siega-Riz AM. Patterns of objectively measured physical activity in the United States. Medicine and science in sports and exercise. 2008; 40:630–638. [PubMed: 18317384]
23. Control CfD. NHANES Analytic and Reporting Guidelines. 2005. http://www.cdc.gov/nchs/data/nhanes/nhanes_03_04/nhanes_analytic_guidelines_dec_2005.pdf.
24. Nelson ME, Rejeski WJ, Blair SN, et al. Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association. Medicine and science in sports and exercise. 2007; 39:1435–1445. [PubMed: 17762378]
25. Loprinzi PD, Cardinal BJ, Gilham B. Association between cardiorespiratory fitness and hearing sensitivity. American journal of audiology. 2012; 21:33–40. [PubMed: 22271908]
26. Curhan SG, Eavey R, Wang M, Stampfer MJ, Curhan GC. Body Mass Index, Waist Circumference, Physical Activity, and Risk of Hearing Loss in Women. The American journal of medicine. 2013

27. Lin MY, Gutierrez PR, Stone KL, et al. Vision impairment and combined vision and hearing impairment predict cognitive and functional decline in older women. Journal of the American Geriatrics Society. 2004; 52:1996–2002. [PubMed: 15571533]
28. Rudberg MA, Furner SE, Dunn JE, Cassel CK. The relationship of visual and hearing impairments to disability: an analysis using the longitudinal study of aging. Journal of gerontology. 1993; 48:M261–M265. [PubMed: 8227996]
29. Harris TJ, Owen CG, Victor CR, Adams R, Ekelund U, Cook DG. A comparison of questionnaire, accelerometer, and pedometer: measures in older people. Medicine and science in sports and exercise. 2009; 41:1392–1402. [PubMed: 19516162]
30. Schmidt MD, Cleland VJ, Thomson RJ, Dwyer T, Venn AJ. A comparison of subjective and objective measures of physical activity and fitness in identifying associations with cardiometabolic risk factors. Annals of epidemiology. 2008; 18:378–386. [PubMed: 18433666]
31. Celis-Morales CA, Perez-Bravo F, Ibanez L, Salas C, Bailey ME, Gill JM. Objective vs. self-reported physical activity and sedentary time: effects of measurement method on relationships with risk biomarkers. PloS one. 2012; 7:e36345. [PubMed: 22590532]
32. Atienza AA, Moser RP, Perna F, et al. Self-reported and objectively measured activity related to biomarkers using NHANES. Medicine and science in sports and exercise. 2011; 43:815–821. [PubMed: 20962693]
33. Lin FR. Hearing loss and cognition among older adults in the United States. The journals of gerontology Series A, Biological sciences and medical sciences. 2011; 66:1131–1136.
34. Lin FR, Ferrucci L, Metter EJ, An Y, Zonderman AB, Resnick SM. Hearing loss and cognition in the Baltimore Longitudinal Study of Aging. Neuropsychology. 2011; 25:763–770. [PubMed: 21728425]
35. Shumway-Cook A, Woollacott M. Attentional demands and postural control: the effect of sensory context. The journals of gerontology Series A, Biological sciences and medical sciences. 2000; 55:M10–M16.
36. Woollacott M, Shumway-Cook A. Attention and the control of posture and gait: a review of an emerging area of research. Gait Posture. 2002; 16:1–14. [PubMed: 12127181]
37. Gates GA, Cobb JL, D'Agostino RB, Wolf PA. The relation of hearing in the elderly to the presence of cardiovascular disease and cardiovascular risk factors. Arch Otolaryngol Head Neck Surg. 1993; 119:156–161. [PubMed: 8427676]

Table 1

Definition of Outcome Variables Used, National Health and Nutrition Examination Survey (NHANES) 2005–2006

Variable	Description	Levels (Minutes of MPA[a] per week)
Self-reported leisure-time physical activity	Self-reported time per week spent on moderate and vigorous activities, expressed in minutes of moderate-intensity physical activity	Inactive (0) Insufficiently Active (>0 and <150) Sufficiently Active (≥150)
Accelerometer-measured physical activity	Accelerometer-measured time per week spent on moderate and vigorous activities, defined as ≥2020 and ≥5999 intensity counts per minute respectively, expressed in minutes of moderate-intensity physical activity	Inactive (0) Insufficiently Active (>0 and <150) Sufficiently Active (≥150)

[a]Minutes of Moderate-Intensity Physical Activity

Table 2

Demographic Characteristics of Participants aged 70+ Years, National Health and Nutrition Examination Survey, 2005–2006

Characteristic	Normal Hearing (n=217) N (%)	Mild Hearing Impairment (n=257) N (%)	Moderate or Greater Impairment (n=232) N (%)	p-value
Female	121 (55.8)	129 (50.2)	81 (34.9)	<.001
Age				
70–74	112 (51.6)	93 (36.2)	37 (15.9)	<.001
75–79	53 (24.4)	71 (27.6)	48 (20.7)	
80–84	32 (14.7)	69 (26.8)	83 (35.8)	
85+	20 (18.4)	24 (9.3)	64 (27.6)	
Race				
White	138 (63.6)	192 (74.7)	194 (83.6)	<.001
Black	56 (25.8)	34 (13.2)	12 (5.2)	
Mexican American	18 (8.3)	24 (9.3)	21 (9.1)	
Other Hispanic	2 (0.9)	4 (1.6)	1 (0.4)	
Other-Including Multiracial	3 (1.4)	3 (1.2)	4 (1.7)	
Education				
Less than High School	35 (16.1)	58 (22.6)	61 (26.3)	.023
Some High School	34 (15.7)	31 (12.1)	42 (18.1)	
High School Graduate	63 (29.0)	87 (33.9)	54 (23.3)	
Some College	45 (20.7)	52 (20.2)	44 (19.0)	
College Graduate	40 (18.4)	29 (11.3)	31 (13.3)	
Income				
<$20k	59 (27.2)	86 (33.5)	82 (35.3)	.079
$20k–$44.9k	80 (36.9)	96 (37.4)	90 (38.8)	
$50k–74.9k	39 (18.0)	37 (14.4)	22 (9.5)	
$75k+	27 (12.4)	23 (8.9)	17 (7.3)	
Don't Know	12 (5.5)	14 (5.4)	20 (8.6)	
Cardiovascular Disease[a]	48 (22.1)	67 (26.1)	64 (27.6)	.387
Hypertension	140 (64.5)	146 (56.8)	123 (53.0)	.046
Smoking Status				
Current	15 (6.9)	22 (8.6)	9 (3.9)	.257
Former	98 (45.2)	115 (44.7)	117 (50.4)	
Never	104 (47.9)	120 (46.7)	106 (45.7)	
Stroke	18 (8.3)	27 (10.5)	35 (15.1)	.065
Body Mass Index				
Underweight (<18.5)	6 (2.8)	3 (1.2)	3 (1.3)	.449
Normal Weight (18.5–25.4)	66 (30.4)	78 (30.4)	84 (36.2)	
Overweight (25.5–29.9)	73 (33.6)	101 (39.3)	77 (33.2)	
Obese (30+)	63 (29.0)	66 (25.7)	59 (25.4)	

Characteristic	Normal Hearing (n=217) N (%)	Mild Hearing Impairment (n=257) N (%)	Moderate or Greater Impairment (n=232) N (%)	p-value
Level of Physical Activity Self-Report				
Inactive (0 mins MPA/week[b])	107 (49.3)	135 (52.5)	135 (58.2)	.246
Insufficiently Active (<150 mins MPA/week)	45 (20.7)	51 (19.8)	48 (20.7)	
Sufficiently Active (≥150 mins MPA/week)	65 (30.0)	71 (27.6)	49 (21.1)	
Level of Physical Activity Accelerometer[c](n=522)	**(n=162)**	**(n=185)**	**(n=175)**	
Inactive (0 mins MPA/week)	120 (74.1)	157 (84.9)	147 (84.0)	.082
Insufficiently Active (<150 mins MPA/week)	32 (19.8)	20 (10.8)	22 (12.6)	
Sufficiently Active (≥150 mins MPA/week)	10 (6.2)	8 (4.3)	6 (3.4)	

[a] Cardiovascular disease includes any history of congestive heart failure, coronary artery disease, angina, myocardial infarction

[b] Minutes of moderate-intensity physical activity per week

[c] Accelerometry data available for subset of complete cohort

Table 3

Association between Hearing Impairment[a] and Self-Reported or Accelerometer-Measured Physical Activity[b], National Health and Nutrition Examination Survey 2005–2006: Stepwise Ordinal Logistic Regression Model

	Odds of Next Lower Category[b] of Physical Activity (PA)			
	Leisure-Time PA: Self-Reported		Accelerometer-Measured PA	
Variable[c]	**Mild Hearing Impairment**	**Moderate or Greater Hearing Impairment**	**Mild Hearing Impairment**	**Moderate or Greater Hearing Impairment**
Base Model (Hearing only)	1.40 (0.75, 2.64) p=.264	1.85 (1.17, 2.90)** p=.011	2.23 (1.00, 4.98)* p=.050	2.54 (1.56, 4.13)** p=.001
Base + Demographic and Cardiovascular Risk Factors[c]	1.23 (0.68, 2.22) p=.475	1.61 (1.14, 2.26)* p.=.010	2.25 (0.94, 5.40) p=.066	1.85 (1.01, 3.41)* p=.046
Base + Demographics and Cardiovascular Risk Factors + Body Mass Index	1.21 (0.65, 2.26) p=.520	1.59 (1.11, 2.28)* p=.015	2.06 (0.90, 4.72) p=.083	1.70 (0.99, 2.91) p=.054

* p<05,

** p<.01

[a] Hearing is defined by the speech-frequency pure tone average (PTA) of hearing thresholds at 0.5, 1, 2, and 4 kHz in the better hearing ear (Normal PTA < 25dB, Mild impairment 25 – <40dB, Moderate or greater ≥ 40dB)

[b] Categories of physical activity are based on the Department for Health and Human Services' Physical Activity Guidelines for Americans: Inactive (0 minutes of moderate-intensity physical activity), Insufficiently Active (<150 minutes of moderate-intensity physical activity), Sufficiently Active (≥150 minutes of moderate-intensity physical activity).

[c] Demographic factors include gender, age, race, education, and income. Cardiovascular risk factors include cardiovascular disease (defined as history of coronary artery disease, congestive heart failure, angina, or myocardial infarction), hypertension, stroke, and smoking status.