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Social engagement and depressive symptoms mediate the relationship between age-related hearing loss and cognitive status

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Author Contributions

Ivy Yan Zhao, Angela Yee Man Leung and Laurence Lloyd B. Parial designed the study and formulated the analysis plan. Laurence Lloyd B. Parial and Ivy Yan Zhao implemented the statistical analysis. Ivy Yan Zhao and Laurence Lloyd B. Parial wrote the manuscript with support from all other authors.

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ABSTRACT

Background and objectives: Age-related hearing loss (ARHL) is the third leading cause of years lived with disability. Connections among ARHL, depressive symptoms, social engagement and cognitive status are increasingly reported but the underlying mechanisms leading to these relationships are largely unknown. Exploring these mechanisms is a worthy goal, especially in older adults. This study aimed to examine the mediating effect of social engagement and depressive symptoms on the relationship between ARHL and cognitive status.

Methods: Structural equation modelling (SEM) with path analysis were performed with data from a cross-sectional study conducted in 11 community centers in 2021, which assessed older adults' intrinsic and sensory capacities using the WHO ICOPE framework. Demographic information, health profile, a binary measure of hearing capacity, depressive symptoms, social engagement, and cognitive status of participants were gathered.

Results: A total of 304 participants were included. ARHL was positively associated with depressive symptoms (β=0.18, p=0.009) and negatively related to social enagegement (β= -0.13, p=0.026). Social engageemnt was positively associated with cognitive status (β=0.17, p=0.005) and negatively associated with depressive symptoms (β= -0.23, p<0.001). Greater depressive sympptoms were negatively associated with the participants' cognition (β= -0.13, p=0.009). Both social engagement (β= -0.02, p=0.029) and depressvive sympotms (β= -0.02, p=0.032) mediated the negative associations between ARHL and cognitive status.

Conclusions: Addressing hearing loss, depressive symptoms, and enhancing social engagement should be investigated as a potential means of minimizing cognitive decline. Well-designed studies are needed to comprehensively inform the clinical practice development, particularly large prospective studies that will facilitate further elucidate possible causal mechanisms behind these observed associations.

KEYWORDS

Age-related hearing loss; cognition; social engagement; depressive symptoms; older adult

Key Points:

- Our findings highlight the potential risks of age-related hearing loss (ARHL), less social engagement and depressive symptoms on cognitive decline among older adults.
- Social engagement and depressive symptoms mediated the negative associations between ARHL and cognitive status. If people have both ARHL and depressive symptoms or both ARHL and social disengagement, the risks of cognitive impairment could increase.
- Treating hearing loss, addressing depressive symptoms, and enhancing social engagement should be investigated as a potential means of minimizing cognitive decline.

INTRODUCTION

Presbycusis or age-related hearing loss (ARHL) is the third leading cause of years lived with disability [1]. While historically treated as a benign effect of aging, ARHL has been recently associated with cognitive decline and dementia [2 3]. Greater ARHL is associated with increased loneliness [4], decreased communication, less social engagement and depression in older adults [5]. Older adults with decreased social engagement also reported worse scores on measures of depressive symptoms [6].

ARHL is a gradual, progressive and bilateral symmetric sensorineural hearing loss with an incidence that increases significantly with age [7]. According to the World Report on Hearing, approximately 70% of people over the age of 70 (>8.3 million people) have ARHL[8]. Epidemiological data regarding the prevalence of ARHL is limited in the Chinese population. In the 2013 census report of Hong Kong on disabilities and chronic diseases, the number of people with self-reported hearing difficulty increased from 92,200 (or 1.3% of the total population) in 2007 to 155,200 (or 2.2% of the total population) in 2013. There were 128,900 people aged 60 and above (21.8% of the total population) reported hearing difficulty and the prevalence of ARHL was high among people over the age of 70 and above (14.2% of the total population) [9].

ARHL is a multifactorial condition that can be impacted by a combination of intrinsic factors, such as genetic predisposition as well as extrinsic factors, such as environmental noise exposures, cardiovascular risk factors [10], living alone [11], and educational level [12]. ARHL is irreversible and the existing hearing interventions mainly include hearing aids and cochlear implantation combined with auditory rehanilitation.

Despite the high prevalence of ARHL, treatment remains vastly underutilized globally [13]. In mainland China, only 0.8% of older adults with hearing loss were found to wear hearing aids [14]. In Hong Kong, over two-thirds (67.5%) of older adults with ARHL had neither been formally diagnosed nor addressed [9]. Numerous studies have shown that untreated ARHL is associated with cognitive decline and increased risk of dementia [15-17]. The hazard ratio for incident dementia increased to 4.9 in older adults with greater hearing loss compared to those without a hearing problem [18]. The Lancet International Commission on Dementia, Prevention, Intervention, and Care estimated that mid-life hearing loss, if treated, might decrease the risk of dementia by 9 percent at a population level[19].

Early intervention for cognitive decline is crucial and more likely to substantially delay the onset of dementia [20]; and early management of ARHL and cognitive decline for older adults is more cost-effective than delayed treatment [21]. While life expectancy has been extended on a global scale, the burden of ARHL, social disengagement and cognitive decline has become higher than ever [2 4]. Depressive symptoms are present in up to a third of older adults, which is associated with more functional and cognitive impairment than depression in younger adults [22]. Current research on the relationships among ARHL, depression, social engagement and cognitive decline are inconsistent. For example, a longitudinal analysis using English Longitudinal Study on Ageing reported that the link between hearing impairment and episodic memory was partly mediated by loneliness and social isolation [23]; while another longitudinal study demonstrated that no mediation effect of loneliness was

found for the association between hearing impairment and cognitive decline [24]. Moreover, less studies have included components of ARHL, cognitive decline, social engagement, and depression at the same time and the underlying mechanisms leading to the connections among them are largely unknown. The commonly reported hypotheses of etiological mechanisms based on previous studies include that the impaired hearing may contribute causally to cognitive decline through either the degradation of auditory signals or the depletion of information for perceptual processing [25]; and the hearing loss could lead to social disengagement, social isolation, or depressive symptoms, which accelerates the rate of brain atrophy [26 27]. These possible mechanisms are not mutually exclusive and well-designed studies are needed to investigate if hearing loss interventions could serve as means to improve cognitive status in older adults [28].

METHODS

Aims and hypotheses

This study aimed to test a hypothetical path model (Figure 1) estimating the relationships of ARHL with cognitive status, depressive symptoms, and social engagement among community-dwelling Chinese older adults in Hong Kong. Six hypotheses were proposed: ARHL has significant direct effects on cognitive status (hypothesis 1); ARHL has significant direct effects on depressive symptoms (hypothesis 2); ARHL has significant direct effects on social engagement (hypotheses 3); Social engagement has significant direct effects on depressive symptoms and cognitive status (hypotheses 4); ARHL has significant indirect effects on cognitive

status via social engagement (mediating the effects of social engagement between ARHL and cognitive status) (hypotheses 5); ARHL has significant indirect effects on cognitive status via depressive symptoms (mediating the effects of depressive symptoms between ARHL and cognitive status) (hypotheses 6).

(Insert Figure 1 here)

Study design and participants

The secondary data analysis was performed with data from a cross-sectional study conducted in 11 community centers in Hong Kong in 2021[29], which assessed older Chinese adults' intrinsic capacity domains of locomotion, cognition, vitality, psychological well-being, and sensory capacity (hearing and vision) by using the WHO Integrated Care for Older People (ICOPE) framework [30]. Older adults aged 60 years or above, living in their own homes, receiving no or some support with self-care (feeding, bathing, dressing, toileting) were recruited. We excluded those with acute cardiovascular diseases, acute infection, multiple organ dysfunction, dementia, acute mental illness, and nearly total- or total-dependent on self-care. Ethical approval of the cross-sectional study was obtained from the Human Subjects Ethics Sub-committee of the (*blinded*) University and written informed consent was collected from each participant prior to data collection [29].

The sample size required for Structural Equation Modelling (SEM) was computed based on the number of variables and indicators [31]. Particularly, we identified five factors (latent variables) and 26 indicators (observed variables) in this study. We also considered the following parameters in sample size calculation, as recommended by

Westland and his colleague [32] , effect size of 0.3, power of 0.80, and significance level of 0.05. Using the Free Statistics Calculator version 4 [33], the minimum sample size for this study was projected at 150.

Variable description

Demographic information and health profiles of participants, including age, sex, living situation (comprises living alone; living with spouse; living with family; living with friends; or living with others), education level, lifestyle behaviors, and medical history were obtained. Participants' hearing capacity, depressive symptoms, social engagement, and cognitive status were also gathered. Age, education level, living situation and cardiovascular risk factors were the covariates adjustment.

Hearing capacity

Weber and Rinne test and Whisper voice test in a quiet room were performed by a trained research assistant (RA) to assess whether an individual has normal hearing or potential hearing loss following the WHO ICOPE assessment guideline [30]. Prior to the assessment, the RA has completed a two-day knowledge and skills training following the ICOPE framework and passed the examination on assessment practices. Participants who could not correctly repeat the whisper words and failed both the Weber and Rinne test were considered to have hearing problems and included into data analysis.

Depressive symptoms

Patient Health Questionnaire (PHQ-9) was used to measure depressive symptoms in this study, which is documented as valid in Chinese [34]. PHQ-9 contains nine items on a

4-point Likert scale (marked 0 to 3), with higher scores indicating more severe depression. A score of 10 or above or reported suicidal ideas is considered in need of further diagnostic assessment, and a score between 5 to 9 indicates mild depression [34].

Social engagement

Social engagement was determined by one item which asked the extent of pursuing interests that are important to the participant, including hobbies, work, volunteering, supporting family, and educational or spiritual activities. A 3-point Likert scale was used to determine the level of engagement (1 = inactive, 2 = less active, 3 = active), with a higher score indicating being more active [30].

Cognitive status

Cognitive status was measured by the local version of the Montreal Cognitive Assessment (HK-MoCA), which is validated among Chinese older adults [35]. This instrument measures seven cognitive skills, such as visuospatial function, naming, attention, language, delayed recall, abstraction, and orientation. The HK-MoCA has adequate sensitivity and specificity in differentiating people with mild cognitive impairment (≥ 22 and < 26) from those with dementia (< 22, sensitivity: 93.2% and specificity: 71.7%) and normal cognitive function (≥ 26, sensitivity: 92.4% and specificity: 88.4%). For people who only attained primary school education or less, one point was added to their total score, whereas participants scoring below 22 were recommended for further evaluation. The research assistant was trained to make sure people with ARHL can hear and understand all the questions.

Data analysis

SPSS software version 25.0 (Armonk, NY: IBM Corp) was utilized for statistical analyses, with a significance value set at <0.05. Descriptive statistics, such as frequency, percentage, mean, and standard deviation (SD), were used to summarize the participants' demographic characteristics and clinical variables. Correlations among the study variables were assessed via Spearman rho coefficient before path analysis [36]. Variables with correlation coefficients <0.20 were considered for removal [37]. Hence, living status and cardiovascular risk factors were removed from the model for path analysis.

To identify the relationships among AHRL, social engagement, depressive symptoms, cognitive status, and other variables, structural equation modelling with path analysis was employed. We used the following parameters to determine model fitness: Chi-square/degrees of freedom ratio (CMIN/df) ≤ 3.00, comparative fit index (CFI) ≥ 0.90, Tucker-Lewis fit index (TFI) ≥ 0.90, normed fit index (NFI) ≥ 0.90, root mean square error of approximation (RMSEA) ≤ 0.08 [38]. IBM SPSS AMOS version 25 was utilized for this analytical method.

RESULTS

Participant characteristics

A total of 304 participants were included in this study. The participants' demographic and health profiles are shown in Table 1. The sample had a mean age of 76.73 (*SD* = 7.25), and 80.6% (n=245) of them were females. A majority of the participants received primary education (n=189, 62.2%), were divorced/widowed (n=149, 49. 9%), retired from work/unemployed (n=300, 98.7%), and were living in the same household with

their spouse/relatives (n=186, 61.2%).

A total of 82 older adults (27%) were screened to have hearing impairment, while 32.2% (n=98) of the participants had inactive/less active social engagement. Participants had an average of 1-2 CVRFs (*M* = 1.69; *SD* = 1.21), mean PHQ-9 score of 3.63 (*SD* = 3.97), and mean MoCA score of 24.16 (*SD* = 4.91).

(Insert Table 1 here)

An emerging model of the relationships among AHRL, social engagement, depressive symptoms, and cognitive status

Correlations among the variables are shown in Table 2. Goodness of fit in the hypothetical path model was : χ^2/df = 0.11; p = 0.737; CFI = 0.99; NFI = 0.99; TLI = 0.96; RMSEA = 0.01. In the final path model (Figure 2), three paths were not supported (education ⟶ age-related hearing loss, age ⟶ depressive symptoms, and age-related hearing loss ⟶ cognitive status).

(Insert Table 2 and Figure 2 here)

Participants' demographic characteristics were found to be associated with ARHL, depressive symptoms, cognitive status and social engagement. Particularly, age is positively associated with AHRL (β=0.24, p<0.001), but negatively associated with social engagement (β= -0.29, p<0.001) and cognitive status (β= -0.38, p<0.001). While education was negatively associated with depressive symptoms (β= -0.15, p=0.032) and cognitive status (β= 0.33, p<0.001).

AHRL was positively associated with depressive symptoms (β=0.18, p=0.009) and negatively related to social engagement (β= -0.13, p=0.026). However, AHRL did

not have significant, direct associations with cognitive status.

Social engagement was positively associated with cognitive status (β=0.17, p=0.005) and negatively associated with depressive symptoms (β= -0.23, p<0.001). Meanwhile, greater depressive symptoms were negatively associated with the participants' cognition (β= -0.13, p=0.009).

Further analysis revealed that both social engagement (β= -0.02, p=0.029) and depressive symptoms (β= -0.02, p=0.032) mediated the relationship between AHRL and cognitive status. The direct and indirect associations and standardized regression coefficients of the study variables are shown in Table 3.

(Insert Table 3 here)

DISCUSSION

In this study, we reported that social engagement and depressive symptoms mediated the negative associations between ARHL and cognitive status, which was predicted by a few studies based on behavioral and neuroimaging research [26] [27]. Although the associations observed in this study are small, the findings are significant and could provide further evidence to support those previously speculated causal mechanisms. For example, behavioral mechanisms suggested that hearing and communicating difficulties of older adults may prohibit them from interacting with others and may contribute to the development of social isolation, loneliness, depression and consequent cognitive decline [39] [40]. At a neural level, ARHL is associated with reduced activation in central auditory pathways, resulting in reduced functional brain network connectivity[27]. As suggested by Rutherford[27], these pathologic changes increase depression risk by

reducing cognitive reserve and functions, resulting in cognitive performance decline.

In the final model, older adults with ARHL were more likely to have depressive symptoms than individuals without ARHL, and the depressive symptoms had significant, direct associations with the cognition of older adults. Multiple studies showed that older adults experiencing hearing loss reported higher levels of depression mainly due to difficulties in following conversations, participating in social activities, and maintaining meaningful relationships with others [41]. Researchers have reported an independent association between ARHL and cognitive impairment [10], but we did not identify significant, direct associations between ARHL and cognitive status in the model, which might be due to the small sample size and/or the cross-sectional research design. Moreover, the lack of a measure of hearing capacity that provides information on severity likely contributes to the lack of association between hearing loss and cognitive status. In consistent with our findings, prior studies have found that older adults with depressive symptoms or depression had an increased risk of cognitive impairment and dementia [42 43], and suggested that memory, executive function, and processing speed examinations are useful to identify cognitive decline in older adults who have depressive symptoms and depression [44]. Based on our model, we might expect that if people have both ARHL and depressive symptoms, the risks of cognitive impairment and/or dementia would be largely increased. Therefore, addressing hearing loss, including the use of hearing aids and cochlear implantation, could have a beneficial effect on social engagement, which in turn may be effective for minimizing the effect of ARHL on dementia [45] and depression [10]. In a range of interventions

available, it is still largely unknownn whether pharmacological therapy such as antidepressant treatment improves cognition and lowers dementia risk [46], therefore effects of non-pharmaceutical interventions should be examined further to support people with ARHL and depressive symptoms to facilitate participation in social activitie, and maintain meaningful interpersonal relationships.

Our model corroborated that ARHL was negatively related to social engagement and older adults with better social engagement tended to have better cognitive status. Previous studies have identified that ARHL is associated with increased social isolation [47], loneliness [4] and social disengagement [48] among older adults living both at home and residential care settings. For example, older people with hearing loss are more likely to be left out of conversations or to avoid social networking with others [49]. A recent review has shown that auditory training, for example, to help people with ARHL better filter out background noise to focus on the voice the individual is listening to [50] might be able to enhance communication and engagement [51]. Furthermore, communication difficulties for older people with hearing loss can be intensified when the person also has cognitive impairment [50]. The effect of mishearing information combined with not being able to comprehend information would negatively impact the information processing they have heard [49]. Intervetions developed for people with cognitive impairement might also need to consider their hearing capacity. Since the nature of associations between social engagement and cognitive function remains unclear [52], more evidence is needed to determine whether interventions for enhancing social engagement for older adults with ARHL would effectively prevent their cognitive

decline.

Implication for future research

Based on the mediations informed by our model, evidence-based suggestions are proposed for future studies to treat ARHL, such as promoting the use of hearing aids and cochlear implantation, to enhance social engagement and treat depressive symptoms for people with ARHL to prevent cognitive decline. It would be also important to know whether increased social engagement and/or reduced depressive symptoms could effectively delay progression to dementia in the case of ARHL. In addition, rigorously designed research is needed to determine whether interventions for ARHL are effective for the prevention of depressivesive symptoms and cognitive decline. Considering both neurobiological and behavioral data to facilitate the development of novel interventions/approaches is essential.

Limitations

This study has several limitations. First, the analysis is based on cross-sectional data; thus, causality cannot be drawn among the relationships of the variables and we may not evaluate an individual at the precise time he or she is symptomatic. Second, the Whisper test and Weber and Rinne test rather than pure-tone audiometry were performed to screen conductive or sensorineural hearing loss, these tests have limitations as a true diagnostic measure of hearing loss or problems. While the tests were validated tools and implemented by well-trained research assistants following the ICOPE framework, the sensitivity of tests and the lack of data on the severity of hearing loss might impact the data analysis because that some degraded hearing cases might not

be revealed but influence the cognition assessment. Third, the survey used a convenience sampling method due to the COVID-19 pandemic, with the focus on older Chinese community-dwelling adults, and the cohort is primarily female; although we have conducted a multi-site data collection (from 11 community centres out of 41 centres in Hong Kong), these factors might still limit the generalizability.

CONCLUSION

ARHL is a potential risk factor for cognitive impairment, dementia, social disengagement, and late-life depression. This study depicted the mediating role of social engagement and depressive symptoms between ARHL and cognitive status. ARHL, social engagement and depressive symptoms are modifiable risk factors in preventative strategies for preventing cognitive decline. Further research, particularly large prospective studies in diverse cohorts that include objective hearing status, such as pure tone audiometry are needed to further elucidate possible causal mechanisms behind the associations observed, and to comprehensively inform clinical practices.

Conflict of Interest

None reported.

Data available on request due to privacy/ethical restrictions

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REFERENCE

1. Collaborators GDaIIaP. Global, regional, and national incidence, prevalence, and years lived with disability for 328 diseases and injuries for 195 countries, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016.

Lancet 2017;390(10100):1211-59. doi: 10.1016/S0140-6736(17)32154-2

2. Lin FR, Ferrucci L, Metter EJ, et al. Hearing loss and cognition in the Baltimore Longitudinal Study of Aging. Neuropsychology 2011;25(6):763–70. doi: 10.1037/a0024238

3. Saji N, Makizako H, Suzuki H, et al. Hearing impairment is associated with cognitive function in community-dwelling older adults: A cross-sectional study. . Archives of gerontology and geriatrics 2021;93(104302.) doi: 10.1016/j.archger.2020.104302

4. Applebaum J, Hoyer M, Betz J, et al. Long-term subjective loneliness in adults after hearing loss treatment. International journal of audiology 2019;58(8):464–67. doi: 10.1080/14992027.2019.1593523

5. Marques T, Marques FD, Miguéis A. Age-related hearing loss, depression and auditory amplification: a randomized clinical trial. Eur Arch Otorhinolaryngol 2022;279:1317–21. doi: https://doi.org/10.1007/s00405-021-06805-6

6. Shukla A, Harper M, Pedersen E, et al. Hearing Loss, Loneliness, and Social Isolation: A Systematic Review. Otolaryngology--head and neck surgery : official journal of American Academy of Otolaryngology-Head and Neck Surgery 2020;162(5): 622–33. doi: 10.1177/0194599820910377

7. Chern A, Golub JS. Age-related Hearing Loss and Dementia. . Alzheimer disease and associated disorders 2019;33(3): 285–90. dio:10.1097/WAD.0000000000000325

8. World Health Organisation. World Report on Hearing Geneva World Health

Organisation 2021.

9. Census and Statistics Department. Special Topics Report No. 62. Hong Kong Census and Statistic Department, 2013.

10. Sharma RK, Chern A, Golub JS. Age-Related Hearing Loss and the Development of Cognitive Impairment and Late-Life Depression: A Scoping Overview. Seminars in hearing 2021;42(1):10–25. doi: 10.1055/s-0041-1725997

11. Ray J, Popli G, Fell G. Association of Cognition and Age-Related Hearing Impairment in the English Longitudinal Study of Ageing. JAMA otolaryngology-- head & neck surgery 2018;144(10):876–82. doi: https://doi.org/10.1001/jamaoto.2018.1656

12. Kim SY, Kim H, Park E. Severe hearing impairment and risk of depression: a national cohort study. PLoS ONE 2017;12(6):1-11. doi: https://doi.org/10.1371/journal.pone.0179973

13. Goman AM, Lin FR. Hearing loss in older adults - From epidemiological insights to national initiatives. Hearing research 2018;369:29–32. doi: 10.1016/j.heares.2018.03.031

14. Heine C, Browning CJ, Gong CH. Sensory Loss in China: Prevalence, Use of Aids, and Impacts on Social Participation. Frontiers in public health 2019;7(5) doi: https://doi.org/10.3389/fpubh.2019.00005

15. Uchida Y, Nishita Y, Tange C, et al. The longitudinal impact of hearing impairment on cognition differs according to cognitive domain Front Aging Neurosci 2016;8 201. doi: 10.3389/fnagi.2016.00201

16. Loughrey DG, Kelly ME, Kelley GA, et al. Association of Age-Related Hearing Loss With Cognitive Function, Cognitive Impairment, and Dementia: A Systematic Review and Meta-analysis. . JAMA otolaryngology-- head & neck surgery 2018;144(2):115–26. doi: 10.1001/jamaoto.2017.2513

17. AT J, Dias A, Philp I. Identifying common impairments in frail and dependent older people: validation of the COPE assessment for non-specialised health workers in low resource primary health care settings. BMC Geriatr 2015;15,(123) doi: 10.1186/s12877-015-0121-1

18. Lin FR, Ferrucci L, An Y, et al. Association of hearing impairment with brain volume changes in older adults. . Neuroimage 2014;90: 84-92. doi: 10.1016/j.neuroimage.2013.12.059

19. Livingston G, Sommerlad A, Orgeta V, et al. Dementia prevention, intervention, and care. The Lancet 2017;390:2673–734.

20. Ryu SH. The Clinical Significance of Cognitive Interventions for the Patients with Mild Cognitive Impairment. J Korean Neuropsychiatr Assoc 2018;57:23–29.

21. Shah H, Albanese E, Duggan C, et al. Research priorities to reduce the global burden of dementia by 2025. The Lancet Neurology 2016;15:1285–94. doi: 10.1016/S1474- 4422(16)30235-6

22. Wilkinson P, Ruane C, Tempest K. Depression in older adults. BMJ 2018;363:k4922. doi:10.1136/bmj.k4922

23. Maharani A, Pendleton N, Leroi I. Hearing Impairment, Loneliness, Social Isolation, and Cognitive Function: Longitudinal Analysis Using English Longitudinal

Study on Ageing. Am J Geriatr Psychiatry 2019;27(12):1348-1356. doi:10.1016/j.jagp.2019.07.010

24. Ge S, Pan W, Wu B, Plassman BL, Dong X, McConnell ES. Sensory impairment and cognitive decline among older adults: An analysis of mediation and moderation effects of loneliness. Front Neurosci 2023;16:1092297. doi:10.3389/fnins.2022.1092297

25. Wingfield A, Tun PA, McCoy SL. Hearing Loss in Older Adulthood: What It Is and How It Interacts With Cognitive Performance. Current Directions in Psychological Science 2005; 14(3):144-148. doi:10.1111/j.0963-7214.2005.00356.x

26. Gopinath B, Wang JJ, Schneider J, Burlutsky G, Snowdon J, McMahon CM, . . . Mitchell P. Depressive symptoms in older adults with hearing impairments: the Blue Mountains Study. Journal of the American Geriatrics Society 2009; 57(7): 1306–1308. doi:10.1111/j.1532-5415.2009.02317.x

27. Lin FR, Ferrucci L, An Y, Goh JO, Doshi J, Metter EJ. Association of hearing impairment with brain volume changes in older adults. Neuroimage 2014; 90: 84-92. doi:10.1016/j.neuroimage.2013.12.059

28. Rutherford BR, Brewster K, Golub JS, et al. Sensation and Psychiatry: Linking Age-Related Hearing Loss to Late-Life Depression and Cognitive Decline. The American journal of psychiatry 2018;175(3):215–24. doi: https://doi.org/10.1176/appi.ajp.2017.17040423

29. Leung A, Su JJ, Lee E, et al. Intrinsic capacity of older people in the community

using WHO Integrated Care for Older People (ICOPE) framework: a cross-sectional study. BMC geriatrics 2022;22(1):304. doi: 10.1186/s12877-022-02980-1

30. World Health Organization. Guidance on person-centred assessment and pathways in primary care. Geneva: World Health Organization 2019.

31. Wolf EJ, Harrington KM, Clark SL, et al. Sample Size Requirements for Structural Equation Models: An Evaluation of Power, Bias, and Solution Propriety. Educational and psychological measurement 2013;76(6):913–34. doi: https://doi.org/10.1177/0013164413495237

32. Westland JC. Lower bounds on sample size in structural equation modeling. Electronic Commerce Research and Applications 2010;9(6):476-87. doi: https://doi.org/10.1016/j.elerap.2010.07.003

33. Soper DS. A-priori Sample Size Calculator for Structural Equation Models 2018 [Available from: http://www.danielsoper.com/statcalc.

34. Wang W, Bian Q, Zhao Y, et al. Reliability and validity of the Chinese version of the Patient Health Questionnaire (PHQ-9) in the general population. Gen Hosp Psychiatry 2014;36:539–44.

35. Yeung PY, Wong LL, Chan CC, et al. A validation study of the Hong Kong version of Montreal Cognitive Assessment (HK-MoCA) in Chinese older adults in Hong Kong. Hong Kong Med J 2014;20:504–10.

36. Fidelis I, Sunday OE. Application and Relevance of Path Analysis in Casual Modeling. Global Journal of Arts, Humanities and Social Sciences

2018;6(10):26-50.

37. Mukaka MM. Statistics corner: A guide to appropriate use of correlation coefficient in medical research. Malawi medical journal : the journal of Medical Association of Malawi 2012;24(3):69–71.

38. Hooper D, Coughlan J, Mullen MR. Structural Equation Modelling: Guidelines for Determining Model Fit. The Electronic Journal of Business Research Methods 2008;6:53-60.

39. Cacioppo JT, Hawkley LC. Perceived social isolation and cognition. Trends Cogn Sci 2009;13:447–54.

40. Pichora-Fuller MK, Mick P, Reed M. Hearing, cognition, and healthy aging: social and public health implications of the links between age-related declines in hearing and cognition. Semin Hear 2015;36:122–39.

41. Brewster KK, Ciarleglio A, Brown PJ. Age-related hearing loss and its association with depression in later life. Am J Geriatr Psychiatry 2018;26(7):788-96.

42. Chow YY, Verdonschot M, McEvoy CT, et al. Associations between depression and cognition, mild cognitive impairment and dementia in persons with diabetes mellitus: A systematic review and meta-analysis. . Diabetes research and clinical practice 2022;185(109227) doi: https://doi.org/10.1016/j.diabres.2022.109227

43. Zilkens RR, Bruce DG, Duke J, et al. Severe psychiatric disorders in mid-life and risk of dementia in late- life (age 65–84 years): a population based case-control study. Curr Alzheimer Res 2014;11(7):681-93.

44. Shimada H, Park H, Makizako H, et al. Depressive symptoms and cognitive

performance in older adults. Journal of psychiatric research 2014;57:149–56. doi: https://doi.org/10.1016/j.jpsychires.2014.06.004

45. Mosnier I, Vanier A, Bonnard D, et al. Long-Term Cognitive Prognosis of Profoundly Deaf Older Adults After Hearing Rehabilitation Using Cochlear Implants. Journal of the American Geriatrics Society 2018;66(8):1553–61. doi: https://doi.org/10.1111/jgs.15445

46. Brewster KK, Ciarleglio A, Brown PJ, et al. Age-Related Hearing Loss and Its Association with Depression in Later Life. . The American journal of geriatric psychiatry : official journal of the American Association for Geriatric Psychiatry;26(7):788–96. doi: https://doi.org/10.1016/j.jagp.2018.04.003

47. Mick P, Kawachi I, Lin FR. The association between hearing loss and social isolation in older adults. Otolaryngology--head and neck surgery : official journal of American Academy of Otolaryngology-Head and Neck Surgery 2014;150(3):378–84. doi: 10.1177/0194599813518021

48. Surkalim DL, Luo M, Eres R, et al. The prevalence of loneliness across 113 countries: systematic review and meta-analysis. BMJ 2022;376:e067068. doi: doi.org/10.1136/bmj-2021-067068

49. Ludlow K, Mumford V, Makeham M, et al. The effects of hearing loss on person-centred care in residential aged care: a narrative review. . Geriatric nursing (New York, NY) 2018;39(3):296–302. doi: Ludlow, K., Mumford, V., Makeham, M., Braithwaite, J., & Greenfield, D. (2018). The effects of hearing loss on person-centred care in residential aged care: a narrative review. Geriatric nursing (New

York, N.Y.), 39(3), 296–302. https://doi.org/10.1016/j.gerinurse.2017.10.013

50. Sweetow RW, Henderson-Sabes J. The need for and development of an adaptive listening and communication enhancement (LACE™) program. J Am Acad Audiol 2006;17:538–58.

51. Mamo SK, Wheeler KA. The Combined Burden of Hearing Loss and Cognitive Impairment in a Group Care Setting for Older Adults. . Journal of speech, language, and hearing research : JSLHR 2021;64(2):328–36. doi: 10.1044/2020_JSLHR-20-00068

52. Kelly ME, Duff H, Kelly S, et al. The impact of social activities, social networks, social support and social relationships on the cognitive functioning of healthy older adults: a systematic review. Systematic reviews, 2017;6(1):259. doi: 10.1186/s13643-017-0632-2