

Review Article

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Global burden of hearing impairment and ear disease

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Abstract

Background. Hearing loss can present at birth or be acquired as a result of illness, middle-ear disease, injury, age, overuse of certain medications, and/or induced by exposure to damaging noise levels. There are serious short-term consequences for people living with hearing impairment, including the effects on language acquisition, education, employment and overall well-being. There are also complex long-term implications.

Objectives. This review aimed to present some of the leading causes of ear disease and hearing loss globally, and to identify their impact at both an individual and societal level.

Introduction

Hearing impairment is one of the leading contributors to years lived with a disability, with over 5 per cent of the world's population (360 million people) currently living with a disabling hearing loss.¹ There are varying definitions regarding the degrees of hearing impairment, with the World Health Organization (WHO) grading hearing impairment as mild (26–40 dB HL), moderate (41–60 dB HL), severe (61–80 dB HL) or profound (81 dB HL or greater) in the better ear. Hearing levels of 35 dB HL (for children) and 40 dB HL or more (for adults) in the better ear are regarded as disabling, although even a mild and unilateral hearing impairment can cause significant difficulties for an individual.

Hearing impairment can result from ear disease affecting the middle ear (conductive hearing loss), inner ear or cochlear nerve (sensorineural hearing loss), or both (mixed hearing loss). Depending on the aetiology, hearing loss may be permanent or transient. The following sections describe the causes, epidemiology, and risk factors for ear disease and hearing loss.

Otitis media

Otitis media is the most common cause of temporary hearing impairment in children^{2,3} and refers to a class of inflammatory conditions of the middle ear. It is not a single pathology, but rather a spectrum of different conditions, including: acute otitis media with or without perforation; otitis media with effusion or glue ear; and perforated tympanic membrane. A perforated tympanic membrane may be associated with a new episode of acute otitis media or may be chronic. Chronic perforations can be dry, but if they are associated with persistent discharge, the diagnosis becomes chronic suppurative otitis media (CSOM). Other serious middle-ear conditions include mastoiditis (inflammation of the mastoid space) and cholesteatoma (perforation of the attic region or pars tensa associated with ectopic squamous epithelium).

Several studies report that in low- and middle-income countries, 50 per cent of otitis media cases will also have an associated hearing impairment, although some studies have reported estimates as high as 60–100 per cent.^{4–7} The degree of hearing loss associated with otitis media is commonly mild.^{8,9} Depending on the degree of hearing loss and the fluctuating nature of the middle-ear fluid, speech sounds can be distorted and speech intelligibility may be compromised,^{10,11} which can significantly delay a child's ability to acquire speech and language. In addition, higher-level auditory processing, such as localisation and listening ability in the presence of background noise, may be affected,^{12,13} which can have a detrimental impact on a child's learning and education.

Epidemiology

In high-income countries, otitis media is one of the most common reasons for children to present to healthcare providers,^{14,15} with most children experiencing at least one episode in their first few years of life.¹⁶ Approximately 80 per cent of children will have at least one episode of acute otitis media before they start school,^{17,18} and nearly half (40 per cent) will have six or more acute otitis media recurrences by the age of seven years.¹⁹ In US children younger than five years, the average child has 1.5 visits to a primary healthcare provider

for upper respiratory tract infections annually, approximately half of which are for otitis media.²⁰ Otitis media is also one of the most common reasons for antibiotic prescription, making it a major driver of the global antibiotic resistance epidemic.^{15,20,21}

A 2012 review of 114 otitis media studies estimated incidence annually of 709 million cases of acute otitis media and 31 million cases of CSOM.¹⁶ However, there is publication bias in otitis media epidemiological studies. For example, when the authors of this paper searched for otitis media prevalence studies reporting tympanic membrane perforations, there were a total of 70 studies, but they were from only 31 countries (Figure 1). However, the most recent International Society of Otitis Media Panel report noted that many of the recent studies were from low- and middle-income countries.²²

Although there are large variations in otitis media incidence between countries,²² the highest incidence is in low- and middle-income countries. In a systematic review, regions with the highest burden included Oceania, and Central and West Sub-Saharan Africa, which recorded maximum incidence rates between 29 and 43 new episodes per 100 people per year.¹⁶ This is compared to high-income regions, including Europe Central and Asia Pacific, with rates lower than 5 per 100 people per year. Similarly, CSOM burden was highest in Oceania and Central Sub-Saharan Africa, with the lowest rates recorded in high-income regions.

Variation also exists within countries, particularly between indigenous and non-indigenous populations. In Australia, for example, some of the lowest rates of otitis media in the world have been recorded in the non-Aboriginal population, yet some of the highest recorded rates are present in the indigenous population.²³ In fact, otitis media rates in children from these settings are much higher than rates found in: children from impoverished settings including the sub-Saharan areas of Africa,²⁴ child labourers²⁵ or slum dwellers in India.²⁶ Indigenous populations may be at greater risk of developing otitis media because of factors related to colonisation, including exposure to high population density pathogens since colonisation, and the influence of socioeconomic conditions (which drive infection), particularly in remote areas.²⁷

In other indigenous populations, there has been a trend towards decreased otitis media. Amongst Arctic Circle Inuit school children, otitis media prevalence decreased from 30–50 per cent in the 1960s to around 10 per cent in the 1990s.²⁸ In addition, CSOM prevalence in New Zealand Maori children halved over the 1980s.²⁹ Improvement in socioeconomic factors including housing quality may explain the reduction in otitis media rates.

Risk factors

Infections in childhood are exceedingly common, as infants have immature immune systems, limited prior exposure to infections, waning maternal immunoglobulin G protection, and rapid exposure to common viral and bacterial pathogens through vertical transmission or unfettered exploration and contact with other children or adults.

A significant relationship between a history of upper respiratory tract infections and recurrent otitis media has been found.³⁰ Furthermore, patients presenting with a history of acute otitis media or recurrent otitis media are at higher risk of future chronic otitis media and recurrent otitis media.³¹

Other risk factors found to be associated with a higher incidence of otitis media include not being breastfed, the presence

of allergic disease, day-care attendance, pacifier use, passive smoking, craniofacial abnormalities, gastroesophageal reflux and the presence of adenoids.²² Genetic factors have also been implicated in the rates of otitis media,¹⁹ acute otitis media,³² CSOM³³ and cholesteatoma.³⁴

Congenital hearing loss

Congenital hearing loss is present at birth, and can be hereditary, or due to issues at birth or *in utero*. Congenital hearing loss is predominantly permanent in nature, and, depending on the severity and configuration, it can have significant detrimental consequences on a child's speech and language development.

Epidemiology

Hearing loss is one of the most common conditions that presents at birth, affecting between 1 and 3 per 1000 live births.³⁵ The WHO estimates that 32 million children are living with hearing impairment;¹ however, there is uncertainty regarding the rates for cases that are congenital in nature.

The recent introduction of hearing screening technology has led to an increase in the identification of significant childhood hearing loss. The widespread use of ototoxic medications to treat neonatal infections may also have accounted for the rise in childhood hearing impairment, particularly in low- and middle-income countries.³⁶

Prevalence rates of childhood hearing loss vary between regions, with disabling hearing loss not surprisingly being greatest in developing regions such as south Asia (2.4 per cent) and Sub-Saharan Africa (1.9 per cent). Rates are significantly lower in higher-income countries (0.5 per cent), largely because of lower rates of infection, combined with better access to preventative measures and healthcare services.¹

Risk factors

Genetic factors account for 40 per cent of congenital hearing loss cases,³⁷ with a higher rate amongst offspring of consanguineous relationships. Thus, the remaining 60 per cent of childhood hearing loss is made up of non-genetic causes, including maternal infections such as rubella and cytomegalovirus (the most common cause in developed countries), prematurity, and low birth weight (Figure 2).¹

Amongst cases with non-genetic causes, an estimated 49 per cent are preventable in high-income countries, and as much as 75 per cent are preventable in low- and middle-income countries.¹ Neonatal complications such as asphyxia and jaundice are likely to contribute to the higher rates of congenital hearing impairment in low- and middle-income countries, where neonatal services may be limited or lacking, particularly in rural and remote areas. The most significant risk factor for preventable hearing loss in low-resource settings, however, remains inadequate vaccine coverage, leading to maternal infections.³⁸

Presbycusis

Presbycusis is a progressive and irreversible hearing loss that occurs as an effect of ageing, accounting for most hearing impairment cases in adults. The hearing loss is usually bilateral, symmetrical and typically affects high frequency hearing.³⁹ Age-related hearing impairment can impact a person's

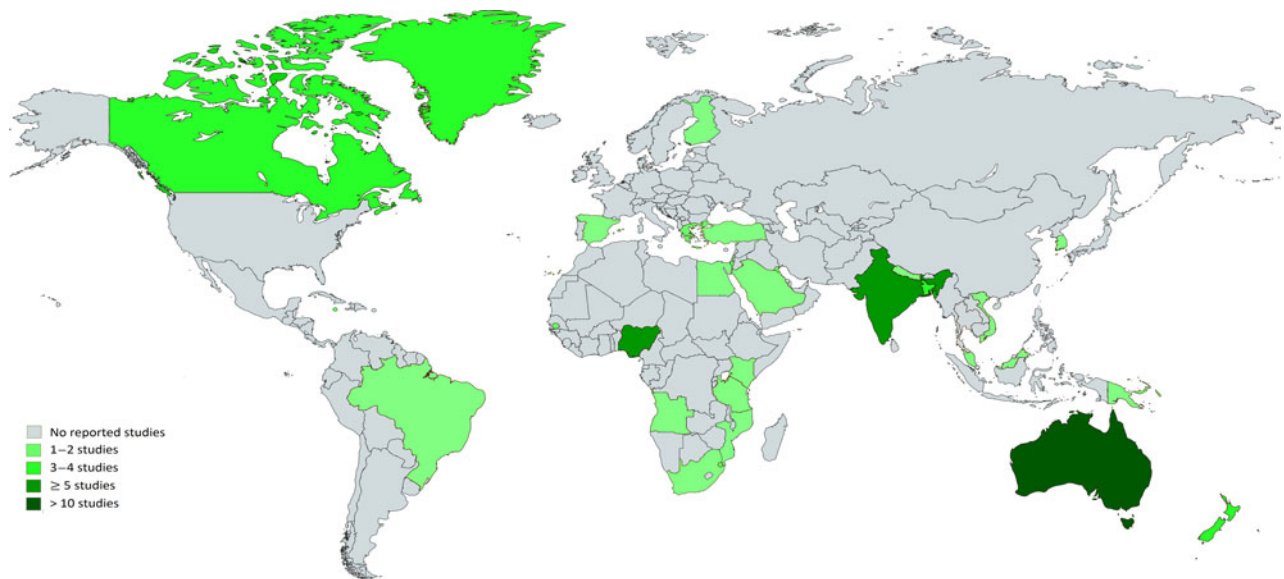


Fig. 1. Number of published studies reporting prevalence of tympanic membrane perforation by country.

ability to communicate effectively, with the most noticeable and immediate effect on speech detectability in the presence of noise. Furthermore, there is increasing evidence that listening difficulties may directly or indirectly affect a person's quality of life.⁴⁰

Epidemiology

Hearing loss prevalence increases exponentially with age, with a higher incidence in men than women.⁴¹ In a population-based study conducted in Australia, 33 per cent of participants aged 49 years or older had a hearing loss.⁴¹ In the 60–69-year-old age bracket, the incidence of hearing loss increased to 48 per cent, a slightly lower figure than that reported in the USA (63 per cent).⁴² Prevalence in low- and middle-income countries is likely higher given the reduced access to preventative measures and health services. According to WHO, global estimates predict that 500 million people over the age of 60 years will have hearing loss due to presbycusis by 2025.¹

Risk factors

The most significant risk factor for presbycusis is age, with the likelihood of experiencing hearing loss increasing significantly from 5 per cent in those less than 50 years of age, to 58 per cent by 60 years of age.⁴³

Presbycusis is a result of a lifetime of insults to the auditory system, with onset and severity affected by both genetic susceptibility and environmental factors,⁴⁴ although the relative contribution of these factors is difficult to gauge given the inability to separate these variables.⁴⁵ The environmental factors known to be associated with presbycusis include lifetime exposure to noise (both recreational and occupational), exposure to ototoxic drugs, and aspects of physical health including smoking status, or other chronic diseases such as diabetes or cardiac disease. Smoking cessation, and effective hypertension and diabetes management, have been shown to delay presbycusis onset.⁴²

In low-resource countries, where exposure to all abovementioned risk factors may be greater, the prevalence of presbycusis is also expected to be higher, although this may vary

depending on the age bracket, given the lower life-expectancy in low- and middle-income countries.¹

Noise-induced hearing loss

Excessive exposure to harmful levels of noise within the workplace, or from recreational noise sources, can lead to: hearing loss (both temporary and permanent), tinnitus, stress, sleeping difficulties and reduced performance.⁴⁶ One effect of excessive noise exposure is noise-induced hearing loss. Typically, exposure to loud noise for any length of time leads to fatigue of cochlear hair cells, resulting in a temporary threshold shift and/or tinnitus.⁴⁷ Regular, prolonged exposure results in irreversible cochlear damage and permanent sensorineural hearing loss.⁴⁸ As the effects of noise-induced hearing loss are cumulative, excessive exposure can result in earlier onset of age-related hearing loss.

Epidemiology

Occupational noise-induced hearing loss

Estimates from the WHO suggest that 10 per cent of the world's population is exposed to potentially damaging sound pressure levels. In both developing and industrialised countries, 50 per cent of cases of damage to the auditory system are attributable to intense noise exposure.⁴⁹

Noise-induced hearing loss has been reported as the most significant preventable cause of hearing loss, and the greatest compensable occupational hazard in the USA.⁵⁰ Worldwide, 16 per cent of disabling hearing loss in adults is due to occupational noise exposure, and the latter affects more males than females.

Noise-induced hearing loss is greatest amongst factory workers (in all regions, but particularly in low- and middle-income countries⁴⁶), but is also found in those working in agriculture, mining, construction, manufacturing, utilities, transportation and the military. It is likely that the prevalence of noise-induced hearing loss is now higher in low- and middle-income countries, given the programmes and legislation to protect workers from noise in higher-income countries, and the shift of manufacturing from high- to lower-income regions.⁴⁹

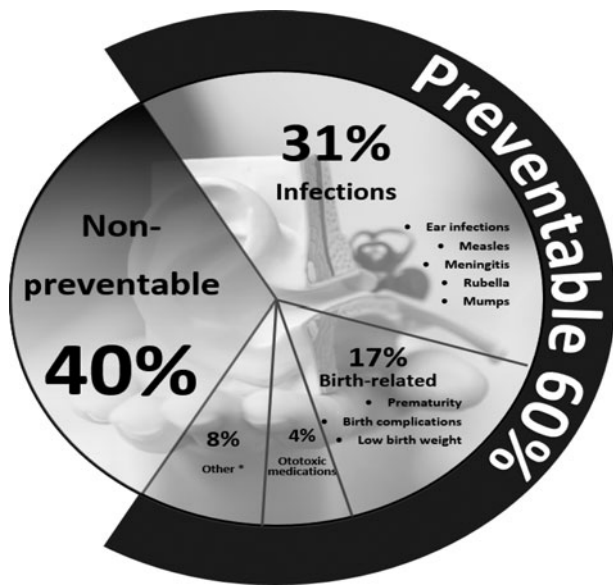


Fig. 2. Estimates of hearing loss causes. Adapted with permission.¹ *Other causes indicate congenital non-genetic factors and other maternal prenatal causes

Recreational noise-induced hearing loss

Exposure to hazardous recreational noise sources, such as those from personal listening devices and noisy entertainment venues, can also cause hearing loss. Estimates from WHO in 2015 indicated that 1.1 billion young people worldwide could be at a risk of developing hearing loss because of unsafe listening practices. This is evidenced in studies where nearly half of all the individuals aged 12–35 years were shown to have been exposed to unsafe levels of sound, either from personal audio devices, or at clubs and bars.⁵¹ In Australia and high-income countries, the number of young people with recreational noise exposure between 1980 to 2000 tripled from 6 per cent to 18 per cent.⁵² These findings would suggest that recreational noise-induced hearing loss is going to be a serious problem, and has the potential to be an even greater problem than occupational noise-induced hearing loss, particularly in Western countries.

Risk factors

Some studies point to genetic factors influencing the susceptibility to noise-induced hearing loss. These include studies on superoxide dismutase polymorphisms in Taiwanese factory workers⁵³ and Chinese workers.⁵⁴ Other studies, conducted on Polish and Swedish sample populations, point to potential noise susceptibility genes.⁵⁵

Whilst genetics appears to significantly influence the extent of noise trauma, nutrition and the physiological state of individuals may also contribute.⁴⁹ Animal studies suggest that deficiencies of magnesium (Mg^{2+}) or vitamin B₁₂ may increase noise trauma susceptibility, but confirm that diet is also likely to contribute.⁵⁶ Other factors that may promote noise-induced hearing loss include pre-existing sensorineural hearing loss, the use of certain medications, exposure to solvents, age, and chronic health conditions such as diabetes and hypertension.

Ototoxicity

Ototoxicity is defined as the use of therapeutic agents that cause a functional impairment of the inner ear resulting in bilateral hearing loss and/or vestibular disturbance.⁵⁷ The

most common compounds used clinically with known ototoxic properties include platinum-based chemotherapeutic agents, aminoglycoside antibiotics, salicylates, anti-malarial drugs and loop diuretics.³⁶ Industrial chemicals, including several solvents and nitriles, are also known to be ototoxic.⁵⁸ Ototoxicity is usually permanent because of damage to outer hair cell function, but the damage may be reversed if it only affects marginal cells.⁵⁹

Epidemiology

Prevalence rates of ototoxicity-related sensorineural hearing loss are unclear because of the variability between studies. Ototoxicity may be under-reported given the subtleties of the hearing loss, and so there is potential for hearing impairment to go undetected.⁶⁰

In children, the WHO estimate that the use of ototoxic drugs during pregnancy and in neonates accounts for 4 per cent of childhood hearing losses.¹ The use of aminoglycosides, which are broad-spectrum antibiotics used in the treatment of life-threatening acute infections, accounts for the majority of ototoxicity in children, with incidence as high as 40 per cent in children receiving treatment for tuberculosis.⁶¹

Again, rates of hearing loss associated with ototoxicity are expected to be higher in low- and middle-income countries, where access to other effective antibiotics is expensive or restricted, and the monitoring of safe dosages is not always feasible.

Another commonly used ototoxic drug (the most ototoxic) is cisplatin,⁶² which is used in cancer treatment. Cisplatin causes a bilateral high frequency hearing loss, with the degree of hearing impairment directly correlated to the dose, route and duration of administration. Reported rates of cisplatin-induced ototoxicity depend on differences in treatment schedules, but cisplatin has been shown to cause at least some degree of hearing loss in approximately 60 per cent of paediatric patients treated for a variety of cancers,⁶³ and in 18 per cent of men successfully treated for testicular cancer.⁶⁴ Despite this, cisplatin treatment is often preferred, given its lifesaving benefits, which outweigh the cost of hearing loss.

Risk factors

Individuals with pre-existing hearing loss, renal complications or a genetic predisposition are more susceptible to ototoxic hearing loss. In addition, the risk is greater in children aged four years and under, and in cases where the drug is administered in combination with cranial irradiation or other ototoxic or nephrotoxic drugs.⁶² Aminoglycosides are one of the more commonly used ototoxic drug groups. They are relatively inexpensive to produce, yet highly effective in the treatment of multidrug-resistant tuberculosis, cystic fibrosis, urinary tract infections and against multidrug-resistant bacteria. They continue to be the drug of choice in low- and middle-income countries where such illnesses are prolific.⁶⁵

Discussion

Globally, there are 1.33 billion people living with hearing loss.¹ Hearing impairment has the potential to have significant ramifications on many aspects of a person's life, including their socioeconomic status, mental and physical wellbeing, and educational and employment opportunities.

Burden of ear disease and hearing loss on individuals

Education

Hearing impairment in childhood can affect spoken language development and communication abilities. Furthermore, children presenting with hearing loss early in life (either permanent or temporary) are likely to miss critical developmental periods essential for the wiring of higher-level auditory processes. These processes are responsible for sound discrimination, localisation, lateralisation and speech perception in noise.^{66,67} The inability to communicate or process sounds accurately and effectively can have an adverse effect on educational outcomes; children with hearing loss have been shown to have poorer literacy skills and lower academic performance compared to normally hearing peers.^{68,69}

In high-income regions, children with significant hearing impairment will have access to interventions, including cochlear implantation, hearing aids, sign language and specialised schools to enable them to participate on a par with normally hearing peers. Given the limited access to specific diagnostic services, intervention and specialised education, children with a disabling hearing loss in low- and middle-income countries are more likely to have difficulties assimilating into mainstream schooling, or be less able to access the curriculum.

As well as affecting education, hearing loss also has serious consequences for a child's self-esteem and overall wellbeing. Even in low- and middle-income countries with access to services, children with a hearing loss experience a lower academic performance and poorer social development,¹ perhaps reflecting local limited resources, and a lack of community understanding and acceptance of hearing impairment.

Employment and financial impacts

Hearing loss can have a significant influence on an individual's ability to enter the workforce or stay in the workforce, with hearing-impaired individuals disadvantaged in job seeking or self-selecting out of employment. People with hearing loss typically experience a higher unemployment rate, lower earning potential,⁷⁰ earlier retirement, greater absenteeism, reduced productivity and greater stress related to the hearing impairment.⁷¹

The impact of hearing loss on employment in low- and middle-income countries is often more pronounced, given the limited access to hearing loss prevention programmes, older technologies, and fewer medical and rehabilitative interventions. In low- and middle-income countries, for example, less than 3 per cent of hearing aid needs have been met.¹ Furthermore, in low- and middle-income countries, those with hearing loss experience higher rates of unemployment and are in lower grades of employment.⁷² Changes within the workforce, with moves away from manual labour based positions towards more communication-based positions, particularly in high-income countries, may bring additional challenges for those with hearing impairment.

Physical health

There is a large body of evidence showing a strong link between a decline in hearing and a decline in physical health.^{73–75} Recently, a link has been established between hearing loss co-existing with other health conditions, social isolation or increased cognitive load (as a result of degraded auditory signals), and factors such as walking ability and cognitive impairment. For instance, hearing loss that presents in

conjunction with other factors has been linked to an increased risk of falls.⁷⁶ Those experiencing falls may not seek professional assistance for medical issues related to their hearing loss, with serious consequences, including death.⁷¹

A more specific physical health condition relates to untreated middle-ear disease. Complications of untreated otitis media include cholesteatoma and extracranial complications, such as facial paralysis, subperiosteal abscess and mastoiditis, which occur in around 0.5–1.4 per cent of cases, and intracranial complications, such as meningitis, cerebral abscess and encephalitis, which occur in 0.3–2.0 per cent of cases.⁷⁷ There are estimated to be around 21 000 deaths globally per year due to complications associated with otitis media.¹⁶ Whilst the mortality rate in high-income nations has reduced significantly as a result of public health improvements, it remains high in low- and middle-income countries.^{7,66}

Socialisation and mental health

There is evidence that hearing loss, and its impact on education, communication and financial success, can affect overall quality of life.^{22,74} A reduced ability to interact and communicate can negatively affect cognition, social interaction, and physical and mental wellbeing. Recent evidence also indicates a longer-term correlation between hearing loss and cognitive decline,⁴⁰ with dementia occurring earlier and more often in hearing-impaired individuals.⁷⁸ Hearing loss has a considerable impact on social interaction; the inability, or reduced ability, to communicate with friends and family can affect relations at home, work and school. This can have socio-economic consequences, and can also affect overall wellbeing.⁴⁰

The stigma associated with hearing loss can lead to withdrawal and social isolation, with psychological conditions prevalent when compared to the general population.^{79,80} Similarly, the social stigma of otorrhoea with CSOM can also lead to withdrawal and separation. Furthermore, a recent systematic review of parental views found that otitis media in children caused parental guilt over failure to recognise symptoms, helplessness and despair, disruption of life schedules, and, again, social isolation.⁸¹

Burden of ear disease and hearing loss on society

Economics

Issues at the individual level can also have significant global financial implications. Hearing loss is estimated to cost 750 billion dollars internationally per year.¹ Costs include those related to healthcare, educational support, loss of productivity, and social costs associated with the stigma of having hearing loss.

Recent investigations into hearing loss in Australia showed total financial costs of \$15.9 billion per year (\$648 per head of population), comprising: healthcare system costs (\$881 million), productivity losses (\$12.8 billion), informal care costs (\$141 million), deadweight losses (\$1.6 billion) and other financial costs (\$480 million).⁷¹

The financial components incurred by society include: medical expenses, such as medical appointments, hearing aids and accessories; and non-medical costs associated with special education and rehabilitation. The largest contribution to financial loss is related to lost work productivity (67 per cent of the total loss),⁸² most of which is related to reduced employment. A hearing-impaired person is more likely to: be unemployed; enter the workplace later or leave earlier

because of issues related to their hearing loss; have more days off work; and/or require extra support because of stresses related to their hearing impairment. These factors lead to significantly reduced earnings over their lifetime compared to non-hearing-impaired peers.^{83,84} A conservative total on lost productivity has been estimated to be \$100 billion annually, with most of the loss incurred by low- and middle-income countries.¹

Whilst lost productivity contributes significantly to the global financial burden, the largest cost of hearing impairment relates to loss of wellbeing. That is, the cost of people's suffering and early death because of hearing loss. In Australia, for example, the financial costs contributed to 48 per cent of the total costs, with poor wellbeing accounting for the remaining 52 per cent (\$17.4 billion).⁷¹

Overall, costs to the economy over a lifetime for an individual experiencing hearing impairment have been estimated to be approximately US\$300 000.^{82,85} These costs increase substantially if the hearing loss is diagnosed in childhood, whereupon costs can exceed US\$1 million per person over their lifetime.⁸²

Conclusion

Hearing impairment and disease-related hearing loss can have significant consequences for the individual, and can be a substantial financial drain to society. The presence and impact of disabling hearing loss is unequally distributed across the world, with the burden of hearing loss (both individual and societal) being greatest in low-resource countries, where access to education, medications, technology and interventions is limited. Given the social, emotional and significant economic impact of hearing loss, it is important that resources are targeted towards minimising the load.

Interventions aimed at reducing the burden of disabling hearing loss, through the prevention, identification and management of ear disease and hearing loss, are imperative. These include: building stronger otological and audiological service delivery models, developing affordable hearing aid and rehabilitative services, improving health and community education programmes, providing closer regulation and monitoring of medications, creating incentive schemes to encourage attendance at health clinics, and improving the uptake of immunisations. At a government level, stricter legislation and public campaigns are required to promote safe listening regarding occupational and recreational noise exposure. Finally, further research into alternative service delivery models is required, particularly in low-resource regions.

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