Archives of Gerontology and Geriatrics 85 (2019) 103907

Contents lists available at ScienceDirect

Archives of Gerontology and Geriatrics

journal homepage: www.elsevier.com/locate/archger

Hearing loss is a risk factor of disability in older adults: A systematic review

Tzu-Chia Lin[a,b], Miaofen Yen[c,*], Yen-Chi Liao[b,d]

[a] International Doctoral Program in Nursing, Department of Nursing, National Cheng Kung University, College of Medicine, National Cheng Kung University, Tainan, Taiwan
[b] Department of Nursing, Ditmanson Medical Foundation Chia-Yi Christian Hospital, Chiayi, Taiwan
[c] Department of Nursing & Institute of Allied Health Sciences, College of Medicine, National Cheng Kung University, Tainan, Taiwan
[d] College of Medicine, Taipei Medical University, Taipei, Taiwan

ARTICLE INFO

Keywords:
Aging
Hearing loss
Impairment
Activity limitation
Participation restriction

ABSTRACT

Background and Objectives: Hearing loss (HL) is a public health problem affecting older adults. HL is not only a health condition but also a complex, dynamic phenomenon related to disability. Previous studies identified associations between HL and undesirable outcomes; however, their correlation remains inconclusive. Hearing loss can have profound impact on daily life in the elderly, and an understanding of how HL contributes to disability is needed. A systematic review was conducted to comprehensively examine current evidence and determine the association between HL and disability regarding impairment, activity and participation in older adults.

Research Design and Methods: The Meta-analysis Of Observational Studies in Epidemiology (MOOSE) guidelines were applied in this systematic review. Quality assessment was conducted using the Newcastle-Ottawa Scale for longitudinal studies and the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for cross-sectional studies.

Results: In this systematic review of 20 studies, HL was associated with mobility limitation, activity limitation and participation restriction. The severity of HL was associated with impaired mobility and physical performance, but the association was only found in persons with severe/major HL. HL was also associated with activities of daily living (ADL) dependency, however these findings were mainly based on cross-sectional studies.

Discussion and Implications: HL is related to disability by impairment, activity limitations or participation restrictions in older adults. Future studies should include participation restrictions as a mediation factor to better understand this association. Consistent and accurate hearing measurements and hearing loss criteria are also required to determine the impact of HL on disability.

1. Introduction

Hearing loss is a common chronic condition affecting older adults (Kiely et al., 2016). As the ageing population has increased, hearing loss has become a public health problem. Previous studies have identified certain associations between hearing loss and undesirable outcomes, such as affected mental health (Contrera et al., 2016; Gates & Mills, 2005; Mikkola et al., 2016), deterioration of quality of life (Ishine, Okumiya, & Matsubayashi, 2007; Polku et al., 2016), cognitive decline (Gates & Mills, 2005), impaired mobility (Viljanen, Kaprio, Pyykkö, Sorri, Koskenvuo et al., 2009), restriction of daily activities and falls (Jiam, Li, & Agrawal, 2016), but the correlation between hearing loss and these undesired outcomes remains inconclusive.

Hearing loss is defined as a sudden or gradual decline in the auditory system (National Institute on Deafness and Other Communication Disorder, 2018). The severity of hearing loss varies from slight/mild to profound (World Health Organization, 2019). Hearing loss is often used interchangeably with age-related hearing loss and presbycusis (Gates & Mills, 2005). According to the International Classification of Functioning, Disability, and Health (ICF), hearing loss is not only a health condition but also a complex, dynamic phenomenon regarding impairment, activity, participation and contextual factors (World Health Organization, 2013). Therefore, there is a need to explore how hearing loss can contribute to disability with respect to impairment, activity limitation and participation restriction.

Several mechanical pathways involved in increasing cognitive and attention resources and impairing psychosocial conditions explain the association between hearing loss and disability. First, degeneration of the cochlea, which dominates neural encoding of sounds, is the main pathology in hearing loss. Cognitive and attention resources will then

* Corresponding author at: No.1, Ta-Hsueh Road, Tainan 701, Taiwan.
E-mail address: miaofen@mail.ncku.edu.tw (M. Yen).

https://doi.org/10.1016/j.archger.2019.103907
Received 28 January 2019; Received in revised form 18 June 2019; Accepted 5 July 2019
Available online 08 July 2019
0167-4943/

have to share the load with sound signal processing. The overload of cognitive and attention resources is not only related to the risk of fall (Jiam et al., 2016) but also critical elements contributing to disability. Second, elderly persons with greater hearing loss may have communication problems, which could affect their self-esteem and cause social isolation and loneliness, worsening their physical functioning (Chen, Genther, Betz, & Lin, 2014; Gates & Mills, 2005).

Hearing loss can have a profound impact on daily life in the elderly. As age advances, reduced cognition, motor problems and multiple comorbidities are frequently reported among the elderly and often been seen as process of aging. However, all of these factors become wosen when hearing loss developing gradually in the elderly. An understanding of how hearing loss can contribute to disability is needed. A systematic review was conducted to comprehensively examine current evidence and determine the association between hearing loss and disability regarding impairment, activity and participation in older adults. We adopted the World Health Organization (WHO) model of the International Classification of Functioning, Disability and Health (ICF) as a conceptual framework for exploring this association.

2. Methods

2.1. Search strategy

The Meta-analysis Of Observational studies in Epidemiology (MOOSE) guidelines were applied (Stroup et al., 2000). The search strategy was developed in conjunction with an experience investigator (Yu-Chen Liu) expertise in systematic reviews to avoid publication bias and ensure the search quality. A comprehensive systematic literature search was conducted through November 2018 to December 2018. Studies were identified using online libraries, including PubMed, Cochrane Library (CENTRAL, via the Cochrane Library) and CINAHL. The search algorithm included all possible combinations of (1) ageing, elderly, geriatrics; (2) hearing loss, impairment, deaf; (3) disability, activity limitations. The specific search algorithm is provided in Appendix A. Reference lists from the selected articles were also used to identify additional studies that met the inclusion criteria.

2.2. Eligibility criteria

Studies were included if (1) the subjects were at least 60 years old; (2) participants self-reported or were diagnosed as having hearing loss in one or both ears regardless of hearing aid usage; (3) the outcome measurement of the study incorporated any ICF components, including impairments, activity limitations and participation restrictions; (4) Cross-sectional and longitudinal study research; (5) articles were published in English. Studies were excluded if the outcome measurement of the study did not meet the ICF definition or if the hearing ability did not measure properly or if vision and hearing loss were combined as a construct. Two investigators (T. Z. L and M.Y) independently reviewed the title, abstract, and full text of publications during inclusion screening. Disagreements were discussed and resolved by a third researcher (Y. C. L).

2.3. Data extraction and quality assessment

Two investigators (T. Z. L and M.Y) independently extracted data from all included studies (Table 1). The extracted information included authors, country, terms used to describe hearing loss, study design, sample demographics, definition and measurement of hearing loss, and measurement of disability. The data were independently checked again by one of the investigators for accuracy. Discrepancies were discussed as consensus was achieved.

Quality evaluation of the selected studies was conducted using the Newcastle-Ottawa Scale (NOS) and the Joanna Briggs Institute (JBI) critical appraisal checklist for longitudinal and cross-sectional studies, respectively. The NOS scale includes 8 items evaluating four dimensions including sample selection and representativeness, comparability, and outcome assessment. Each item is awarded a maximum of one star except for the domain of 'Comparability' which is awarded a maximum of two stars. More stars indicate a higher quality study (Stang, 2010). The JBI critical appraisal checklist contains 8 items assessing sample selection criteria, subject description, measurement of exposure, measurement of subject condition, confounding factors identification, control of confounding factors, outcome assessment, and statistical analysis. Each item is categorized as yes, no, unclear, or not applicable (Joanna Briggs Institute, 2016).

3. Results

3.1. Studies included in the review

The initial database searches identified 2508 articles for review. A total of 2139 titles were screened after 369 duplicates were removed. After 2086 articles were excluded based on title, 53 articles were screened, and 25 full-text were reviewed for eligibility. Twenty articles met inclusion criteria for literature synthesis (Fig. 1). Quality of the studies ranged from fair to good (Tables 2 and 3). Funnel plots could not be performed to assess publication bias as less than 10 studies were included for each outcome (Dalton, Bolen, & Mascha, 2016).

All studies were written in English. Eight studies used cross-sectional designs, and 12 were longitudinal studies. Studies were conducted internationally, in the United States (n = 6), Finland (n = 6), Japan (n = 3), and the United Kingdom, Italy, Australia, Norway and France (n = 1 each). Sample sizes ranged from 84 to 9447 participants. The age of the participants ranged from 63 to 99 years old. The terms used to describe hearing loss included hearing impairment (n = 8), hearing difficulty (n = 3), hearing loss (n = 3), hearing problem (n = 3), age-related hearing loss (n = 1), and hearing function (n = 1). The prevalence of hearing loss in older adults ranged from 19.9% to 69.3%, with 32.5% to 52.6% having mild loss and 10% to 50.4% having moderate loss.

Seven studies used pure-tone audiometry to measure hearing loss, and 12 studies described a self-reported questionnaire using one to three items across studies. One study used both objective and subjective measurements (Table 1). One studies measured hearing loss with the Hearing Handicap Inventory for the Elderly Screening Version (HHIE-S), a self-reported questionnaire with good psychometric properties. The reliability of HHIE-S has been reported as Cronbach's alpha coefficient from 0.77 (Öberg, 2016) to 0.91 (Tomioka et al., 2013). Criterion validity of the HHIE-S with pure-tone audiometry (PTA) in Japanese elderly population was r = 0.69 (Tomioka et al., 2013) and r = 0.52 in Taiwanese elders (Chang, Ho, & Chou, 2009). Eleven studies that detect hearing loss with subjective questionnaires did not report psychometric properties.

The criteria of hearing loss also differed across the studies. Among the studies that measured hearing loss with pure-tone audiometry, only four adopted the WHO standard, which defines hearing loss as greater than 25 decibels (Studies 11–14). Others defined hearing loss as greater than 20 decibels (Study 8), 21 decibels (Study 19), 39 decibels (Study 1) or 40 decibels (Study 20). In studies that used a subjective questionnaire, the definition of hearing loss also varied across studies, such as "I have a little difficulty hearing and understanding what a person says to me in a quiet room if they speak normally to me" and HHIE-S scores greater than 8.

Disability was described as impairment, activity limitations or participation restrictions within the domains defined in ICF framework. Impairments are understood to be problems related to body function and structure. Activity limitations refer to difficulties in executing activities or task. Participation restrictions are defined as problems relating to experience in involvement in life situations. Seven studies investigated the association between hearing loss and impairment.

Table 1
Study Reference Numbers, Termiology, and Measurement Instruments Used in Included Publications.

Authors/study number/country	Terms used	Study design (years of follow up)	Sample demographics	Hearing measures	Outcome measures
Lin et al. (2004) #1 USA	Hearing impairment	Longitudinal (4.4 years)	Community–based female 76.1 (SD NR) years *n* = 5,345	Measurement Measured using a hand-held audiometer (not applicable to the use of hearing aids). Impairment: inability to hear a tone of 40 dB or greater than 2000 Hz in the better ear.	Activity limitation: ADL Questionnaires from the 1984 National Health Interview Survey Supplement on Aging, including difficulty with walking, climbing stairs, preparing meals, shopping, and doing housework.
Rudberg, Furner, Dunn, and Cassel (1993) #2 USA	Hearing impairment	Longitudinal (4 years)	Community–based 70^{+} years *n* = 4,452	Questionnaire Survey response categories including tinnitus, deafness in one or both ears, or trouble hearing with one or both ears. Impairment: positive to any of the categories	Activity limitation: ADL Questionnaires including difficulty with bathing, dressing, eating, getting up from bed or chair, walking, going out, and toileting
Tomioka, Okamoto et al. (2015) #3 Japan	Hearing loss	Longitudinal (5 years)	Community–based 72.4 (65-93) years *n* = 3,936	Questionnaire "Do you feel have a hearing loss": Yes, No, I don't know. Impairment: Yes to the question, regardless of hearing aid usage.	Activity limitation: IADL measured by TMG-IC subscale Participation restriction: Social role measured by TMG-IC subscale
Yamada et al. (2012) #4 Japan	Hearing loss	Longitudinal (3 years)	Community–based 75.4 (65-98) years *n* = 1,254	Questionnaire "Do you have difficulty hearing and understanding what a person says to you in a quiet room if they speak normal to you (even when wearing your hearing aid)?": no difficulty, a little difficulty, a lot of difficulty. Impairment: a little difficulty or a lot of difficulty to the question, irrespective of hearing aid use.	Activity limitation: IADL measured by TMG-IC subscale Participation restriction: Social role measured by TMG-IC subscale
Yamada, Nishiwaki, Michikawa, and Takebayashi (2011) #5 Japan	Hearing difficulty	Longitudinal (3 years)	Community–based No difficulty: 54.9% participants age 65-74 *n* = 1,055 Little difficulty: 51.5% participants age 75-84 *n* = 171 A lot of difficulty: 45.8% participants age 75-84 *n* = 24	Questionnaire "Do you have difficulty hearing and understanding what a person says to you in a quiet room if they speak normal to you (even when wearing your hearing aid)?": no difficulty, a little difficulty, a lot of difficulty. Impairment: a little difficulty or a lot of difficulty to the question	Activity limitation: ADL measured by Katz index of ADL
Mikkola et al. (2016) #6 Finland	Hearing problem	Longitudinal (1 and 2 years)	Community–based Good hearing: 79.8 (7.0) years (median, IQR) *n* = 339 Some problem: 80.0 (7.0) years (median, IQR) *n* = 349 Major problem: 82.9 (6.4) years (median, IQR) *n* = 78	Questionnaire "Do you have difficulties hearing when having a conversation with another person in a noisy environment?": No difficulty, Sometimes, some difficulty and Yes, major difficulty Impairment: some or major difficulty to the question	Participation restriction: 1.Time spent out of home recorded in a structured diary 2.Withdrawal from leisure activity interviewed by telephone
Polku et al. (2015) #7 Finland	Hearing difficulty	Longitudinal (2 years)	Community–based 80.0 (4.3) years *n* = 848	Questionnaire "Do you have difficulties hearing when having a conversation with several people simultaneously?", "Do you have difficulty hearing when conversing with another person in the presence of noise?", "Do you have difficulties hearing where a particular sound (i.e. phone ringing, sound of a car) is coming from?". 0 = no difficulty; 1 = sometimes, some difficulty; 2 = yes, major difficulty. Scores were summed. Impairment: no hearing difficulty (score 0), mild hearing difficulty (score 1-2), major hearing difficulty (3 or higher)	Impairment: Life-space mobility measured by the University of Alabama at Brimingham LPA
Viljanen, Kaprio, Pyykkö, Sorri, Koskenvuo et al. (2009) #8 Finland	Hearing impairment	Longitudinal (3 years)	Community–based $BEHL_{0.5\text{-}4kHz}$ < 21dB: 68 (3.2) years *n* = 255	Measurement Measured using clinical audiometry equipped with headphones following ISO protocol 8253-1.	Impairment: 1.Maximal walking speed over 10m 2.Walking endurance assessed with 6-minute walking test

(*continued on next page*)

Table 1 (*continued*)

Authors/study number/country	Terms used	Study design (years of follow up)	Sample demographics	Hearing measures	Outcome measures
			BEHL≧$_{0.5\text{-}4kHz}$ 21dB: 69.5 (3.5) years *n* = 179	Impairment: mean of the pure-tone air conduction threshold at 500, 1000, 2000, and 4000 Hz was at least 21 dB in the better ear.	3.Self-rated walking difficulties assessed using a structured questionnaire
Brennan, Su, and Horowitz (2006) #9 USA	Hearing impairment	Longitudinal (6 years)	Community–based 25.6% participants age 70-74 24.4% participants age 75-79 28.7% participants age 80-84 21.2% participants age 85-99 *n* = 1,309	Questionnaire "Which statement best describes your hearing even wearing hearing aid?": No trouble, A little trouble, A lot of trouble Impairment: A little trouble or a lot of trouble to the question.	Activity limitations: Questionnaires from the survey conducted by the National Center for Health Statistics, Hyattsville, Maryland. 1.ADL questionnaires including dressing, bathing/showering, eating, getting in or out of bed/chair, walking, getting outside, and toileting 2.IADL questionnaires including preparing meals, shopping, using the telephone, managing money, doing heavy housework, and doing light housework
Lijas et al. (2016) #10 UK	Hearing impairment	Longitudinal (2 years)	Community–based male 72.0 (5.4) years *n* = 3,981	Questionnaire "Do you use a hearing aid?" "Using a hearing aid if needed, is your hearing good enough to follow a TV programme at a volume others find acceptable": Could follow TV and used no hearing aid, Could follow TV and used hearing aid, Could not follow TV and did not use hearing aid, Could not follow TV and used hearing aid. Impairment: Could follow TV and used no hearing aid to the question.	Impairment: Questionnaires asking if the participants had problems taking the stairs and problems walking 400 yards Activity limitations: 1.ADL measured by Katz index of ADL 2. IADL measured by Lawton-Brody scale
Chen et al. (2015) #11 USA	Hearing impairment	Longitudinal (10 years)	Community–based Normal hearing: 73.3 (2.7) years *n* = 908 Mild hearing problem: 74.2 (2.8) years *n* = 829 Moderate or greater hearing impairment: 74.9 (2.9) years *n* = 453	Measurement Measured using portable audiometer and supra-aural earphones calibrated with the American National Standard Institute standards. Impairment: mean of the pure-tone air conduction threshold at 500, 1000, 2000, and 4000 Hz was over 25 dB in the better ear.	Impairment: 1.Physical functioning assessed by SPPB 2.Severe difficulty or inability to walk 1/4 mile and/or climb 10 steps, and needing equipment to ambulate Activity limitations: 1.Any difficulty performing activities of daily living, including getting in and out of bed or chairs, bathing or showering, and dressing
Amieva, Ouvrard, Meillon, Rullier, and Dartigues (2018) #12 French	Hearing problem	Longitudinal (25 years)	Community–based 75.3 (6.8) years *n* = 3,588	Questionnaire "Do you have hearing trouble?": I do not have hearing trouble, I have trouble following the conversation with two or more people talking at the same time or in a noisy background, I have major hearing trouble. Impairment: have trouble or major trouble to the question	Activity limitations: 1.ADL measured by Katz index of ADL 2. IADL measured by Lawton-Brody scale
Chen et al. (2014) #13 USA	Hearing impairment	Cross-sectional	Community–based Normal hearing: 55% participants age 70-74 *n* = 529 Hearing impairment: 47% participants age≧80 *n* = 1,140	Measurement Measured using PTA Impairment: mean of the pure-tone air conduction threshold at 500, 1000, 2000, and 4000 Hz was at least 25 dB in the better ear.	Impairment: 1.Questionnaires from NHNES including lower extremity mobility and general physical activity Activity limitations: Questionnaires from NHNES 1.ADL: getting in and out of bed, eating, and dressing yourself 2.IADL: managing money, performing house chores, and preparing meals Participation restriction: Questionnaires from NHNES including leisure and social activities
Gispen, Chen, Genther, and Lin (2014) #14 USA	Hearing impairment	Cross-sectional	Normal hearing: 51.6% participants age 70-74 *n* = 217 Mild hearing problem: 36.2% participants age 70-74	Measurement Measured using PTA Impairment: mean of the pure-tone air conduction threshold at 500, 1000, 2000, and 4000 Hz was at least 25 dB in the better ear.	Activity limitations: Physical activity assessed by retrospective questions and measured by accelerometers for 7 days

(*continued on next page*)

Table 1 (*continued*)

Authors/study number/country	Terms used	Study design (years of follow up)	Sample demographics	Hearing measures	Outcome measures
			n = 257 Moderate or greater hearing impairment: 35.8% participants age 80-84 *n* = 232		
Gopinath et al. (2012) #15 AUS	Age-related hearing loss	Cross-sectional	Community–based No hearing loss: 70.4 (6.6) years *n* = 886 Hearing loss: 77.2 (7.0) years *n* = 686	Measurement Measured using PTA Impairment: mean of the pure-tone air conduction threshold at 500, 1000, 2000, and 4000 Hz was over 25 dB in the better ear. Questionnaire measured using HHIE-S. Impairment: a total HHIE-S score of > 8.	Activity limitations: ADL and IADL measured by OARS ADL scale
Mikkola, Polku et al. (2015) #16 Finland	Hearing problem	Cross-sectional	Community–based Good hearing: 80.0 (6.9) years (median, IQR) *n* = 366 Some hearing problem: 81.0 (7.4) years (median, IQR) *n* = 393 Major hearing problem: 83.0 (6.6) years (median, IQR) *n* = 88	Questionnaire "Do you have difficulty hearing when conversing with another person in a noisy environment?" : No difficulty, Sometimes, some difficulty and Yes, major difficulty Impairment: some or major difficulty to the question	Impairment: 1.Physical functioning assessed by SPPB 2.Perceived the level of difficulty of mobility: moving indoors, stair climbing, 0.5 km walk and 2 km walk Activity limitations: ADL and IADL assessed by Evergreen ADL
Mikkola, Portegijs et al. (2015) #17 Finland	Hearing difficulty	Cross-sectional	Community–based No hearing difficulty: 80.0 (6.9) years (median, IQR) *n* = 366 Some hearing difficulty: 81.0 (7.4) years (median, IQR) *n* = 393 Major hearing difficulty: 83.0 (6.6) years (median, IQR) *n* = 88	Questionnaire "Do you have difficulty hearing when conversing with another person in a noisy environment?": No difficulty, Sometimes, some difficulty and Yes, major difficulty Impairment: some or major difficulty to the question	Participation restriction: 1.Objective participation in social and leisure activities measured by structured questionnaires 2. Perceived participation in social and leisure activities measured by the domain of autonomy outdoors of IPA questionnaire
Cacciatore et al. (1999) #18 Italy	Hearing function	Cross-sectional	Community–based 74.2 (6.4) years *n* = 1,332	Questionnaire "With/ without a hearing aid can you usually hear and understand what a person says without seeing his face if that person talks to you in a normal voice in a quiet room?" Impairment: four point scale (1 = no hearing problem, 4 = deaf)	Activity limitations: ADL assessed by Katz index of ADL
Viljanen, Kaprio, Pyykkö, Sorri, Pajala et al. (2009) #19 Finland	Hearing impairment	Cross-sectional	Community–based female twins 68.6 (3.4) years *n* = 429	Measurement Measured using PTA, ISO protocol 8253-1. Impairment: mean of the pure-tone air conduction threshold at 500, 1000, 2000, and 4000 Hz was the least 21 dB in the better ear.	Impairment: Postural balance measured COP movement in semitandem stance
Solheim, Kværner, and Falkenberg (2011) #20 Norway	Hearing loss	Cross-sectional	Community–based 78 years (SD NR) *n* = 84	Measurement Measured using PTA, ISO protocol 8253-1. Impairment: mean hearing loss in dB HL at frequencies of 500, 1000, 2000, and 4000 Hz was 40 dB HL or less.	Participation restriction: Interpersonal distress and threat to the self-image measured by the Norwegian version of HDHS

Notes: ADL = activity of daily living; BEHL = best ear hearing level; COP = center of pressure; dB = decibel; HDHS = Hearing Disability and Handicap Scale; HHIE-S = Hearing Handicap Inventory for the Elderly Screening version; Hz = hertz; IADL: instrumental activity of daily living; IPA = Impact on Participation and Autonomy; ISO = international standards organization; IQR = interquartile range; LPA = life space assessment; NHNES = national health and nutrition examination survey; NR = Not reported; OARS = Older American Resources and Services; SD = standard deviation; PTA = pure-tone audiometry; SPBB = Short Physical Performance Battery; TMG-IC = Tokyo Metropolitan Institute of Gerontology Index of Competence.

Fourteen studies explored the association between hearing loss and activity limitations. Six studies discussed the association between hearing loss and participation restrictions.

3.2. Results of the reviewed studies

3.2.1. Impairment

As evident in Table 1, the most commonly examined association was mobility limitation (Studies 7, 10, 13, and 16). The outcomes of these studies demonstrated that participants with hearing loss had mobility limitations; however, in one study, this association was attenuated after adjusting for social engagement (Study 10). Compared to elderly persons with normal hearing, those with more severe hearing loss had a greater possibility of mobility limitations (Studies 7, 13, and 16). Only a few studies investigated the association between hearing loss and walking speed, walking difficulty, handgrip strength or physical performance, including gait speed, chair stand or balance. The outcomes of these studies revealed that associations exist for all variables. No studies were included in the meta-analysis due to their differences in measurements or insufficient data.

3.2.2. Activity limitation

Seven studies revealed that hearing loss was associated with activities of daily living (ADL) dependency (Studies 5, 11–13, 15, 16, and 18). Four of these studies found that elderly persons with moderate/severe hearing loss have a higher probability of ADL dependency than elderly persons with good hearing; this finding was not true for those with mild hearing loss (Studies 5, 11, 15, and 16). The association between hearing loss and activity limitation existed in all cross-sectional studies (Studies 13, 15, 16, and 18) but not in four longitudinal studies (Studies 1, 2, 9, and 10). However, different ADL measurements and incomplete data prohibited a meta-analysis calculation.

Four studies revealed that hearing loss was associated with instrumental activities of daily living (IADL) dependency (Studies 4, 10, 13, and 16). Two of these studies, using the same assessment tool but different in follow-up periods, found that elderly persons with moderate/severe hearing loss had a higher probability of IADL dependency than those with good hearing (Studies 10 and 16).

3.2.3. Participation restriction

The majority of studies identified that hearing loss was associated with time spent outside of the home, withdrawal from leisure activity, participation in social/leisure activities, and social roles. However, two studies concluded that the association only existed in persons without difficulty ambulating (Study 6) or cognitive impairment (Study 17).

4. Discussion

The aim of this systematic review was to evaluate the association between hearing loss and disability in older adults. In this systematic review of 20 studies, hearing loss was associated with mobility limitations, activity limitations and participation restrictions. Severity of hearing loss was associated with mobility limitations and physical performance but that the association was only found in elderly persons with severe/major hearing loss. A possible explanation could be that hearing loss in the elderly is often the result of degeneration of the vestibular system and cochlea, which contributes to balance problems and poorer physical performance. The deteriorated cochlea can impact the neural encoding of sounds, placing greater burden on the elders cognitive and attention resources. These mechanisms contribute to physical performance and function (Chen et al., 2015).

According to studies that assessed IADL with TMG-IC, hearing loss is associated with IADL dependency. IADL assessment was designed to measure abilities that are required to maintain independence. However, communication is an essential element to execute activities in daily life. Communication problems resulting from hearing loss may increase the extent of IADL dependency. Alternatively, IADL are associated with social engagement (Ishizaki, Watanabe, Suzuki, Shibata, & Haga, 2000; Tomioka, Kurumatani, & Hosoi, 2016). Being more socially engaged can strengthen one's motivation for maintaining daily activities, resulting in greater life satisfaction, improved self-esteem and provide more opportunities to obtain health knowledge to maintain IADL independency (Tomioka et al., 2016). Hearing loss is associated with participation restrictions. Social participation levels may play a mediating role in hearing and IADL. Some inconsistencies in the study design regarding follow-up periods, and the measurement and criteria of hearing loss should be noticed. The follow-up periods in Tomioka, Okamoto, Morikawa, and Kurumatani (2015) and Yamada, Nishiwaki, Michikawa, and Takebayashi (2012) were five and three years, respectively. Although both studies used a single question to detect hearing loss, Tomioka, Okamoto et al. (2015) achieved acceptable validity and reliability in their measurements, but no psychometric analyses were found in Yamada et al. (2012). Finally, Tomioka, Okamoto et al. (2015) classified participants as having hearing loss if they answered "yes" when questioned, which is equal to moderate hearing loss with pure-tone audiometry according to the WHO standard. However, participants with a "little" or "a lot of" difficulty hearing were regarded as having hearing loss by Yamada et al. (2012).

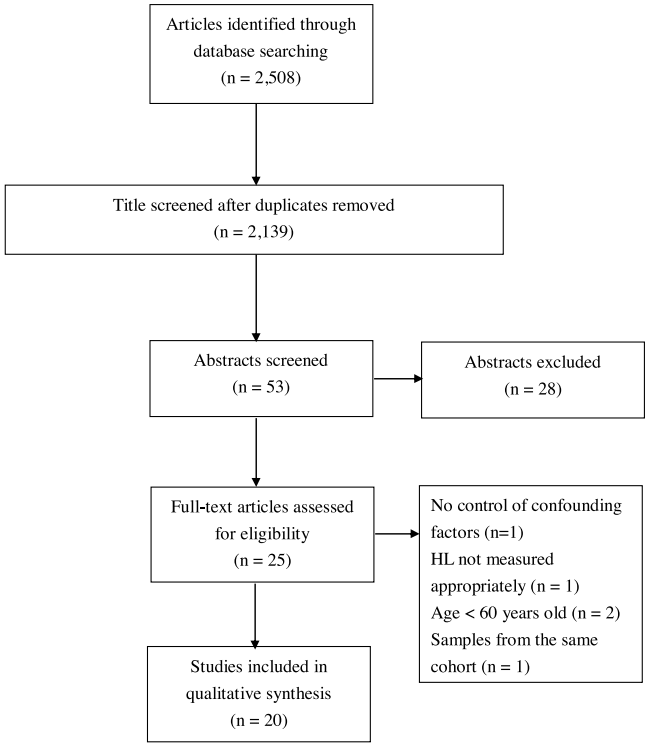

Fig. 1. Flow chart of systematic literature review.

There were several limitations of this study. Not only hearing measurements and thresholds but also confounding factors varied in the included studies. While hearing loss was associated with ADL dependency, the findings were based on cross-sectional studies, with the association did not exist in longitudinal studies. Thus, a causal relationship between hearing loss and ADL dependency cannot be determined with the current literature. Another limitation is the relatively short follow-up time, which limits our understanding of the longer term effects of hearing loss on disability.

5. Conclusion

As longevity increases, hearing loss will have a dramatic impact on the lives of millions of older people. Although there have been many

Table 2
Quality assessment of longitudinal studies (n = 12) using the Newcastle-Ottawa Scale.

Source	Criteria								
	Representation of the exposed cohort	Selection of the non-exposed cohort	Ascertainment of exposure	Demonstration that outcome of interest was not present at start of study	Comparability of cohorts on the basis of the design or analysis	Assessment of outcome	Was follow-up long enough for outcomes to occur	Adequacy of -up of cohorts	Total score
Lin et al. (2004)	✓	✓	✓	✓	✓	✓	✓	✓	8
Rudberg et al. (1993)	✓	✓	✓		✓	✓	✓	✓	7
Tomioka, Okamoto et al. (2015)	✓	✓	✓	✓	✓		✓	✓	7
Yamada et al. (2012)	✓	✓	✓	✓	✓✓	✓	✓	✓	9
Yamada et al. (2011)	✓	✓	✓	✓	✓✓	✓	✓	✓	9
Mikkola et al. (2016)	✓	✓		✓	✓		✓	✓	6
Polku et al. (2015)	✓	✓		✓	✓		✓	✓	6
Viljanen, Kaprio, Pyykkö, Sorri, Koskenvuo et al. (2009)	✓	✓	✓	✓	✓	✓	✓	✓	8
Brennan et al. (2006)	✓	✓	✓	✓	✓	✓	✓	✓	8
Lijas et al. (2016)	✓	✓		✓	✓	✓✓	✓	✓	8
Chen et al. (2015)	✓	✓	✓	✓	✓	✓	✓	✓	8
Amieva et al. (2018)	✓	✓	✓	✓	✓	✓	✓	✓	8

Table 3
Quality assessment of analytical cross-sectional studies (n = 8) using the JBI critical appraisal checklist.

Source	Criteria								
	Were the criteria for inclusion in the sample clearly defined?	Were the study subjects and the setting described in detail?	Was the exposure measured in a valid and reliable way?	Were objective, standard criteria used for measurement of the condition?	Were confounding factors identified?	Were strategies to address confounding factors stated?	Were the outcomes measured in a valid and reliable way?	Was appropriate statistical analysis used?	Total scores
Chen et al. (2014)	Y	Y	Y	Y	Y	Y	Y	Y	8
Gispen et al. (2014)	Y	Y	Y	Y	Y	Y	Y	Y	8
Gopinath et al. (2012)	Y	Y	Y	Y	Y	Y	Y	Y	8
Mikkola, Polku et al. (2015)	Y	Y	U	Y	Y	Y	Y	Y	7
Mikkola, Portegijs et al. (2015)	Y	Y	U	Y	Y	Y	Y	Y	7
Cacciatore et al. (1999)	Y	Y	Y	Y	Y	Y	Y	Y	8
Viljanen, Kaprio, Pyykkö, Sorri, Pajala et al. (2009)	Y	Y	Y	Y	Y	Y	Y	Y	8
Solheim et al. (2011)	Y	Y	Y	Y	Y	Y	Y	Y	8

Notes: Y = Yes; U = Unknown.

studies investigating the impact of hearing loss on disability in older adults, many variations exist in the measurement of hearing, with non-conclusive results. The research definition of hearing loss should adhere to a universal definition, such as the WHO classification of hearing impairment. The reliability and validity of self-reported questionnaires designed to measure hearing loss should also be tested. The present study found that hearing loss was associated with participation restrictions. Participation restrictions are also a key factor in mediating the association between hearing loss and disability. Future studies should include participation restrictions as a mediation factor to better understand this association.

Funding

The authors have no funding, financial relationships, or conflicts of interest to disclose.

Declaration of Competing Interest

None reported.

Appendix A. Keyword search strategy

Database	Key terms and algorithm
PubMed	(aged OR older adults OR senior OR elderly OR geriatric OR ageing OR ageing) AND (hearing loss [mesh] OR hearing impairment OR age-related hearing loss OR presbycusis OR deaf OR hearing handicap) AND (disability OR activity limitation OR participation restriction) **Refined by:** Human, English
Cochrane Library	(aged OR older adults OR senior OR elderly OR geriatric OR ageing OR ageing) AND (hearing loss [mesh] OR hearing impairment OR age-related hearing loss OR presbycusis OR deaf OR hearing handicap) AND (disability OR activity limitation OR participation restriction) **Refined by:** Language: English
CINAHL	(aged OR older adults OR senior OR elderly OR geriatric OR ageing OR ageing) AND (hearing loss OR hearing impairment OR age-related hearing loss OR presbycusis OR deaf OR hearing handicap) AND (disability OR activity limitation OR participation restriction) **Refined by:** Language: English

References

Amieva, H., Ouvrard, C., Meillon, C., Rullier, L., & Dartigues, J. F. (2018). Death, depression, disability, and dementia associated with self-reported hearing problems: A 25-year study. *The Journals of Gerontology: Series A, 73*(10), 1383–1389. https://doi.org/10.1093/gerona/glx250.

Brennan, M., Su, Y. P., & Horowitz, A. (2006). Longitudinal associations between dual sensory impairment and everyday competence among older adults. *Journal of Rehabilitation Research and Development, 43*(6), 777–792.

Cacciatore, F., Napoli, C., Abete, P., Marciano, E., Triassi, M., & Rengo, F. (1999). Quality of life determinants and hearing function in an elderly population: Osservatorio Geriatrico Campano Study Group. *Gerontology, 45*(6), 323–328.

Chang, H. P., Ho, C. Y., & Chou, P. (2009). The factors associated with a self-perceived hearing handicap in elderly people with hearing impairment—Results from a community-based study. *Ear and Hearing, 30*(5), 576–583. https://doi.org/10.1097/AUD.0b013e3181ac127a.

Contrera, K. J., Betz, J., Deal, J. A., Choi, J. S., Ayonayon, H. N., Harris, Y., ... Lin, F. R. (2016). Association of hearing impairment and emotional vitality in older adults. *The Journals of Gerontology: Series B, 71*(3), 400–404. https://doi.org/10.1093/geronb/gbw005.

Chen, D. S., Genther, D. J., Betz, J., & Lin, F. R. (2014). Association between hearing impairment and self-reported difficulty in physical functioning. *Journal of American Geriatric Society, 62*(5), 850–856. https://doi.org/10.1111/jgs.12800.

Chen, D. S., Betz, J., Yaffe, K., Ayonayon, H. N., Kritchevsky, S., Martin, K. R., Harris, T. B., ... Health ABC study (2015). Association of hearing impairment with declines in physical functioning and the risk of disability in older adults. *The Journals of Gerontology: Series A, 70*(5), 654–661. https://doi.org/10.1093/gerona/glu207.

Dalton, J. E., Bolen, S. D., & Mascha, E. J. (2016). Publication bias: The elephant in the review. *Anesthesia and Analgesia, 123*(4), 812–813. https://doi.org/10.1213/ANE.0000000000001596.

Gates, G. A., & Mills, J. H. (2005). Presbycusis. *The Lancet, 366*(9491), 1111–1120. https://doi.org/10.1016/S0140-6736(05)67423-5.

Gispen, F. E., Chen, D. S., Genther, D. J., & Lin, F. R. (2014). Association between hearing impairment and lower levels of physical activity in older adults. *Journal of the American Geriatrics Society, 62*(8), 1427–1433. https://doi.org/10.1111/jgs.12938.

Gopinath, B., Schneider, J., McMahon, C. M., Teber, E., Leeder, S. R., & Mitchell, P. (2012). Severity of age-related hearing loss is associated with impaired activities of daily living. *Age and Ageing, 41*(2), 195–200. https://doi.org/10.1093/ageing/afr155.

Ishine, M., Okumiya, K., & Matsubayashi, K. (2007). A close association between hearing impairment and activities of daily living, depression, and quality of life in community-dwelling older people in Japan. *Journal of the American Geriatric Society, 55*(2), 316–317.

Ishizaki, T., Watanabe, S., Suzuki, T., Shibata, H., & Haga, H. (2000). Predictors for functional decline among nondisabled older Japanese living in a community during a 3-year follow-up. *Journal of the American Geriatrics Society, 48*(11), 1424–1429.

Jiam, N. T., Li, C., & Agrawal, Y. (2016). Hearing loss and falls: A systematic review and meta-analysis. *The Laryngoscope, 126*(11), 2587–2596. https://doi.org/10.1002/lary.25927.

Joanna Briggs Institute (2016). *Checklist for analytical cross sectional studies.* Retrieved fromhttp://joannabriggs.org/research/critical-appraisal-tools.html.

Kiely, K. M., Mitchell, P., Gopinath, B., Luszcz, M. A., Jagger, C., & Anstey, K. J. (2016). Estimating the years lived with and without age-related sensory impairment. *The Journals of Gerontology: Series A, 71*(5), 637–642. https://doi.org/10.1093/Gerona/glv198.

Lijas, A. E., Wannamethee, S. G., Whincup, P. H., Papacosta, O., Walters, K., Iliffe, S., ... Ramsay, S. E. (2016). Hearing impairment and incident disability and all-cause mortality in older British community-dwelling men. *Age and Ageing, 45*(5), 662–667. https://doi.org/10.1093/ageing/afw080.

Lin, M. Y., Gutierrez, P. R., Stone, K. L., Yaffe, K., Ensrud, K., Fink, H. A., ... Mangione, C. M. (2004). Vision impairment and combined vision and hearing impairment predict cognitive and functional decline in older women. *Journal of the American Geriatrics Society, 52*, 1996–2002.

Mikkola, T. M., Portegijs, E., Rantakokko, M., Gagné, J. P., Rantanen, T., & Viljanen, A. (2015). Association of self-reported hearing difficulty to objective and perceived participation outside the home in older community-dwelling adults. *Journal of Aging and Health, 27*(1), 103–122. https://doi.org/10.1177/0898264314538662.

Mikkola, T. M., Polku, H., Portegijs, E., Rantakokko, M., Rantanen, T., & Viljanen, A. (2015). Self-reported hearing status is associated with lower limb physical performance, perceived mobility, and activities of daily living in older community-dwelling men and women. *Journal of the American Geriatrics Society, 63*(6), 1164–1169. https://doi.org/10.1111/jgs.13381.

Mikkola, T. M., Polku, H., Portegijs, E., Rantakokko, M., Tsai, L. T., Rantanen, T., ... Viljanen, A. (2016). Self-reported hearing is associated with time spent out-of-home and withdrawl from leisure activities in older community-dwelling adults. *Aging Clinical and Experimental Research, 28*, 297–302. https://doi.org/10.1007/s40520-015-0389-1.

National Institute on Deafness and Other Communication Disorder (2018). *Hearing loss and older adults.* Retrieved fromhttps://www.nidcd.nih.gov/health/hearing-loss-older-adults#1.

Öberg, M. (2016). Validation of the Swedish Hearing Handicap Inventory for the Elderly (screening version) and evaluation of its effect in hearing aid rehabilitation. *Trends in Hearing, 20*, 1–7. https://doi.org/10.1177/2331216516639234.

Polku, H., Mikkola, T. M., Rantakokko, M., Portegijs, E., Törmäkangas, T., Rantanen, T., ... Viljanen, A. (2015). Self-reported hearing difficulties and changes in life-space mobility among community-dwelling older adults: A two-year follow-up study. *BMC Geriatrics, 15*, 121. https://doi.org/10.1186/s12877-015-0119-8.

Polku, H., Mikkola, T. M., Rantakokko, M., Portegijs, E., Törmäkangas, T., Rantanen, T., ... Viljanen, A. (2016). Hearing and quality of life among community-dwelling older adults. *The Journals of Gerontology: Series B, 73*(3), 543–552. https://doi.org/10.1093/geronb/gbw045.

Rudberg, M. A., Furner, S. E., Dunn, J. E., & Cassel, C. K. (1993). The relationship of visual and hearing impairments to disability: An analysis using the longitudinal study of aging. *Journal of Gerontology, 48*(6), 261–265.

Solheim, J., Kværner, K. J., & Falkenberg, E. S. (2011). Daily life consequences of hearing loss in the elderly. *Disability and Rehabilitation, 33*(23-24), 2179–2185. https://doi.org/10.3109/09638288.2011.563815.

Stang, A. (2010). Critical evaluation of the Newcastle-Ottawa scale for the assessment of the quality of nonrandomized studies in meta-analyses. *European Journal of Epidemiology, 25*(9), 603–605. https://doi.org/10.1007/s10654-010-9491-z.

Stroup, D. F., Berlin, J. A., Morton, S. C., Olkin, I., Williamson, G. D., Rennie, D., ... Group f. t. -a. i, M. O. O. S. E. (2000). Meta-analysis of Observational Studies in EpidemiologyA Proposal for Reporting. *JAMA, 283*(15), 2008–2012. https://doi.org/10.1001/jama.283.15.2008.

Tomioka, K., Kurumatani, N., & Hosoi, H. (2016). Association between social

participation and instrumental activities of daily living among community-dwelling older adults. *Journal of Epidemiology, 26*(10), 553–561. https://doi.org/10.2188/jea.JE20150253.

Tomioka, K., Ikeda, H., Hanaie, K., Morikawa, M., Iwamoto, J., Okamoto, N., ... Kurumatani, N. (2013). The Hearing Handicap Inventory for Elderly-Screening (HHIE-S) versus a single question: reliability, validity, and relations with quality of life measures in the elderly community, Japan. *Quality of Life Research, 22*(5), 1151–1159. https://doi.org/10.1007/s11136-012-0235-2.

Tomioka, K., Okamoto, N., Morikawa, M., & Kurumatani, N. (2015). Self-reported hearing loss predicts 5-year decline in higher-level functional capacity in high-functioning elderly adults: The Fujiwara-Kyo study. *Journal of the American Geriatrics Society, 63*, 2260–2268. https://doi.org/10.1111/jgs.13780.

Viljanen, A., Kaprio, J., Pyykkö, I., Sorri, M., Koskenvuo, M., & Rantanen, T. (2009). Hearing acuity as a predictor of walking difficulties in older women. *Journal of the American Geriatrics Society, 57*(12), 2282–2286. https://doi.org/10.1111/j.1532-5415.2009.02553.x.

Viljanen, A., Kaprio, J., Pyykkö, I., Sorri, M., Pajala, S., Kauppinen, M., ... Rantanen, T. (2009). Hearing as a predictor of falls and postural balance in older female twins. *The Journals of Gerontology: Series A, 64*(2), 312–317. https://doi.org/10.1093/gerona/gln015.

World Health Organization (2013). *How to use the ICF: A practical manual for using the International Classification of Functioning, Disability and Health (ICF). Exposure draft for comment.* Geneva: WHO.

World Health Organization (2019). *Grades of hearing loss* (n.d.) Retrieved fromhttp://www.who.int/pbd/deafness/hearing_impairment_grades/en/.

Yamada, M., Nishiwaki, Y., Michikawa, T., & Takebayashi, T. (2011). Impact of hearing difficulty on dependence in activities of daily living (ADL) and mortality: A 3-year cohort study of community-dwelling Japanese older adults. *Archives of Gerontology and Geriatrics, 52*, 245–249. https://doi.org/10.1016/j.archger.2010.04.023.

Yamada, M., Nishiwaki, Y., Michikawa, T., & Takebayashi, T. (2012). Self-reported hearing loss in older adults is associated with future decline in instrumental activities of daily living but not in social participation. *Journal of the American Geriatrics Society, 60*, 1304–1309. https://doi.org/10.1111/j.1532-5415.2012.04039.x.