

The Impact of Hearing Loss on Cognitive Health and Dementia:

WHY HEARING WELL MATTERS

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Hearing loss is the largest potentially modifiable risk factor for age-related dementia.
([World Report on Hearing, WHO, 2021, page 46](#))

HEARING LOSS, COGNITIVE DECLINE AND DEMENTIA: WHAT WE KNOW

As the ageing population grows, the numbers of those with hearing loss, cognitive decline and dementia are increasing across the world, leading to urgent public health and social challenges.
([Kingston et al 2018](#))

- In 2019 age-related hearing loss was the third largest cause of Years Lived with Disability globally, and the leading cause for adults older than 70 years. ([World Report on Hearing WRH, WHO 2021](#))
- “By 2050, it is estimated that some 2.5 billion (1 in every 4) people will experience hearing loss, with nearly 700 million (1 in every 14) living with moderate or higher levels of hearing loss. . . urgent public health action is needed to mitigate this projected growth.” ([WRH, WHO, page 139](#)). The cost of unaddressed hearing loss is over \$980 billion annually ([WRH, WHO 2021](#))
- Over 50 million people above 65 years of age have been diagnosed with dementia, and that number is expected to triple by 2050 due to the rising number of older people.
- The cost of caring for those with dementia in 2015 was approximately \$820 billion, and 85% of those costs were related to family and social costs. ([Livingston et al., 2017, World Alzheimer Report 2016](#))
- Over 60% of adults living with dementia will have also have a hearing impairment ([Nirmalasari et al., 2017](#)) and over 90% of adults living with dementia in aged care will have a hearing impairment. ([Hopper et al., 2016](#))



Hearing loss and its association with cognitive decline and poor health therefore presents one of the largest public health challenges we face but the implications often go unrecognised and unaddressed. We need to address this growing challenge, in line with the recommendations of WHO World Report on Hearing ([WHO, 2021](#)) and to develop new approaches to hearing care in the context of updated approaches to healthy ageing.
([Beard et al., 2016](#))

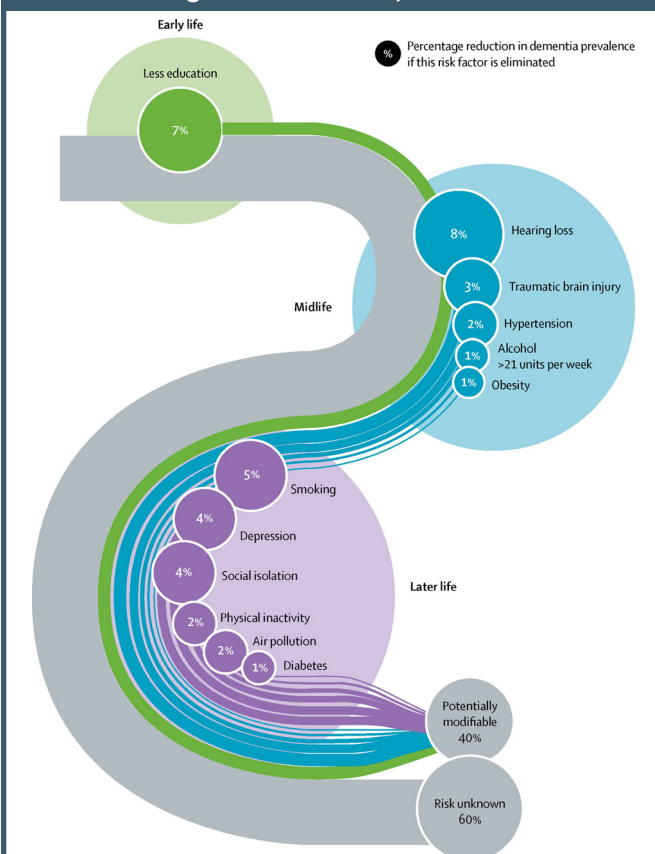
Note. Some degree of cognitive decline (loss of thinking and memory abilities) can be normal as we age. When a cognitive impairment becomes severe enough to interfere with daily activities, a person is considered to have dementia

THE ASSOCIATION OF HEARING LOSS WITH COGNITIVE DECLINE AND DEMENTIA

Emerging evidence has provided new insights into hearing health as a key part of healthy ageing. Hearing loss impairs communication, has been linked to reduced social support from others and loneliness which, in turn, could increase depression and other health risks. More specifically, communication and social connectedness are critical to brain health, addressing dementia and maintaining cognition. [Hearing well matters.](#)

- Hearing loss is now understood to be linked with the risk of cognitive decline and dementia, but these implications of hearing loss often go unrecognized. ([Lin & Albert, 2014](#))
- Hearing loss in adulthood is linked to higher rates of unemployment, depression, cognitive decline, and greater risk of falls, social isolation and other co-morbidities when compared with peers with normal hearing. ([WRH, 2021](#))
- An analysis of studies found that age-related hearing loss is a potential risk factor for cognitive decline, cognitive impairment, and dementia. ([Loughrey et al 2018](#)). In other meta-analyses ([Ford et al., 2018](#), [Thomson et al., 2017](#)) and in longitudinal studies, ([Davies et al., 2017](#)) an increased risk of incident dementia was associated with hearing impairment.
- People with mild hearing loss are twice as likely to develop dementia as people without hearing loss, and the risk increases fivefold for people with severe hearing loss. ([Lin et al., 2011, 2013](#))
- Evidence from imaging studies showing that individuals with hearing impairment have higher rates of brain atrophy in the right temporal lobe and reductions in total brain volume, compared to individuals without hearing impairment. ([Lin et al., 2014](#))
- A large study among nearly 38,000 older Australian men found a 69% increased risk of dementia for those who report having a hearing loss compared to counterparts with normal hearing. ([Ford et al., 2018](#))
- In a matched cohort study using administrative claims data, hearing loss was significantly associated with an increased 10-year risk of dementia. ([Deal et al., 2019](#))
- People who have dementia and hearing impairment have poorer functional ability ([Guthrie et al., 2018](#)) and a more severe communication impairment ([Slaughter & Bankes 2007](#)) as compared to individuals who have dementia and no hearing impairment.

Source: Livingston et al 2020, The Lancet



“Hearing loss is the largest potentially modifiable risk factor for age-related dementia - unaddressed hearing loss may be responsible for over 8% of cases of dementia among older adults, and significantly increases the relative risk of dementia and cognitive impairment.” ([WHO, page 46; 2021](#))

As with hearing loss, dementia and cognitive dysfunction contribute to falls, length of stay in hospital, more intensive nursing care, and poorer recovery after surgery. ([Pichora-Fuller et al., 2015](#))

Declines in hearing and cognitive functioning are both strongly associated with each other and with increasing age. Although the causal relationships between these two age-related declines are still unclear, we do know that optimal cognitive performance can depend on hearing well. For example, remembering information in noise is more difficult than in quiet. If a person with a hearing loss has to concentrate more to hear information then they may have more trouble remembering it than someone with normal hearing would have in the same situation. In the short-term, hearing loss can hamper memory and it is possible that prolonged hearing loss can exacerbate declines in cognition. It is also possible that a common factor causes declines in both cognition and hearing. ([Uchida et al 2018](#))

Focusing on hearing loss presents major opportunities for health systems to invest in healthy ageing and for the public to take action about their hearing, particularly as they age.

HEARING WELL MATTERS: THE IMPACT OF HEARING TECHNOLOGIES

Impact of Hearing Aids

A growing body of evidence suggests that those with hearing loss who use hearing aids may have a reduced risk of cognitive decline and other poor health outcomes than those who do not use hearing aids. Because past studies have not been randomized control trials it is difficult to know if those who self-selected to use hearing aids and cochlear implants have other characteristics that may protect cognitive health.

Preliminary evidence comparing those who use to those who do not use hearing aids is promising;

- Self-reported hearing loss was associated with accelerated cognitive decline in elderly adults and the use of hearing aids and the consequential improvements in social connectedness, almost eliminates this cognitive decline. (*Amieva et al., 2015, 2018*)
- A large scale study found that hearing loss had a negative association with cognition. However, this association was seen only in the individuals who did not use hearing aids. Cognitive decline associated with Age Related Hearing Impairment may be preventable for older adults by early rehabilitation and increased opportunistic screening for the elderly. (*Ray et al., 2018*)
- One longitudinal study found that hearing aids may have a mitigating effect on trajectories of cognitive decline in later life. (*Maharani et al., 2018*)
- Another longitudinal study found “that HI may be a risk factor for cognitive decline in older adults and that hearing aid use could possibly reduce that risk.” (*Deal et al., 2015 p688*)
- A large scale study found that participants who used hearing aids were at significantly lower risk of developing all cause dementia compared to those not using hearing aids. The percentage of participants who had not developed dementia five years after the baseline Mild Cognitive Impairment (MCI) diagnosis was 19% for non-users of hearing aids and 33% for those using hearing aids. (*Buchloc et al., 2021*)
- Another large scale population study found that “Hearing aid use was associated with better cognition in a large cross-sectional study of UK adults.” The association was independent of social isolation and depression. (*Dawes et al., 2015, p7*)

- A study of the UK Bio Bank with over 82,000 participants has shown that difficulty hearing spoken conversations is associated with up to 91% increased risk of dementia with a lack of evidence for reverse causation and limited evidence of mediation by social isolation and depressive symptoms. Further “that the association between hearing impairment and dementia risk was largely attenuated in those who wore hearing aids” but that because of the smaller sample of those with hearing aids the results were not statistically significant. (*Stevenson et al., 2021*)

Impact of Cochlear Implants

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Cochlear implant is one of the most successful of all neural prostheses developed to date

(*WHO, WRH, page 100*)

Cochlear Implants (CI) are surgically implanted devices intended to restore hearing function to those with profound hearing loss and who can't benefit from hearing aids. People fitted with a cochlear implant highly value the associated positive impact on social isolation, greater employability and general wellbeing. (*Ng et al., 2016*). Age is not considered a barrier to cochlear implantation (*WHO, WRH, p 105-106*). The best possible hearing can support independence for longer and healthy living into older age.

There is growing evidence that being fitted with cochlear implants can delay cognitive decline and improve cognition and therefore possibly impact on the onset of dementia and its progression. There needs to be more research and it is important to recognise that CI patients and candidates may not be typical of the population at large as they are more motivated, usually in good health, and typically more independent. Nevertheless, preliminary evidence points towards cochlear implants having a positive impact on cognitive decline even if the nature of the association is not fully understood.

For example;

- A number of studies have found a positive impact of CI's on various domains of cognitive functioning. (*Castiglione, et al., 20215; Cosetti, et al., 2016; Ambert-Dahan, et al., 2017; Jayakody, et al., 2017*)
- A systematic review of studies on cognitive decline and those fitted with Cochlear Implants (*Claes et al., 2018*) found that five out of the six studies reported improvements in cognition post implantation but that more research was needed before a definitive link on causation could be made.
- Another recent systematic review and consensus statement on Cochlear Implantation found that "Cochlear implants may improve cognition in older adults with bilateral severe to profound sensorineural hearing loss." (*Buchman et al., 2020*)
- Studies looking at long term prognosis after Cochlear Implant found that cochlear implantation improved cognitive function and contributes to preservation of cognitive function in the elderly population with CI's. (*Mosnier, et al., 2015, 2018*)
- Mosnier, et al., 2015 found an improvement in global cognitive function in 81% of patients after implantation.
- CI's have been shown to improve cognitive skills in hearing impaired adults aged 50 years or more. (*Völter,et al., 2018*)
- Another study (*Mertens, et al., 2020*) found that "Intervention with a CI improved cognitive functioning (area of attention in particular) in older adults with severe hearing impairment compared to that of the matched controls with hearing impairment without a CI."
- Significant improvements in executive function were observed for non-tertiary educated males, while cognitive function did not decline for the other participants in a prospective trial. (*Sarent et al., 2019*)
- Improvements were also noted in enhancement of cognitive performance regarding working memory and processing speed which are essential for speech perception (*Knopke et al., 2021*) and (*Zhan et al., 2020*) also found that implantation may lead to improvements in some cognitive domains.

These studies all point towards CIs mitigating cognitive decline and improving cognition. More recent studies (*Claes et al.,2018; Kramer et al., 2018; Amieva & Ouvreard, 2020*) have started to address the concern that more evidence is need before a conclusive link can be made between improved cognition and Cochlear Implants. Further research is also needed to assess the long-term effect of cochlear implantation on cognitive decline (*Mosnier et al., 2015, Claes et al., 2018*). There are important caveats in that older CI users may need additional cognitive rehabilitation in the long term after implantation. (*Mertens et al., 2020*). Enhanced rehabilitation for those with CIs was identified as crucial in the World Report on Hearing. (*WHO, 2021*)

While there are important caveats the results are encouraging overall (*Amieva et al., 2020*) and there is growing evidence which points towards Cochlear Implants having the potential to impact on improving cognition or at least arresting cognitive decline for key groups of CI recipients. This in turn would suggest that Cochlear Implants, and other hearing instruments, combined with appropriate cognitive rehabilitation could positively impact on the progression of dementia while not necessarily being able to reverse it. (*Griffiths et al., 2020*)

SCREENING FOR HEARING LOSS AND FOR DEMENTIA

More research needs to be undertaken on the health benefits of treating hearing loss with hearing aids and cochlear implants and screening implemented in line with latest WHO screening guidelines. (*WHO Screening Handbook, 2021*)

Addressing hearing loss earlier, including adult hearing screening, is both a challenge and an opportunity for the whole of the public health and care system as our ageing population grows. (*Lamb et al., 2016*). As WHO concluded “Adult Hearing Screening and Early Intervention have become even more relevant given the links between hearing loss and dementia in older adults.” (*WHO, WRH, page 91*). Screening for hearing loss is essential in early identification and action to address hearing loss and mitigate the effects of cognitive decline and dementia. (*WHO 2021*). Also screening of cognitive function in patients with severe and profound hearing loss is crucial given to potential prevalence of cognitive decline in the older age group.

There is a lack of understanding of how to screen for hearing loss and dementia in older adults with complex needs. (*Guthrie et al., 2018*). There is no standard screening process for dementia or cognitive ability in current audiology practice. (*Ladduwahetty et al., 2013*). Moreover, there are a limited number of inter-professional teams linking specialists in cognition, hearing and gerontology which would enable screening to be effectively followed up. Audiologists have little experience or training in assessing or managing the hearing of those with dementia or cognitive decline. (*Wright et al., 2014*). Conversely, other health professionals dealing with the older population have little experience of understanding or managing hearing loss. We need a greater awareness that good hearing helps people stay connected, reduces loneliness and supports health and wellbeing. (*Kricos 2009; Pichora-fuller et al., 2013; Beck et al., 2018; Weinstein, 2013*)

It is only by investing early in developing new approaches to living well with hearing loss that we can fully realise the gains in terms of increased independence, better health and cognition while taking the strain off other public services provided by hospitals, (*Mahmoudi et al., 2018*) doctors, and social care. (*O’Neil et al 2016; Xiao & O’Neill 2018; Crealey & O’Neill, 2020*)

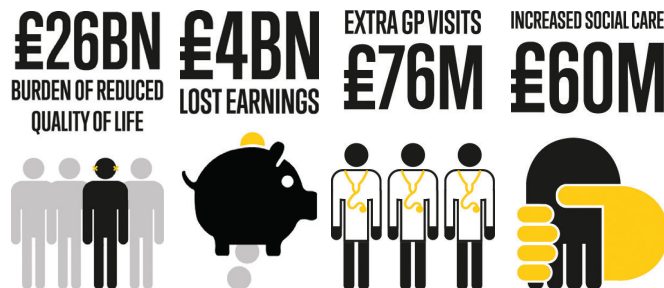
We also know that money invested in hearing care gives a 1:10 return in savings on health, social care and other costs. (*Decall/AoHL 2013; Archbold et al 2015; Kervasdoue, 2016*). A recent study of the cost benefit ratios of using hearing aids to reduce the symptoms of dementia found that the total benefits, mainly coming from the direct benefits, were extremely large relative to the costs, with cost benefit ratios over 30. (*Brent 2018*). It is estimated that a 1-year delay in dementia for individuals would lead to a 10% reduction in prevalence by 2050. (*Brookmeyer et al 2007; Pichora-Fuller et al., 2015*). Early adoption of hearing technology can ensure continued ease of communication so as to prevent social isolation and increased risk of cognitive decline. Hearing loss may be misdiagnosed as dementia with damaging consequences for the individual (*Weinstein 2013, et al., 2016*) while providing hearing aids is cost effective in addressing dementia. (*Mukadam et al., 2020*)

If we can mitigate the onset or effects of dementia through addressing hearing loss early this could make a large impact on reducing the overall costs associated with dementia and the burden on caregivers and society.



Available from
www.who.int/health-topics/hearing-loss

HEARING WELL MATTERS: THE IMPACT OF NOT ADDRESSING HEARING LOSS AND DEMENTIA




Not addressing hearing loss has very significant costs to society associated with additional health and social care. (Huddle et al., 2017; Lamb et al., 2016; O’Neil et al 2016; Mick et al 2018; Reed et al., 2019; Shield 2019; WHO, WHR, 2021). Hearing impairment is generally associated with increased use of primary and secondary healthcare services in European counties, whereas those with the best take up of hearing instruments have the lowest relative additional costs. (Xiao & O’Neill 2018; Reed et al., 2019). Investing in prevention, early support for individuals, increasing hearing accessibility in the community, and changing social attitudes towards hearing loss is a much more cost-effective solution than dealing with the consequences of unaddressed hearing loss. (Archbold et al., 2015). “The increased healthcare costs related to CI are more than compensated for by the value of the health benefits and by savings in educational and productivity costs.” (Neve et al., 2021). In particular, for children and working adults, the societal benefit is positive even without taking health benefits into account. Therefore, CI generates an advantage for both patients and society. (Neve et al., 2021)

With unilateral cochlear implants, estimations based on actual costs in a high-income setting showed a return of **2.59 International dollars for every 1 dollar invested**, and a lifetime value of DALYs averted of **38,153 dollars for each individual**. In the example of a lower-middle-income setting, the return on investment ratio was **1.46 International dollars** with a lifetime value of DALYs averted of **6,907 dollars**.

For an upper-middle-income setting, the return on investment ratio was estimated to be **4.09 International dollars** with a lifetime value of DALYs averted of **24,161 dollars**. (WHO, World Report on Hearing, P104)

An additional annual investment of

 **\$1.40**

per capita can:

benefit 1.4 billion people

bring a return of

\$16 for every \$ invested over 10 years



#hearingcare

 World Health Organization

(From WHO World Hearing Report, 2021)

As we learn more about the connection between hearing loss and dementia and cognitive decline, we also have abundant evidence relating hearing loss treatment to improved communication, reduced social isolation and increased independence and activity. Since good hearing supports cognition, the provision of hearing technologies may also have a preventative aspect in respect of dementia.

National health strategies need to reflect the huge gains in health and the financial savings that can be potentially achieved, by promoting good hearing health and the benefits which follow.

HEARING WELL MATTERS-CALL TO ACTION

Actions for Government

- Each country needs to develop a specific National Action Plan on Hearing Loss, linked to other national public health healthy aging strategies and including age-friendly community initiatives, improved accessibility for disabled people and dementia strategies. (DoH & NHSE 2015; WHO, WRH, 2021)
- Public health awareness campaigns on preserving hearing and taking early action to address hearing loss are needed to promote healthy ageing. (Wilson et al., 2017; WHO, 2021)
- Raise awareness and education of Primary Health Care Professionals about the links between hearing loss and healthy aging and the importance of addressing hearing loss early in their adult patients
- There is a need to invest in Rehabilitation programmes following the fitting of hearing devices to ensure that best use is made of device. (WHO, WRH, 2021)
- Policy makers should work with consumer advocacy and professional associations on additional measures to implement programs that address the under treatment of hearing loss in older people.

Adult National Screening programmes for hearing loss

- “It is essential to provide active screening services for older adults in an easy and accessible manner, followed by suitable interventions.” (WHO, WRH, page 90)
- Screening programmes need to be sensitive to the association between hearing loss, dementia and cognitive decline. (Weinstein 2013; Weinstein et al., 2016)
- Targeted screening programmes for both hearing loss and cognitive decline for those receiving home care or living in residential homes. (DCAL/AoHL 2013; Lamb & Archbold 2016; Ray et al., 2018)

Training and raising knowledge of primary health care professionals

- Training for health and social care professionals in identifying and managing hearing loss for those with or at the risk of dementia. (Cox et al., 2016; Weinstein et al., 2016; Speech-Language & Audiology Canada 2018)
- An enhanced role for the Audiology and hearing professionals in inter-professional teams involved in the diagnosis and management of dementia and cognitive decline. (Beck et al 2018; Weinstein 2018)
- Primary care practitioners need additional awareness through training programmes in the association between cognitive decline and hearing loss.
- Supporting personal advocacy in the on-going management of hearing loss for adults living with dementia. (WHO, WRH, 2021)

Managing hearing loss well in later life improves communication and independence, and reduces loneliness, social isolation and may help to alleviate cognitive decline. The challenge for health systems, commissioners and professionals working in hearing loss is to support healthy aging by ensuring good hearing health. Investments in early intervention and early provision of hearing aids and implants will not only improve quality of life for older people, but will also save health systems additional medical and social care costs in the future.

While future research is needed to better evaluate the mechanisms, hearing loss is the most important potentially reversible risk factor for dementia. (WHO, 2021). Professionals, Health Authorities and those with hearing loss should be aware of this association.

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Hearing loss is the largest potentially modifiable risk factor for age-related dementia.

(World Report on Hearing, WHO 2021, page 46)

REFERENCES

- Ambert-Dahan, E.; Routier, S.; Marot, L.; Bouccara, D.; Sterkers, O.; Ferrary, E.; Mosnier, I. Cognitive Evaluation of Cochlear Implanted Adults Using CODEX and MoCA Screening Tests. *Otol. Neurotol.* 2017, 38, 282–284.
- Archbold S, Lamb, B, O'Neill C, Atkins J (2015). The Real Cost of Adult Hearing Loss: reducing its impact by increasing access to the latest hearing technologies. Ear Foundation <http://www.earfoundation.org.uk/research/adult-strategy-reports>
- Amieva H. & Ouvrard C. (2020) Does Treating Hearing Loss in Older Adults Improve Cognitive Outcomes? A Review. *Journal of Clinical Medicine.* 2020 Mar 16;9(3): Art. 805. P 1-12.
- Beard, J R., Officer, A, Carvalho I, MD, Sadana, R., et al (2016). The World report on ageing and health: a policy framework for healthy ageing. *Lancet.* 2016 May 21; 387(10033): 2145–2154. Published online 2015 Oct 29. doi: 10.1016/S0140-6736(15)00516-4
- Beck, D L., Weinstein, B E., Harvey M A. Dementia Screening: A Role for Audiologists. *Audiology & Neuroscience.* July 2018 Hearing Review
- Brent, Robert, J (2019). A cost–benefit analysis of hearing aids, including the benefits of reducing the symptoms of dementia, *Applied Economics*, DOI: 10.1080/00036846.2018.1564123
- Brookmeyer R, Johnson E, Ziegler-Graham K, Arrighi HM. (2007) Forecasting the global burden of Alzheimer's disease. *Alzheimers Dement* 2007; 3(3):186–191
- Bucholc, Magda., McClean, Paula L. Bauermeister, Sarah. Todd, Stephen. Ding, Xuemei. Desheng, Qinyong Ye. Huang, Wang Wei. Maguire, Liam P: (2021) Translational Research and Clinical Interventions. <https://doi.org/10.1002/trc2.12122>
- Buchman et al. (2020) International Consensus paper; Unilateral Cochlear Implants for Severe, Profound, or Moderate Sloping to Profound Bilateral Sensorineural Hearing Loss: A Systematic Review and Consensus Statements. *JAMA Otolaryngol Head Neck Surg.* 146(10),942-953. doi:10.1001/jamaoto.2020.0998
- Castiglione, A.; Benatti, A.; Girasoli, L.; Caserta, E.; Montino, S.; Pagliaro, M.; Bovo, R.; Martini, A. Cochlear implantation outcomes in older adults. *Hear. Balance Commun.* 2015, 13, 86–88.
- Claes, A.J., Van de Heyning, P., Gilles, A., Van Rompaey, V., and Mertens, G. (2018). Cognitive outcomes after cochlear implantation in older adults: a systematic review. *Cochlear Implants Int.* 19, 239–254. <https://doi.org/10.1080/14670100.2018.1484328>
- Cosetti, M.K.; Pinkston, J.B.; Flores, J.M.; Friedmann, D.R.; Jones, C.B.; Roland, J.T.; Waltzman, S.B. Neurocognitive testing and cochlear implantation: Insights into performance in older adults. *Clin. Interv. Aging* 2016, 11, 603–613.
- Cox R, Johnson J & Xu J (2016). Impact of hearing aid technology on outcomes in daily life I: The Patients' Perspective. *Ear and Hearing*, 37(4), 224-37
- Crealey, Grainne, E and O'Neill Ciaran (2020). Hearing loss, mental well-being and healthcare use: results from the Health Survey for England (HSE). *Journal of Public Health*, Volume 42, Issue 1, March 2020, Pages 77–89.
- Davies, HR., Cadar D, Herbert A., Orrell M., Steptoe A. (2017) Hearing impairment and incident dementia: findings from the English longitudinal study of ageing. *J Am Geriatr Soc.* 2017; 65(9):2074–2081
- Dawes P, Emsley R, Cruickshanks KJ, Moore DR, Fortnum H, Edmondson-Jones M et al (2015). Hearing Loss and Cognition: The Role of Hearing Aids, Social Isolation and Depression. *PLoS ONE* 10(3): e0119616. doi:10.1371/journal.pone.0119616
- DCAL and Action on Hearing Loss (2013). *Joining Up: Why people with hearing loss or deafness would benefit from an integrated response to long-term conditions.* Available from: www.actiononhearingloss.org.uk/
- Deal J.A, Sharrett A R, Albert M S, Coresh J, Mosley T H, Knopman D, Wruck L M and Lin F R (2015). Hearing impairment and cognitive decline: a pilot study conducted within the atherosclerosis risk in communities neurocognitive study. *American journal of epidemiology*, 181 (9) pp. 680-690
- Deal JA, Reed NS, Kravetz AD et al. Incident Hearing Loss and Comorbidity: A Longitudinal Administrative Claims Study. (2019) *JAMA Otolaryngol Head Neck Surg.* 145(1):36–43. doi:10.1001/jamaoto.2018.2876
- Department of Health & National Health Service England (2015). *Action Plan on Hearing Loss* <https://www.england.nhs.uk/wp-content/uploads/2015/03/act-plan-hearing-loss-upd.pdf>
- Ford AH, Hankey GJ, Yeap BB, Golledge J, Flicker L, Almeida OP. Hearing loss and the risk of dementia in later life. (2018) *Maturitas.*;112:1-11. doi:10.1016/j.maturitas.2018.03.004. Epub 2018 Mar 13
- Griffiths, Timothy D. Lad, Meher. Kumar, Sukhbinder. Holmes, Emma. McMurray, Bob. Maguire, Eleanor A. Billig, Alexander J. and Sedley, William. How Can Hearing Loss Cause Dementia? (2020) *Neuron* <https://doi.org/10.1016/j.neuron.2020.08.003>
- Guthrie DM, Davidson JGS, Williams N, Campos J, Hunter K, Mick P et al (2018). Combined impairments in vision, hearing and cognition are associated with greater levels of functional and communication difficulties than cognitive impairment alone: Analysis of interRAI data for home care and long-term care recipients in Ontario. *PLoS ONE* 13(2): e0192971. <https://doi.org/10.1371/journal.pone.0192971>
- Huddle, Matthew G, Goman, Adele M, Kernizan, Faradia C, Foley Danielle M, Price Carrie, Frick Kevin D, Frank Lin, R. (2017). The Economic Impact of Adult Hearing Loss A Systematic Review. *JAMA Otolaryngology–Head & Neck Surgery* Published online August 10, 2017
- Hopper T, Slaughter S E, Hodgetts B, Ostevik A, & Ickert C (2016). Hearing Loss and Cognitive-Communication Test Performance of Long-Term Care Residents With Dementia: Effects of Amplification. *Journal of Speech, Language, and Hearing Research*, 59(6), 1533-1542. doi:10.1044/2016_JSLHR-H-15-0135
- Jayakody, D.M.P. Friedland, P.L. Nel, E. Martins, R.N. Atlas, M.D. Sohrabi, H.R. Impact of Cochlear Implantation on Cognitive Functions of Older Adults: Pilot Test Results. (2017) *Otol. Neurotol.* 38, 289–295.
- Johnson J, Xu J, Cox, R. (2016). Impact of Hearing Aid Technology on Outcomes in Daily Life II: Speech. Understanding and Listening Effort. *Ear and Hearing*, 37(5), 529-40
- Kervasdoué J (2016). Economic Impact of Hearing Loss in France and Developed Countries. A survey of academic literature 2005-2015. <https://www.ehima.com/wpcontent/uploads/2016/05/FinalReportHearingLossV5.pdf>
- Kingston A, Comas-Herrera, Jagger A (2018). Forecasting the care needs of the older population in England over the next 20 years: estimates from the Population Ageing and Care Simulation (PACSim) modelling study. *Lancet Public Health* volume 3, issue 9, pe447-e455, September 01, 2018
- Knopke, Steffen., Schubert, Arvid., Häussler, Sophia Marie., Gräbel, Stefan., Szczepek, Agnieszka J., Olze, Heidi. (2021). Improvement of Working Memory and Processing Speed in Patients over 70 with Bilateral Hearing Impairment Following Unilateral Cochlear Implantation. *J. Clin. Med.* 2021, 10, 3421. <https://doi.org/10.3390/jcm10153421>
- Kramer, Scott.; Vasil, Kara J.; Adunka, Oliver F.; Pisoni, David B.; Moberly, Aaron, C. (2018) Cognitive Functions in Adult Cochlear Implant Users, Cochlear Implant Candidates, and Normal-Hearing Listeners. *Laryngoscope Investigative Otolaryngology* 3:
- Kricos PB (2009). Providing hearing rehabilitation to people with dementia presents unique challenges. *The Hearing Journal*, 62(11), pp.39-40. Available from <http://journals.lww.com/thehearingjournal/>
- Ladduwahetty S, Dowell R C and Winton E (2013). Dementia and cochlear implant outcomes: can we screen for dementia effectively using the mini mental state examination in implant candidates? *Australian and New Zealand Journal of Audiology*, Vol. 33 No. 1, pp. 88-102
- Lamb B, Archbold S, O'Neill C (2015). Bending the Spend: Expanding access to hearing technology to improve health, wellbeing and save public money. Ear Foundation
- Lamb B, Archbold S (2016). Adult Hearing Screening: Can we afford to wait any longer? Ear Foundation.
- Lamb B, Archbold S, O'Neil C (2017). Spend to save: Investing in hearing technology improves lives and saves society money. A Europe Wide Strategy. Ear Foundation.

- Lin F R, Metter E, O'Brien R J, Resnick S M, Zonderman A B, Ferrucci L (2011). Hearing Loss and Incident Dementia. *Arch Neurol*. 68 (2) pp. 214-2 2011. Available from <http://hearingpro.com.au/wp-content/uploads/2016/08/Research-Hearing-loss-and-incident-dementia-2011-1.pdf>
- Lin, F R., Yaffe K, Xia J., Xue Q L, Harris., Purchase-Helzner., T B., et al (2013). Hearing loss and cognitive decline in older adults. *JAMA Internal Medicine*. 173 (4) pp.293-299. Available from <http://jamanetwork.com/journals/jamainternalmedicine/fullarticle/1558452>
- Lin ,FR, Ferrucci L, An Y, Doshi J, Metter E, Davatzikos C (2014). Association of hearing impairment with brain volume changes in older adults. *Neuroimage*;15(90):84
- Lin, F R, & Albert M (2014). Hearing loss and dementia - who is listening? *Aging & mental health*, 18(6), 671-3
- Livingston G, et al., Dementia prevention, intervention, and care. *The Lancet*. 2017. [https://doi.org/10.1016/s0140-6736\(17\)31363-6](https://doi.org/10.1016/s0140-6736(17)31363-6)
- Livingston G, et al., (2020). Dementia prevention, intervention, and care: 2020 report of the Lancet Commission, *Lancet*, 396, 413-446. [https://doi.org/10.1016/S0140-6736\(20\)30367-6](https://doi.org/10.1016/S0140-6736(20)30367-6) [https://www.thelancet.com/article/S0140-6736\(20\)30367-6/fulltext](https://www.thelancet.com/article/S0140-6736(20)30367-6/fulltext)
- Mahmoudi E, Zazove P et al (2018). Association Between Hearing Aid Use and Health Care Use and Cost Among Older Adults With Hearing Loss. *JAMA Otolaryngol Head Neck Surg*. Published online April 26, 2018. doi:10.1001/jamaoto.2018.0273
- Loughrey, D.G., Kelly ME, Kelley, G.A., Brennan, S., Lawlor, B, A. (2018). Association of Age-Related Hearing Loss With Cognitive Function, Cognitive Impairment, and Dementia: A Systematic Review and Meta-analysis. *JAMA Otolaryngol Head Neck Surg*. 2018 Feb 1; 144(2):115-126
- Maharani A, Dawes P et al (2018). Longitudinal Relationship Between Hearing Aid Use and Cognitive Function in Older Americans. *Journal of the American Geriatric Society*. 10 April 2018 <https://doi.org/10.1111/jgs.15363>
- Mertens, Griet., Andries, Ellen., Claes, Annes J., et al., (2020) Cognitive Improvement After Cochlear Implantation in Older Adults With Severe or Profound Hearing Impairment: A Prospective, Longitudinal, Controlled, Multicenter Stud. *Ear and Hearing*
- Mick P, Foley D, Lin F, Pichora-Fuller, M. K. (2018) Hearing Difficulty Is Associated With Injuries Requiring Medical Care *Ear & Hearing* 2018;39:631–644
- Mosnier, Isabelle MD; Bebear, Jean-Pierre MD; Marx, Mathieu MD, PhD; Fraysse, Bernard MD; et al., (2015) Improvement of Cognitive Function After Cochlear Implantation in Elderly Patients. *Otolaryngol Head Neck Surg*. 2015;141(5):442-450. doi:10.1001/jamaoto.2015.129
- Mosnier I., Vanier A., Bonnard D., Lina-Granade G., Truy E., Bordure P., Godey B., Marx M., Lescanne E., Venail F., Poncet C., Sterkers O., Belmin J. (2018). Long-Term Cognitive Prognosis of Profoundly Deaf Older Adults After Hearing Rehabilitation Using Cochlear Implants. *Journal of American Geriatrics Society*, 66(8), 1553-1561. doi:10.1111/jgs.15445.
- Mukadam, N., Anderson, R., Knapp, M., Wittenberg, R., Karagiannidou, M., et al., (2020) Effective interventions for potentially modifiable risk factors for late-onset dementia: a costs and cost-effectiveness modelling study. *Lancet Healthy Longev* 2020;1: e13–20
- Nirmalasari O, Mamo S K, Nieman C L, Simpson, A, Zimmerman J, Nowrangi M A, Oh E S (2017). Age-related hearing loss in older adults with cognitive impairment. *Int Psychogeriatr*, 29(1), 115-121. doi:10.1017/s1041610216001459
- Ng ZN, Lamb B, Harrigan S, Archbold S, Athalye S & Allen S (2016). Perspectives of adults with cochlear implants on current CI services and daily life. *Cochlear Implants International*, 17:sup1, 89-93
- Neve, O, M., Boerman, J, A., van den Hout , W, B., Briaire, J.J., van Benthem , P.G., and Frijns, J, H.M.,(2021) Cost-benefit Analysis of Cochlear Implants: A Societal Perspective. *Ear & Hearing* 2021.
- O'Neill, C., Lamb, B and Archbold S (2016). Cost implications for changing candidacy or access to service within a publicly funded healthcare system? *Cochlear implants international*, 17(sup1), pp. 31-35
- Pichora-Fuller K M, Dupuis K, Reed M and Lemke U (2013). Helping Older People with Cognitive Decline Communicate: Hearing Aids as Part of a Broader Rehabilitation Approach. *Seminars in Hearing* (Vol. 34, No. 4, pp. 308-330)
- Pichora-Fuller M, Mick P, Reed M (2015). 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(03): 122-139
- Ray, J, Popli G., and Fell, G. (2018). Association of Cognition and Age-Related Hearing Impairment in the English Longitudinal Study of Ageing. *JAMA Otolaryngol Head Neck Surg*. 2018;144(10):876-882. doi:10.1001/jamaoto.2018.1656
- Reed NS, Altan A, Deal JA, et al. Trends in Health Care Costs and Utilization Associated With Untreated Hearing Loss Over 10 Years. *JAMA Otolaryngol Head Neck Surg*. 2019;145(1):27–34. doi:10.1001/jamaoto.2018.2875
- Sarant, J., Harris, D., Busby, P., Maruff, P., Schembri, A., Dowell, R, and Robert Briggs. (2019). The Effect of Cochlear Implants on Cognitive Function in Older Adults: Initial Baseline and 18-Month Follow Up Results for a Prospective International Longitudinal Study. *Front. Neurosci.*, 02 August 2019 | <https://doi.org/10.3389/fnins.2019.00789>
- Shield, B. (2019). Hearing Loss – Numbers and Costs Evaluation of the Social and Economic Costs of Hearing Impairment. A report for Hear-It AISBL
- Slaughter, S, E, & Bankes, J. (2007). The Functional Transitions Model: Maximizing ability in the context of progressive disability associated with Alzheimer's disease. *Canadian Journal on Aging*, 26(1), 39-47. doi:10.3138/Q62V-1558-4653-P0HX
- Speech-Language & Audiology Canada (SAC): (2018) Submission to the Public Health Agency of Canada to Inform the National Dementia Strategy
- Stevenson, J.S., Clifton, L., Kuma E, Littlejohns, T.J. Speech-in-noise hearing impairment is associated with an increased risk of incident dementia in 82,039 UK Biobank participants. *Alzheimer's Dement*. 2021;1-12. <https://doi.org/10.1002/alz.12416>
- Thomson RS, Auduong P, Miller AT, Gurgel RK (2017). Hearing loss as a risk factor for dementia: a systematic review. *Laryngoscope Investig Otolaryngol.* ;2(2):69–79
- Uchida Y., Sugiura S., Nishita Y., Saji, N., Sone, M., Ueda H. (2018). Age-related hearing loss and cognitive decline – The potential mechanisms linking the two. *Auris Nasus Larynx* online.
- Völter, C., G, L., Dazert, S., Falkenstein, M., and Thomas, J,P. (2018) Can cochlear implantation improve neurocognition in the aging population? *Clinical Interventions in Aging* 2018;13 701–712.
- Weinstein B (2013). *Geriatric Audiology*, Chap 3 P.62 Psychosocial Changes with Ageing, Thieme, Publishers.NY
- Weinstein B E, Sirow L W, Moser S (2016). Relating hearing aid use to social and emotional loneliness in older adults. *American Journal of Audiology*, 25:54-61
- WHO: Hearing screening: considerations for implementation. Geneva: World Health Organization; 2021. Licence: CC BY-NC-SA 3.0 IGO.
- Wilson B, Tucci D, Merson M, O'Donoghue G (2017). Global hearing health care: new findings and perspectives. *The Lancet*. Published online July 10, 2017 [http://dx.doi.org/10.1016/S0140-6736\(17\)31073-5](http://dx.doi.org/10.1016/S0140-6736(17)31073-5)
- World Alzheimer Report (2016). Improving healthcare for people living with dementia: Coverage, quality and costs now and in the future. Available: <https://www.alz.co.uk/research/WorldAlzheimerReport2016.pdf>
- World Health Organisation (2017) Resolution on the prevention and treatment of deafness and hearing loss.
- World Health Organization (2021). World Report on Hearing www.who.int/health-topics/hearing-loss
- World Health Organization (2021). Hearing screening: considerations for implementation. www.who.int/health-topics/hearing-loss
- Wright N, Stickley T, Mulla I, Bradshaw E, Buckley L and Archbold S (2014). Hearing loss and dementia: an exploratory study of the views of audiologists. *Quality in ageing and older adults journal* vol. 15 no. 4 2014, pp. 220-231
- Xiao, M & O'Neill, C (2018). A comparative examination of healthcare use related to hearing impairment in Europe. *Global & Regional Health Technology, Assessment*, 2018, Vol. 2018: 1–22
- Zhan , K, Y., Lewis , J, H., Vasil , K, J., Tamati, T, N., Harris, M,S., et al., (2020) Cognitive Functions in Adults Receiving Cochlear Implants: Predictors of Speech Recognition and Changes After Implantation. *Otol Neurotol.*;41(3):e322-e329. doi: 10.1097/MAO.0000000000002544.

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