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Review Article

Hearing Loss and Depression in Older Adults: A Systematic Review and Meta-analysis

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Abstract

Background and Objectives: Studies reporting an association between hearing loss and depression in older adults are conflicting and warrant a systematic review and meta-analysis of the evidence.
Research Design and Methods: A search of academic databases (e.g., MEDLINE) and gray literature (e.g., OpenGrey) identified relevant articles published up to July 17, 2018. Cross-sectional or cohort designs were included. Outcome effects were computed as odds ratios (ORs) and pooled using random-effects meta-analysis (PROSPERO: CRD42018084494).
Results: A total of 147,148 participants from 35 studies met inclusion criteria. Twenty-four studies were cross-sectional and 11 were cohort designs. Overall, hearing loss was associated with statistically significantly greater odds of depression in older adults (OR = 1.47, 95% confidence interval [CI] = 1.31–1.65). When studies were stratified by design, hearing loss was associated with greater odds of depression in cross-sectional studies (OR = 1.54, 95% CI = 1.31–1.80) and cohort studies (OR = 1.39, 95% CI = 1.16 – 1.67), and there was no difference between cross-sectional or cohort effect estimates ($Q = 0.64$, $p = .42$). There was no effect of moderator variables (i.e., hearing aid use) on the association between hearing loss and depression, but these findings must be interpreted with caution. There was no presence of publication bias but certainty in the estimation of the overall effect was classified as "low."
Discussion and Implications: Older adults may experience increased odds of depression associated with hearing loss, and this association may not be influenced by study or participant characteristics.

Keywords: Hearing impairment, Mental health, Audiology

Global estimates indicate that over 1.30 billion people currently live with some form of hearing loss and this prevalence will likely rise with the aging population (Wilson, Tucci, Merson, & O'Donoghue, 2017). For older adults (≥60 years of age), hearing loss is often caused by the loss of inner and outer hair cells at the basal end of the basilar membrane, which contributes to the loss of high frequency hearing and increased hearing thresholds experienced during aging (Peelle & Wingfield, 2016). Approximately 13% of adults 40–49 years of age experience some form of hearing loss, whereas almost 45% of older adults aged 60–69 years live with hearing loss and this prevalence increases to 90% for adults 80 years and older (Goman & Lin, 2016). Aging may also be associated with increased

risk of depression (Freeman et al., 2016), which is characterized by sadness, feelings of low self-worth or guilt, a loss of interest in daily activities, and disturbed appetite or sleep, which affect concentration (World Health Organization, 2018). Approximately 15% of older adults experience mild depressive symptoms and 1%–5% live with major depressive disorder (Fiske, Wetherell, & Gatz, 2009). Moreover, research has shown an association between hearing loss and depression in older adults (e.g., Keidser & Seeto, 2017; Rosso et al., 2013), with age-related changes in psychosocial experience as well as degeneration to cortical activity proposed to explain these concomitant conditions.

The association between hearing loss and depression in older adults has most frequently been examined within, and explained by, the potential influence of psychosocial changes experienced during aging. Kiely, Anstey, and Luszcz (2013) initially found that severity of depressive symptoms was associated with hearing loss in older adults, but this association reduced to nonsignificance (i.e., was accounted for) when difficulty completing daily activities and degree of social engagement in daily life were included in the model. Further evidence shows a faster decline in hearing is associated with greater social and emotional loneliness among older adults (Pronk et al., 2014), and when left untreated, hearing loss may develop into a chronic stressor that leads to the proliferation of depression as an additional stressor (West, 2017). Hearing loss may therefore worsen existing difficulties associated with psychosocial and functional abilities during older age, increasing the likelihood of developing depression. Conversely, recent evidence shows no influence of psychosocial factors (i.e., less participation in social activities or access to a social network) on the association between hearing loss and depression in older adults (Cosh et al., 2018). The authors proposed that older adults may accept hearing loss as part of the normal aging experience and therefore adapt to changes in their hearing by modifying/improving their communication skills or using hearing aids to alleviate the burden of hearing loss, which in turn mitigates the potential negative impact of hearing loss on psychosocial experiences that may precede depression (Cosh et al., 2018). It is therefore not clear if the association between hearing loss and depression in older adults can be explained by a psychosocial mechanism in later life. A meta-analysis and systematic review of the literature will provide an estimate of this comorbid association and the potential influence of psychosocial or health characteristics that may account for this relationship in older adults.

Recent evidence also suggests that degeneration to neuropathological mechanisms associated with auditory perception and regulation of mood may explain the relationship between hearing loss and depression in older adults. As extensively reviewed by Rutherford, Brewster, Golub, Kim, and Roose (2018), neuroimaging studies show similar patterns of diminished activity in the limbic system (responsible for emotion and behavior), the frontal cortex (responsible for emotional regulation, reasoning, and planning), and auditory cortex in older adults with hearing loss or depression. These initial findings suggest the presence of common neural degeneration associated with hearing loss and depression in older adults, but more evidence is needed to increase our understanding of the pathophysiology underlying hearing loss and depression in later life.

To date, the association between hearing loss and depression is most frequently reported in epidemiological studies. Some cross-sectional studies report an association between hearing loss and depression during older age (Behera et al., 2016; Keidser & Seeto, 2017; Lee & Hong, 2016), whereas others report no relationship (Bergdahl et al., 2005; Chou & Chi, 2005). Similar evidence exists for cohort studies, with initial results showing hearing loss is associated with increased odds of depression among older adults (Forsell, 2000) and later studies repudiating these findings (Chou, 2008; (Cosh et al., 2018). Conflicting findings in the literature may be the consequence of methodological variance between studies and the limitations associated with epidemiological research. As a method of investigation, epidemiology allows for the examination of health characteristics within large population-based samples of participants when conducting a more controlled clinical trial is not feasible (e.g., examining intercontinental dietary patterns) or ethical (e.g., examining the health effects of smoking). However, epidemiological studies are often influenced by biases that undermine reliability in their results. As reported by Ioannidis (2016), most initial statistically significant epidemiological findings are later not replicated in more scientifically robust randomized controlled trials. Moreover, large longitudinal epidemiological studies examining changes in health characteristics (e.g., U.S. National Health and Nutrition Epidemiological Survey) often find statistically significant correlations between almost all variables of interest (Patel, Ioannidis, Cullen, & Rehkopf, 2015). With these limitations in mind, however, a meta-analysis and systematic review of epidemiological (e.g., cross-sectional and cohort) studies can provide a more rigorous estimate of an association between health characteristics (e.g., hearing loss and depression), while drawing attention to the strengths and weaknesses within the existing evidence and providing recommendations for future clinical practice.

Previous studies investigating the association between hearing loss and depression have estimated hearing loss using objective measures such as pure tone audiometry (Hidalgo et al., 2009; Kiely et al., 2013), but a proportion of studies only report subjective hearing loss measured by self-report outcomes (e.g., Boorsma et al., 2012; Saito et al., 2010). Some of these studies included a proportion of participants with cognitive decline (Perlmutter, Bhorade, Gordon, Hollingsworth, & Baum, 2010). Described as deficits in cognitive function not normal for age and level of education, cognitive decline in older adults may range from mild cognitive impairment to dementia (Albert et al., 2011). Increasing evidence shows an association between hearing

loss and cognitive decline in older adults (Loughrey, Kelly, Kelley, Brennan, & Lawlor, 2017), and a decline in cognitive function has been associated with depression (Wang & Blazer, 2015). We may therefore expect a stronger association between hearing loss and depression in older adults that also demonstrate presence of cognitive decline (Rutherford et al., 2018). Participant experience using hearing aids also varies across studies (Chou, 2008; Pronk et al., 2011; Rosso et al., 2013). Hearing aids may alleviate depressive symptoms associated with hearing loss in older adults (Choi et al., 2016; Manrique-Huarte, Calavia, Irujo, Girón, & Manrique-Rodríguez, 2016), which may influence the association between hearing loss and depression in observational research. In addition, a high proportion of studies do not report outcome results adjusted for the confounding influence of covariates (e.g., health/psychosocial characteristics), which undermines validity of their findings (Al Sabahi, Al Sinawi, Al Hinai, & Youssef, 2014; Chou & Chi, 2005; Hidalgo et al., 2009). It is also well-understood that cross-sectional studies cannot infer causality and are therefore unable to determine if there is temporal relationship between hearing loss and depression. Initial meta-analytic evidence from a small number of studies showed an association between hearing loss and depression in later life (Huang, Dong, Lu, Yue, & Liu, 2010), but more studies have since been published and inconsistency in the findings warrants the need for a systematic review and meta-analysis of the evidence.

The primary aim of this systematic review and meta-analysis was to synthesize the available evidence to provide a summary effect estimate of the association between hearing loss and depression in older adults. The secondary aim was to examine whether study (e.g., design, outcome measures) or participant (e.g., demographic, health) characteristics may influence the association between hearing loss and depression. An extensive systematic review of the literature was conducted and all available evidence was included in this study to provide the most rigorous estimate of the association between hearing loss and depression in older adults.

Methods

Search Strategy

This systematic review and meta-analysis was conducted in accordance with the Meta-analysis of Observational Studies in Epidemiology statement (see Supplementary Table 1; Stroup et al., 2000) and was prospectively registered with PROSPERO (ID: CRD42018084494). Online databases and gray literature were searched to identify relevant articles from first date of publication to July 17, 2018 (see Supplementary Table 2). Reference lists of published articles were also searched.

Study Selection

Studies were included if they (a) included community and/or high care setting samples of older adults at least 60 years of age with and without hearing loss, (b) used a cross-sectional or cohort design, (c) included measures of hearing loss (objective or subjective) and depression, and (d) provided sufficient quantitative data to be included in the meta-analysis. Interventional designs most frequently examine effects of intervention exposure within a relatively small and homogeneous group of participants, rather than measuring the presence of an association between health comorbidities within a large population-based sample. To therefore address the aims of this review and reduce methodological heterogeneity, studies were excluded if they adopted an interventional design rather than measuring hearing loss and depression in cross-sectional or cohort studies. A senior author (B. J. Lawrence) experienced in meta-analysis and systematic reviews screened article titles and abstracts in-line with selection criteria and identified articles for inclusion. A second senior author (R. J. Bennett) completed a follow-up screen of article titles and abstracts in-line with selection criteria and provided a recommendation for the final articles for inclusion.

Data Extraction

Participants, study characteristics, and hearing loss and depression outcomes were extracted from each study. For studies that reported participant subgroups with dual sensory loss, only hearing impairment subgroups were extracted. Most recent studies were included in this meta-analysis when data were reported from the same cohort but in separate studies. To limit the possible false inflation of an association between hearing loss and depression when covariates are not controlled in outcome results, preference was given to outcome effect sizes maximally adjusted for covariates. Corresponding authors were contacted when study information and necessary data to compute an effect size was not reported in published articles.

Study Quality Assessment

The Grading of Recommendations Assessment, Development and Evaluation (GRADE) system was used to assess the quality of evidence (Schünemann, Brozek, & Oxman, 2013). The GRADE system evaluates the quality of evidence across studies for each outcome included in a systematic review and is summarized by an overall "certainty of evidence" grading. Gradings range from "very low" to "high" and represent the extent of certainty in an outcome result as a reliable estimate of an effect (Schünemann et al., 2013).

Statistical Analysis

Odds ratio (OR) represents the effect size in this meta-analysis. ORs equal to or greater than 1.68, 3.47, and 6.71 represent small, medium, and large effects, respectively (Chen, Cohen, & Chen, 2010). When studies did not report ORs, values were computed using available data following recommendations by Borenstein, Hedges, Higgins,

and Rothstein (2011) and Peterson and Brown (2005). Multiple conceptually related outcomes within studies were collapsed into one composite effect size. Participant subgroups within studies were analyzed as individual studies in this meta-analysis. Effect sizes were pooled using a random-effects model with 95% confidence intervals (CIs; Borenstein et al., 2011). Egger's regression asymmetry test and Rosenthal's Fail-Safe *N* were used to assess publication bias. Data analysis was completed using Comprehensive Meta-Analysis version 3.3.070.

Heterogeneity and Sensitivity Analyses

Cochrane's Q and I^2 statistics were used to examine heterogeneity. If Q was statistically significant ($p < .10$), the I^2 statistic estimated the percentage of variation across the samples due to heterogeneity. I^2 values of 0%–40% (low), 41%–60% (medium), and 61%–100% (high) were used to categorize levels of heterogeneity (Moher, Liberati, Tetzlaff, & Altman, 2009). For pooled effect sizes with significant heterogeneity, mixed effects Q-tests for analysis of variance were used to examine whether confounding variables (e.g., subjective vs objective hearing loss) accounted for variance within effect estimates (Borenstein et al., 2011). Sensitivity analyses were also conducted to examine whether removing studies with anomalous characteristics (e.g., large samples) would account for heterogeneity and affect pooled effects.

Results

Search Results

In total, 1,435 titles and abstracts were systematically screened in online databases (see Figure 1). Thirty-five studies, including 147,148 participants, from 18 countries and all seven continents, met inclusion criteria for this meta-analysis.

Study Characteristics

Twenty-four studies were cross-sectional and 11 were cohort designs (see Table 1). Among studies that reported

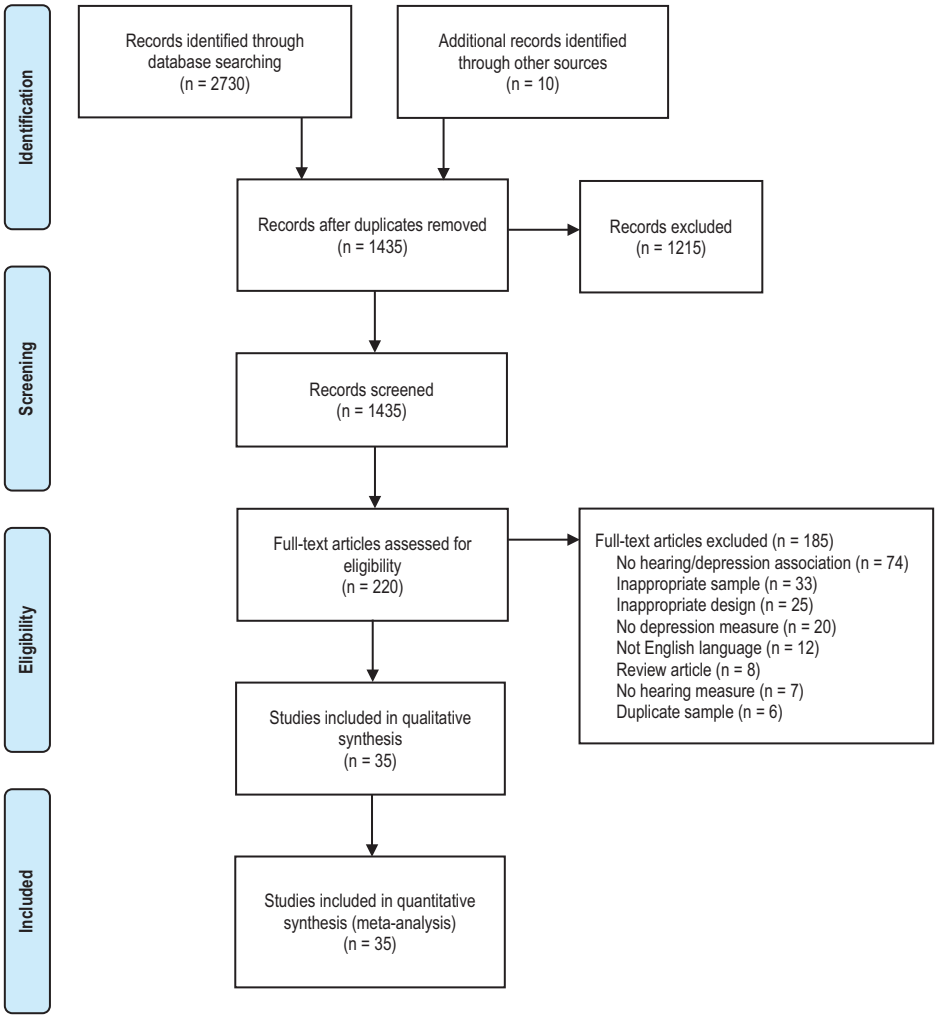


Figure 1. PRISMA flow chart of search results.

Table 1. Summary of Included Studies

Authors	Country	Study name	*N*	Sample	Hearing assessment	Depression assessment	Covariates
Cross-sectional studies							
Al Sabahi et al. (2014)	Oman	NA	1,550	Participants ≥60 years, mean age not reported, 51.60% female	Audiometry (no other details reported) Self-reported hearing ability (no other details reported)	GDS-15, Arabic version, score >5 indicated depression	None
Bazargan et al. (2001)	United States	NA	998	Mean age, 72.41 years (±7.28), 76.10% female	Self-reported hearing ability measured by "How is your hearing?" with response categories of 1 = *excellent*, 2 = *good*, 3 = *fair*, and 4 = *poor*	Brief Symptom Inventory (BSI), cutoff score not reported	None
Behera et al. (2016)	India	CRHSP	395	Mean age, 69.20 years (±7), 56.46% female	Rinnes and Weber Tuning Fork Test at 512 Hz	GDS, Hindi version, score ≥11 indicated depression	Sex, education, type of family, number of family members, living status, income, family decision-making, number of confidants, number of dependents
Bergdahl et al. (2005)	Sweden	Umea 85+ Study	242	Participants ≥60 years, mean age not reported, 77.20% female	Self-reported hearing ability of a normal speaker at 1-m distance	GDS-15 score >5 indicated depression *Diagnostic and Statistical Manual of Mental Disorders* (*DSM-IV*) criteria for "depression"	None
Blay et al. (2007)	Brazil	NA	6,922†	Participants ≥60 years, mean age not reported, 65.91% female	Self-reported hearing ability measured by asking participants whether they had hearing impairment	Short Psychiatric Evaluation Schedule, score ≥2 indicated depression	Health-related characteristics, health service use, physical activity, living alone
Carabellese et al., 2013	Italy	NA	1,054†	Participants ≥60 years, mean age not reported, 63.05% female	Free-field voice test, researcher pronouncing a set of three random numbers with a whispered voice at 0.5 m behind the participant	Beck's Depression Inventory, cutoff score not reported	None
Chou et al. (2005)	Hong Kong	GHS	1,903	Participants ≥60 years, mean age not reported, 53.83% female	Self-reported hearing ability measured by asking participants to rate their hearing with aids on a four-point scale: 1 = *very good*, 2 = *good*, 3 = *poor*, and 4 = *almost or completely unable to hear*	GDS-15, Chinese version, score ≥8 indicated depression	None

Table 1. *Continued*

Authors	Country	Study name	*N*	Sample	Hearing assessment	Depression assessment	Covariates
Crews et al. (2004)	United States	SOA-II	7,774†	Participants ≥60 years, mean age not reported, 56.15% female	Self-reported hearing ability measured by asking participants to respond to whether they had either "deafness in one ear," "deafness in both ears," or "any other trouble hearing"	National Health Interview Survey, cutoff score not reported	Age, sex, ethnicity
Herbst et al. (1980)	United Kingdom	NA	217†	Participants ≥60 years, mean age not reported, 63.64% female	Pure tone audiometry, mean threshold >30 dB in better ear at 0.5, 1, 2, and 4 kHz	CARE score ≥7 indicated depression	None
Hidalgo et al. (2009)	Spain	NA	1,160†	Mean age, 73.30 years, 55.90% female	Pure tone audiometry, mean threshold >40 dB in one or both ears at 1 and 2 kHz	GDS cutoff score not reported	None
Jang et al. (2003)	United States	CCHA	425	Mean age, 72.20 years (±6.25), 51.10% female	Pure tone audiometry, mean threshold >40 dB in better ear at 1 and 2 kHz	GDS-15 cutoff score not reported	Age, sex, marital status, cognition, chronic conditions, vision
Jones et al. (1984)	United Kingdom	NA	626†	Participants ≥60 years, mean age not reported, 61.95% female	Self-reported hearing ability measured by asking participants "do you have any difficulty hearing ordinary conversation (even when wearing your hearing aid)?" Answers were recorded as "no," "a little difficulty," or "a lot of difficulty"	Symptoms States Inventory, cutoff score not reported	None
Keidser et al. (2017)	United Kingdom	UK Biobank	61,979†	Mean age, 64.1 years, 51.26% female	Digit Triplets Test for better ear Self-reported hearing ability measured by asking participants "Do you find it difficult to follow a conversation if there is background noise (such as TV, radio, children playing?)"	Self-reported number of depressive episodes Self-reported experience of depressive symptoms	None
Krsteska (2012)	Macedonia	NA	120	Mean age, 70.78 years (±6.41), 72.50% female	Self-reported hearing ability measured as the severity of hearing loss using a 3-point scale from 1 = mild to 3 = profound	GDS cutoff score not reported	Not reported
Lee et al. (2010)	China	NA	912	Mean age, 71.90 years, 59.50% female	Pure tone audiometry, mean threshold >40 dB in one or both ears at 0.5, 1, 2, and 4 kHz Self-reported hearing ability (no other details reported)	GDS-15 Chinese version, score ≥8 indicated depression	Age, sex, marital status, education, self-perceived health, income, living satisfaction, hospital admissions, psychiatric illness

Table 1. *Continued*

Authors	Country	Study name	*N*	Sample	Hearing assessment	Depression assessment	Covariates
Lee and Hong (2016)	South Korea	National Survey on the Living Status of the Elderly	2,054†	Mean age, 75.77 years (±6.05), 100% female	Self-reported hearing ability measured by asking participants "do you have trouble in activities of daily life due to hearing?" and responses recorded as "trouble" or "no trouble"	GDS-15 Korean version, score ≥8 indicated depression	Education, living standards, living alone, chronic diseases, medications, instrumental activities of daily living, muscle strength, exercise, vision, health status
Lindesay (1990)	United Kingdom	Guy's/Age Concern Survey	890	Participants ≥60 years, mean age not reported, 59.89% female	Self-reported hearing ability measured as a physical health problem within the Older Americans Resources and Services (OARS) questionnaire	CARE score ≥7 indicated depression	None
Malhotra et al. (2010)	Sri Lanka	SLAS	933†	Participants ≥60 years, mean age not reported, 55.20% female	Self-reported hearing ability measured by asking participants whether they had hearing difficulty and recorded as "unable to hear" or "difficult to hear a person speaking at a normal volume	GDS-15 score ≥6 indicated depression	Age, sex, ethnicity, marital status, residence, income, years of education, functional health, physical health, living arrangement
Mick et al. (2016)	United States	NHANES	974†	Participants ≥60 years, mean age not reported, 60% female	Pure tone audiometry, mean threshold >25 dB in better ear at 0.5, 1, 2, and 4 kHz	Patient Health Questionnaire (PHQ-9), score ≥10 indicated depression	Age, sex, ethnicity, level of education, income, history of illnesses
Millan-Calenti et al. (2011)	Spain	NA	460†	Mean age, 75.10 years (±7.50), 40.50% female	Self-reported hearing ability measured as a physical health problem within the Older Americans Resources and Services (OARS) questionnaire	GDS-15 score ≥6 indicated depression	Not reported
Ojagbemi et al. (2016)	Nigeria	ISA	2,308†	Participants ≥60 years, mean age not reported, 39.10% female	Self-reported hearing ability measured by asking participants whether they had "difficulty hearing clearly" and responses recorded as "yes" or "no"	DSM-IV criteria for "depression"	None
Perlmutter et al. (2010)	United States	NA	88	Mean age, 74.30 years (±7.20), 64% female	The Hearing Screening Test that measured a participants' capacity for hearing a combination of high- and low-pitched sounds used in everyday conversation and without the benefit of lip reading	GDS-15 score ≥5 indicated depression	None
Rosso et al. (2013)	United States	WHI-OS	29,544	Mean age, 70.10 years (±3.70), 100% female	Self-reported hearing ability measured as any trouble with hearing during the past 4 weeks	Center for Epidemiologic Studies Depression Scale, Short Form (CES-D), score of .06 indicated depression	None

Table 1. *Continued*

Authors	Country	Study name	*N*	Sample	Hearing assessment	Depression assessment	Covariates
Yasuda et al. (2007)	United States	NA	200	Mean age, 80.01 years (±7.52), 0% female	Self-reported hearing ability (no other details reported)	*DSM-IV* criteria for "major depression"	None
Cohort studies							
Amieva et al. (2018)	France	PAQUID (25-year follow-up)	3,080	Mean age, 75.30 years (±6.80), 57.80% female	Self-reported hearing ability measured by asking participants "do you have hearing trouble?" and responses recorded as either "I do not have hearing trouble," "I have trouble following conversation with two or more people talking at the same time in a noisy background," or "I have major hearing trouble"	CES-D, score ≥17 indicated depression for men and a score ≥23 indicated depression for women	Age, gender, education, health comorbidities
Boorsma et al. (2012)	Netherlands	NA (1.2-year follow-up)	2,453†	Participants ≥60 years, mean age not reported, 71.27% female	Self-reported hearing ability measured as the sum score of four items of hearing difficulties and hearing aid use	*DSM-IV* criteria for "depression"	None
Brewster et al. (2018)	United States	Healthy ABC Study (10-year follow-up)	1,204	Mean age, 73.10 years (±2.75), 53.99% female	Self-reported hearing ability measured by asking participants "can you hear well enough to carry on a conversation in a crowded room?" and responses recorded as "no hearing loss" or "hearing loss"	CES-D, score ≥10 indicated depression CES-D, short-form, score ≥5 indicated depression	Age, race, gender, education
Chou (2008)	United Kingdom	ELSA (2-year follow-up)	3,782	Participants ≥60 years, mean age and sex not reported	Self-reported hearing ability measured by asking participants to rate their hearing with aids on a 5-point scale ranging from "excellent" to "poor"	CES-D, dichotomous score ≥3 indicated depression	Age, sex, marital status, education, employment, income, illnesses, physical impairment, lifestyle factors, family support
Cosh et al. (2018)	Norway	Tromso Study (6-year follow-up)	1,784†	Mean age, 69.39 years (±3.69), 45.03% female	Self-reported hearing ability measured as a participants' inability or difficulty with hearing a normal conversation	Hopkins Symptom Checklist-10 (HSCL-10), cutoff score not reported	Age, sex education, living alone, marital status, use of antidepressants, life style factors, self-reported health, illnesses, mobility
Forsell (2000)	Sweden	NA (3-year follow-up)	894	Mean age, 84.50 years, sex ratio not reported	Self-reported hearing ability measured as presence of a hearing disability associated with impaired activities of daily living	*DSM-IV* criteria for "depression"	None
Kiely et al. (2013)	Australia	ALSA (16-year follow-up)	1,611	Participants ≥60 years, mean age not reported, 51.10% female	Pure tone audiometry, mean threshold >25 dB in better ear at 0.5, 1, 2, and 4 kHz	CES-D, score >16 indicated depression	Age, sex education, marital status, domicile, smoking and alcohol consumption, diabetes, cardiovascular disease, cognitive function, disability, activity engagement

Table 1. *Continued*

Authors	Country	Study name	*N*	Sample	Hearing assessment	Depression assessment	Covariates
Prince et al. (1998)	United Kingdom	NA (1-year follow-up)	654	Mean age, 75.80 years, 61% female	Self-reported hearing ability measured as a physical health problem within the Older Americans Resources and Services (OARS) questionnaire	SHORT—Comprehensive Assessment and Referral Evaluation (SHORT-CARE), cutoff score not reported	Handicap
Pronk et al. (2011)	Netherlands	ALSA+ (1-year follow-up)	1,821	Mean age, 74.50 years, 56.50% female	Speech-in-noise test without hearing aids with the speech-reception-threshold in noise by telephone defined as a signal-to-noise ratio in decibels corresponding to 50% intelligibility. Self-reported hearing ability without hearing aids was measured by asking participants three questions: (a) can you follow a conversation in a group of three or four people?, (b) can you follow a conversation with one person?, and (c) can you use a normal telephone?	CES-D, cutoff score not reported	Education, income, self-reported vision, diseases, cognition
Saito et al. (2010)	Japan	Kurabuchi Study (2-year follow-up)	548	Participants ≥60 years, mean age not reported, 54.38% female	Pure tone audiometry, >30 dB at 1 kHz in better ear. Hearing Handicap Inventory for the Elderly (HHIE)	GDS-15, score ≥6 indicated depression	Age, sex, education, living circumstances, lifestyle factors, history of illnesses, vision impairment, objective hearing loss
Simning et al. (2018)	United States	NHATS (1-year follow-up)	5,589†	Participants ≥60 years, mean age not reported, 50.92% female	Self-reported hearing ability measured by asking participants (with or without hearing aids) if they were able to "hear well enough to carry on a conversation in a room with a radio or TV playing"	Patient Health Questionnaire (PHQ-2)	Age, sex, marital status, race/ethnicity, education, social contacts, medical conditions, activities of daily living, instrumental activities of daily living‡

Notes: ALSA = Australian Longitudinal Study of Ageing; ALSA+ = Amsterdam Longitudinal Study of Ageing; CARE = Comprehensive Assessment and Referral Evaluation; CCHA = Charlotte County Healthy Ageing Study; CES-D = Center for Epidemiologic Studies Depression Scale; CRHSP = Comprehensive Rural Health Services Project; dB = decibels; DSM-IV = *Diagnostic and Statistical Manual of Mental Disorders*; ELSA = English Longitudinal Study of Ageing; GDS-15 = Geriatric Depression Scale-15, GHS = General Household Survey; Healthy ABC = Healthy Aging and Body Composition Study; Hz = Hertz; ISA = Ibadan Study of Ageing; kHz = Kilohertz; NA = not applicable; NHANES = National Health and Nutrition Examination Survey; NHATS = National Health & Aging Trends Study; PAQUID = Personnes Agees QUID? (i.e., What about older persons?); SLAS = Sri Lanka Ageing Survey; SOA-II = Second Supplement on Ageing; WHI-OS = Women's Health Initiative Observational Study.

†Subset of participants from original sample.

‡Authors did not report cohort results adjusted by these covariates.

sample demographics, participants were older adults (age M_{years} = 73.43, SD = 4.40; N = 18) and more frequently female (58.69%, N = 33). Five studies used an objective measure of hearing loss, 26 studies used a subjective measure, and four studies used a combination of both measures. Twelve studies reported including participants with experience using hearing aids and 18 studies reported including a proportion of participants with cognitive decline. Less than half (N = 16) of included studies reported results adjusted for covariates. Sixteen different measures involving 24 different cutoff scores were used to assess depression and 10 different measures involving 34 different cutoff scores were used to assess hearing loss. Among cohort studies, follow-up periods ranged 1–25 years. Two cohort studies were classified as cross-sectional designs in this meta-analysis for only providing baseline data to compute an effect for the association between hearing loss and depression (Ojagbemi, Bello, Luo, & Gureje, 2016; Rosso et al., 2013). No studies from gray literature databases met inclusion criteria for this review. Refer to Supplementary Table 3 for characteristics of included studies and Supplementary Table 4 for the complete reference list of all studies that met inclusion criteria.

Hearing Loss and Depression

Overall hearing loss was associated with a less than small, but statistically significantly greater odds of depression in older adults (OR = 1.47, 95% CI = 1.31–1.65; see Figure 2). Egger's regression was not significant (p = .38) indicating no presence of publication bias within the overall effect and 2,267 studies with nonsignificant results would be needed to render this effect zero. When studies were stratified by design, hearing loss was associated with greater odds of depression among cross-sectional studies (OR = 1.54, 95% CI = 1.31–1.80) and cohort studies (OR = 1.38, 95% CI = 1.15–1.66). There was no statistically significant difference between cross-sectional or cohort effect estimates (Q = 0.77, p = .38). All studies were therefore combined and the overall association between hearing loss and depression was explored in the following analyses.

Quality of Evidence

According to the GRADE criteria (Schünemann et al., 2013), the certainty in evidence for hearing loss associated with increased odds of depression in older adults was low (see Table 2). A majority of studies (N = 19) did not control for covariates in outcome results, which contributed to a one level downgrading of certainty in the quality of evidence. As per GRADE recommendations (Schünemann et al., 2013), certainty in the evidence was downgraded a second level due to the inherent limitations associated with the validity of findings from observational studies.

Heterogeneity

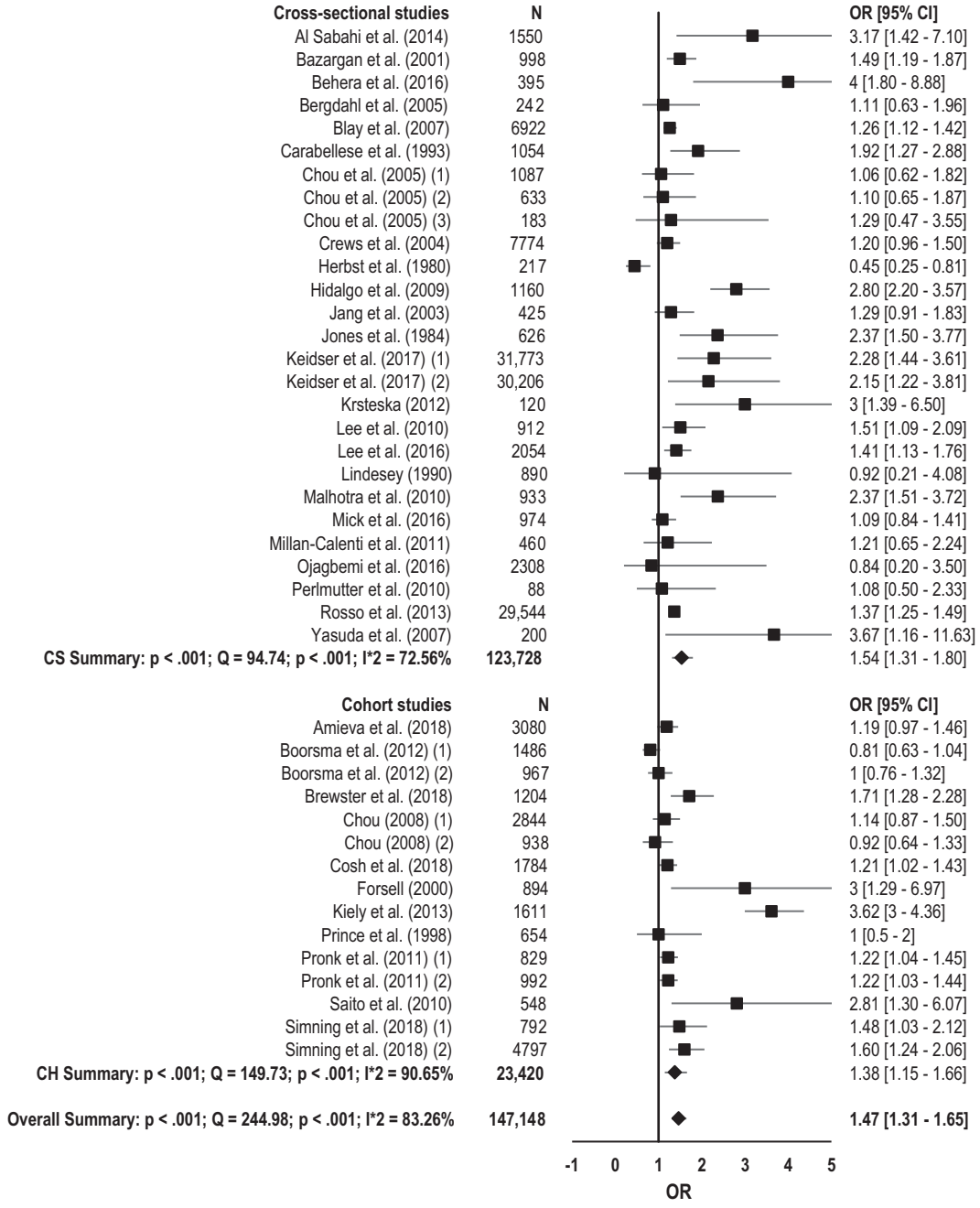
The overall pooled effect contained a large and significant degree of heterogeneity (see Figure 2). Meta-analysis of variance was used to examine whether moderator variables accounted for variance within the effect. No significant differences were observed in the association between hearing loss and depression when studies were grouped and compared by type of hearing measure, use of hearing aids by a proportion of participants, presence of cognitive impairment among a proportion of participants, or inclusion of covariates in outcome results (see Supplementary Table 5).

Sensitivity Analyses

Cosh and colleagues (2018), Jang and colleagues (2003), Kiely and colleagues (2013), and Pronk and colleagues (2011) reported the relationship between hearing loss and depression as beta coefficients that were converted into ORs for this meta-analysis; Rosso and colleagues (2013) included a large sample (N > 20,000); Keidser and Seeto (2017) reported beta coefficients from a large sample; and Boorsma and colleagues (2012), Krsteska (2012), and Yasuda, Horie, Albert, and Simone (2007) examined the association between hearing loss and depression in older adults living in high care settings (e.g., nursing homes, hospitals). Sensitivity analyses were conducted to determine if removing these studies would account for heterogeneity within the association between hearing loss and depression. Following each sensitivity analysis, the association between hearing loss and depression remained statistically significant and with a large-to-moderate degree of heterogeneity (see Supplementary Table 6).

Discussion

Findings from this systematic review and meta-analysis indicate that hearing loss is associated with 1.47 greater odds of depression in older adults. Older adults with hearing loss are likely to experience emotional and social loneliness (Contrera, Sung, Betz, Li, & Lin, 2017; Pronk et al., 2014), poor cognitive function (Jayakody, Friedland, Eikelboom, Martins, & Sohrabi, 2018; Loughrey et al., 2017), and difficulty in completing daily activities (Gopinath et al., 2012), which are also independently associated with increased depressive symptoms in later life (Hörnsten, Lövheim, Nordström, & Gustafson, 2016; Luanaigh & Lawlor, 2008; Wang & Blazer, 2015). Hearing loss may therefore worsen existing difficulties associated with psychosocial and functional abilities during older age, increasing the likelihood of developing depression. Within the stress process paradigm (Pearlin, Menaghan, Lieberman, & Mullan, 1981), extent of social support may explain the association between hearing loss and depression in older adults (West, 2017). In a large (N > 6000) longitudinal study of U.S. adults (aged ≥50 years), West (2017) found that without sufficient



Notes: OR = Odds ratio; CI = Confidence interval; p = Significance level; Q = Cochrane's Q; I*2 = Percentage of heterogeneity; Chou et al. (2005)(1) = 'Young-old' participants; Chou et al. (2005) (2) = 'Old-old' participants; Chou et al. (2005) (3) = 'Oldest-old' participants; Keidser et al. (2017) (1) = Female participants; Keidser et al. (2017) (2) = Male participants; Boorsma et al. (2012) (1) = Residential Care participants; Boorsma et al. (2012) (2) = Nursing Home participants Chou et al. (2008) (1) = Participants not depressed at baseline; Chou et al. (2008) (2) = Participants depressed at baseline; Pronk et al. (2011) (1) = Objective measure of hearing loss; Pronk et al. (2011) (2) = Subjective measure of hearing loss; Simning et al. (2018) (1) = Participants depressed at baseline; Simning et al. (2018) (2) = Participants not depressed at baseline.

Figure 2. Forest plot of the association between hearing loss and depression.

social support, hearing loss manifests as a chronic stressor in older adults leading to the proliferation of depression as an additional stressor. Earlier work by Kiely and colleagues (2013) also reported an association between hearing loss and depression that was fully explained by social engagement and participation in mentally stimulating activities. Few studies in this meta-analysis measured or controlled for social support, which did not permit exploration of

Table 2. The Grading of Recommendations Assessment, Development, and Evaluation Summary of Evidence for the Association Between Hearing Loss and Depression

Population: older adults with or without hearing loss
Setting: community samples

Outcome, no. of participants (studies)	Risk of bias	Inconsistency	Indirectness	Imprecision	Overall certainty of evidence	Effect size, OR (95% CI)	What happens
Depression, 147,148 (35 studies)[†]	Serious	Not serious	Not serious	Not serious	⊕⊕○○ LOW[‡,§,‖,¶,#]	1.47 (1.31–1.65)	Hearing loss is associated with 1.47 times greater odds of depression among older adults

Note: Values in bold are significant at the .001 level. CI = confidence interval; OR = Odds ratio.
[†]35 studies including 42 subgroups.
[‡]Certainty of evidence downgraded one level because majority of studies were graded as high risk of bias for not controlling covariates in outcome results.
[§]Study effects most frequently ranged between small and moderate, which supported consistency within the pooled effect.
[‖]Indirectness was not downgraded considering meta-analytic findings showed participant and study characteristics did not explain heterogeneity within the pooled effect.
[¶]Many studies including large *N* participants were included in the pooled effect, which supported precision and certainty in this result.
[#]Overall certainty of evidence was downgraded one level because the evidence included only observational studies.

this relationship in the current review. Nonetheless, findings from this meta-analysis indicate that older adults with hearing loss experience increased odds of depression and recent studies suggest that adequate social support may mitigate the severity of depressive symptoms.

Neuropathological changes to the aging brain have also been proposed as potential mechanisms associated with hearing loss and depression in older adults (Rutherford et al., 2018). Individuals with hearing loss have shown impaired limbic system and auditory cortex activity in response to emotionally positive and negative auditory stimuli (Husain, Carpenter-Thompson, & Schmidt, 2014; Rutherford et al., 2018). Neuroimaging evidence also shows diminished activation of frontal cortical regions in older adults with hearing loss (Boyen, Langers, de Kleine, & van Dijk, 2013; Husain et al., 2011) and depression (Murrough et al., 2016). Although the cortical pathways associated with hearing loss and depression in older adults are not well understood, these preliminary studies suggest homogeneous neuropathological mechanisms may facilitate hearing loss and depression in older adults. However, more high-quality research combining imaging, audiology, and neuropsychology is needed to increase our understanding of these relationships and potentially determine the temporal relationship between these comorbidities.

There was a large and significant degree of heterogeneity within the overall association between hearing loss and depression, but differences in study and participant characteristics did not explain variance within the effect. When sufficient covariates are measured and controlled in outcome results, cohort studies (compared to cross-sectional studies) provide more meaningful evidence by allowing inference to be made about the temporal nature of comorbid health conditions. Cross-sectional studies are also subject to methodological limitations including participant response bias and convenience sampling (Sedgwick, 2013), which may falsely inflate an association between outcomes when measured at one point in time. A cross-sectional association between hearing loss and depression may therefore diminish when measured consistently over time. However, this meta-analysis showed a significant association between hearing loss and depression in cross-sectional and cohort pooled effects. Findings from this review therefore suggest that older adults appear to experience increased odds of depression associated with hearing loss and this association may remain consistent over time.

Subjective outcome measures may elicit a response bias leading to an over (or under) estimation of the severity of health conditions (Daltroy, Larson, Eaton, Phillips, & Liang, 1999; Dowling, Bolt, Deng, & Li, 2016) and previous studies had suggested the use of hearing aids may improve depressive symptoms associated with hearing loss (Manrique-Huarte et al., 2016). However, this review showed no difference in the association between hearing loss and depression when studies used subjective or objective measures of hearing loss or when they included a

proportion of participants with previous experience using hearing aids. In a large (N > 100,000) community-based study, Keidser, Seeto, Rudner, Hygge, and Rönnberg (2015) found that irrespective of measure used to evaluate hearing loss or whether participants were hearing aids users, severity of hearing loss was associated with increased depressive symptoms. As described by Ioannidis (2016), even the most rigorous and carefully conducted cohort studies often cannot determine the temporal relationship between variables of interest. Considering the observational nature of the current findings, it is therefore difficult to determine whether an individual's hearing loss precedes the onset of depression or experiences of their poor health increase feelings of depression, which negatively affect perception of their hearing. It is also important to note that most studies included in this review did not report the exact proportion of their sample with experience using hearing aids. There is also a discrepancy between hearing aid owners and hearing aid users, with up to 24% of hearing aid owners reporting having never used their hearing aids (Hartley, Rochtchina, Newall, Golding, & Mitchell, 2010). It is therefore likely that hearing aid owners and users were misrepresented in this meta-analysis, which may have contributed to the null finding. With these caveats in mind, results from these preliminary moderator analyses suggest that self-reported hearing loss may be a sufficient estimate of hearing loss and its association with depression in older adults and hearing aids *may* not alleviate depressive symptoms associated with hearing loss.

Epidemiological studies can falsely inflate the strength of an association between outcomes by not controlling variables known to influence the outcomes of interest (Greenland & Pearce, 2015). Less than half of the studies included in this review reported results adjusted by covariates. There was, however, no difference in the association between hearing loss and depression when studies were compared by adjusted or unadjusted results. There was also no difference in the association between hearing loss and depression when studies were compared by whether or not they included a proportion of participants with cognitive deficits. Hearing loss is associated with a decline in cognitive function among older adults (Jayakody et al., 2018; Loughrey et al., 2017), and cognitive impairment is associated with increased levels of depression in later life (Wang & Blazer, 2015). We therefore expected greater odds of depression among studies that included participants with hearing loss and cognitive impairment and those that reported results unadjusted by covariates. Whereas the current findings suggest that older adults with hearing loss and cognitive decline may not experience greater increased odds of depression when compared to individuals with hearing loss but without cognitive decline, and the association between hearing loss and depression may not be influenced by individual or group differences in health and demographic characteristics. Similar to the null effect of hearing aids, however, few studies reported the proportion of their sample with, and the severity of cognitive deficits or primarily examined cognitive impairment associated with hearing loss and depression. It is therefore not clear what proportion of participants in this meta-analysis had cognitive impairment, which must be considered when interpreting these results.

Sensitivity analyses also provided no explanation for heterogeneity within the pooled effect for hearing loss and depression. Studies were removed from the pooled effect for reporting beta coefficients that needed to be converted into ORs for this meta-analysis, for including large samples (N > 20,000) that may bias the association by the weight of their contribution to the effect, and for examining hearing loss and depression in older adults living in high care settings (e.g., nursing homes, hospitals) likely to experience more severe hearing loss and depression (Boorsma et al., 2012; Cosh et al., 2018; Keidser & Seeto, 2017; Kiely et al., 2013; Krsteska, 2012; Pronk et al., 2011; Rosso et al., 2013; Yasuda et al., 2007). However, the association between hearing loss and depression remained significant and with a large-to-moderate degree of heterogeneity following each sensitivity analysis. These findings suggest that the association between hearing loss and depression was not falsely inflated by statistical methods used to convert study effect sizes for meta-analysis, primarily driven by the power of studies with large samples, or influenced by potentially stronger hearing loss and depression associations frequently found in older adults living in high care settings.

Certainty in the evidence supporting the association between hearing loss and depression was low (Schünemann et al., 2013). Certainty in evidence was primarily downgraded due to limitations associated with including only observational studies that lack methodological rigor of more robust designs (e.g., clinical trials). Among the GRADE criteria (Schünemann et al., 2013), only risk of bias was downgraded one level by considering that more than half of included studies did not report results adjusted for covariates. That being said, moderator analysis showed no difference between studies reporting adjusted or unadjusted results. It is also important to note that inconsistency in the evidence was not downgraded despite a large degree of heterogeneity (I^2 = 83.26%) within the pooled effect. Meta-analytic heterogeneity must be considered within the respective body of evidence (Schünemann et al., 2013), and most studies (>70%) included in this meta-analysis reported small-to-medium effects with overlapping CIs. We therefore concluded that differences between study effect estimates were relatively consistent across studies, which supported the statistically significant and consistent association between hearing loss and depression reported this meta-analysis.

There are limitations to this review. Many different outcomes and cutoff scores were used to measure depression and hearing loss and some studies did not provide sufficient detail to determine specific methods used. Only one study (Saito et al., 2010) reported the association between

subjective hearing loss and depression using a validated and standardized questionnaire (e.g., Hearing Handicap Inventory for the Elderly), with remaining studies using a variety of self-report questions and criteria. Variability in methodological reporting across studies led to crude categorization of moderator variables, which likely contributed to the null moderator findings and also limited our ability to explore whether severity of hearing loss and/or depression accounted for variance within the overall effect. Conversion of Kiely and colleagues' (2013) beta coefficient to an OR for this meta-analysis led to a false inflation of their nonsignificant finding to a large and significant association between hearing loss and depression. Removing Kiely and colleagues (2013) had no impact on the overall effect, but this statistical difference between effects must be noted. Moreover, the current findings are limited to older adults (≥60 years) and evidence suggests younger adults may experience more severe depressive symptoms associated with hearing loss (Keidser & Seeto, 2017). To increase our understanding of these concomitant health conditions across the life span, researchers may wish to systematically review and meta-analyze the association between hearing loss and depression in younger adult and adolescent populations. Furthermore, we strongly recommend findings from the moderator analyses be interpreted with caution, and future studies use randomized controlled trial designs to provide more substantive evidence of whether hearing aids improve depressive symptoms in older adults with hearing loss and whether cognitive decline is or is not associated with the relationship between hearing loss and depression. We also recommend future epidemiological studies adopt more rigorous designs by ensuring they consistently measure, report, and control for the influence of hearing aid ownership and use, presence and degree of cognitive decline, severity of depression and hearing loss, and more broadly, general health and demographic characteristics (e.g., age, years of hearing loss) likely to influence the association between hearing loss and depression in later life.

Findings from this review indicate that aural rehabilitation in the form of hearing aids may not alleviate depressive symptoms associated with hearing loss. Recent evidence shows that social support may moderate the relationship between hearing loss and depression in later life (West, 2017), suggesting that older adults may benefit from educational training (Preminger & Meeks, 2010) and psychosocial counseling (Lindsey, 2016) to equip them with resources to assist with their changing health and the associated impact on their quality of life. Adults with severe to profound hearing loss also report not receiving, but wanting referrals to, psychosocial counseling as part of their aural rehabilitation (Hallam, Ashton, Sherbourne, & Gailey, 2006). It is important to note, however, that many older adults associate stigma with depression and mental health disorders (Conner et al., 2010), which often inhibits their intentions to seek help and making it increasingly difficult for audiologists and geriatricians to identify when older adults may be in need of, and will benefit from, intervention. For example, the United Kingdom's Royal College of Psychiatrists reported that upon hospital admission, almost half of all older adults with a diagnosis of depression did not have that diagnosis included in their patient notes or reported in their discharge correspondence to their general practitioner (Hood, Plummer, & Quirk, 2018). Audiologists may benefit from training to increase their understanding of psychosocial difficulties experienced by older adults with hearing loss (Ekberg, Grenness, & Hickson, 2014) and to increase their confidence in identifying and discussing mental health concerns with older clients. Increased use of depression screening tools (e.g., Geriatric Depression Scale) by health professionals working with older adults with hearing loss may also increase awareness of depression in this population and the proportion of individuals benefiting from psychologists and psychiatrists specializing in treatment of depression (Smarr & Keefer, 2011).

Finally, it is important to note the size of the effect found in this meta-analysis. Hearing loss was associated with 1.47 greater odds of depression and following recommended conventions (Chen et al., 2010), this is a less than small effect. Although the association was statistically significant, a less than small increase in the odds of depression indicates that a small proportion of older adults may experience depressive symptoms associated with their hearing loss, but most may not. Within the broader population, depression is frequently associated with negative life events (e.g., death of a loved one, loss of income), long-term stress, personality disorders, substance abuse, and poor diet (Beck & Alford, 2009), and these factors may be worsened for older adults who experience a general decline in their health and/or hold negative perceptions of aging (Freeman et al., 2016). Health practitioners (specifically audiologists) working with older adults with hearing loss must therefore be aware of the heterogeneous etiology of depression and understand that a proportion, but not the majority, of older clients will experience depressive symptoms associated with their hearing loss.

Conclusion

An extensive systematic review and meta-analysis identified 35 studies examining hearing loss and depression in older adults. There are two main findings from this review. First, hearing loss is associated with 1.47 greater odds of depression in older adults, albeit a less than small association. Second, the association between hearing loss and depression may not be influenced by type of hearing loss measure, using of hearing aids, or demographic and health characteristics. These findings are strengthened by evidence from a large (N > 145,000) globally representative sample of older adults. A proportion of older adults may experience depressive symptoms associated with hearing loss, and we recommend allied health professionals and general

practitioners increase their awareness and understanding of depression experienced during aging.

Supplementary Material

Supplementary data are available at *The Gerontologist* online.

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Author Contributions

B. J. Lawrence was responsible for conception, design, and execution of the project, conducted article screening, data extraction, bias assessment, and statistical analysis, and wrote the first draft of the manuscript. R. J. Bennett was responsible for article screening and provided expert review and critique of important intellectual content. D. M. P. Jayakody, Robert H. Eikelboom, N. Gasson, and P. L. Friedland provided expert review and critique of important intellectual content.

Conflict of Interest

B. J. Lawrence, D. M. P. Jayakody, Robert H. Eikelboom, R. J. Bennett, and P. L. Friedland are supported by the Ear Science Institute Australia. The contribution by N. Gasson was supported by Curtin University. The views expressed are those of the authors and not necessarily those of the Ear Science Institute Australia or Curtin University.

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