Global costs of unaddressed hearing loss and cost-effectiveness of interventions

A WHO Report, 2017

World Health Organization

Global costs of unaddressed hearing loss and cost-effectiveness of interventions

World Health Organization

Global costs of unaddressed hearing loss and cost-effectiveness of interventions: a WHO report, 2017

ISBN 978-92-4-151204-6

Suggested citation. Global costs of unaddressed hearing loss and cost-effectiveness of interventions: a WHO report, 2017. Geneva: World Health Organization; 2017. Licence: CC BY-NC-SA 3.0 IGO.

Cataloguing-in-Publication (CIP) data. CIP data are available at http://apps.who.int/iris.

Contents

Acknowledgements

This report was developed under the overall supervision of the World Health Organization. Dr David McDaid and Dr A-La Park of the London School of Economics, London, U.K., have authored the section 'analysis of global costs of unaddressed hearing loss', which forms the main body of this report. The cost-analysis was supported by Dr Jeremy Lauer of WHO. A review to assess the cost-effectiveness of interventions for hearing loss was undertaken by Dr Paras Agarwal, Dr Ricardo Martinez and Dr Lucero Lopez. The report was compiled and reviewed within WHO by Dr Shelly Chadha, Dr Alarcos Cieza, Dr Etienne Krug and Dr Tamitza Toroyan, with support from Dr Ranjeeta Ambett and Ms Adonai Sebastian. It has been edited by Mrs Sarah Balance.

Executive summary

Purpose

Millions of people across the world continue to live with the adverse impacts of unaddressed hearing loss and lack access to required ear and hearing care services. While the impact of hearing loss on individuals and families is well established, there have been relatively few attempts to assess at its economic costs, especially in low- and middle-income countries and at the global level.

This report provides an analysis of the global costs of hearing loss. It sets out different components of cost and, where feasible, attaches monetary values to such elements as direct market-price costs typically incurred by health-care systems for hearing loss, as well as costs that fall beyond the health system, e.g. for special educational support for hearing-impaired children. The report also highlights other aspects of cost, including the adverse impacts of hearing loss on the potential for individuals to contribute to the economy through participation in paid work. Finally, the analysis considers some of the broader societal impacts of hearing loss and the way in which they can be incorporated into estimates of global cost.

The report also reviews evidence on the cost–effectiveness of interventions to address hearing loss and presents the main findings.

Costs of hearing loss

All costs are calculated for moderate or higher degrees of hearing loss, i.e. hearing level greater than 35 dB in the better-hearing ear. The costs are estimated in 2015 international dollars (a unit of currency defined by the World Bank and represented simply as $ throughout the report).

- The cost to the health-care sector is estimated to be in the range $67–107 billion. This includes health-care costs for children and adults, which have been estimated separately; it does not include the cost of providing hearing devices such as hearing aids and cochlear implants.
- A conservative estimate of the cost to the education sector of providing support to children (5–14 years) with unaddressed hearing loss is $3.9 billion. This assumes that only children with at least moderately severe hearing loss (hearing level greater than 50 dB in the better-hearing ear) require educational support.
- Between 63% and 73% of the costs to health and education sectors are incurred outside high- income countries.

- Loss of productivity, due to unemployment and premature retirement among people with hearing loss, is conservatively estimated to cost $105 billion annually.
- Societal costs – the result of social isolation, communication difficulties and stigma – add a further $573 billion each year. These costs are calculated on the basis of the monetary value attached to avoidance of a year lived with disability and draw upon disability-adjusted life years (DALYs) attributed to hearing loss.

Overall, this cautious analysis suggests that the annual cost of unaddressed hearing loss is in the range $750–790 billion globally. The analysis takes no account of certain aspects of hearing loss, the costs of which are not well documented in literature, such as the costs of providing informal care, or preschool learning and higher education for people with unaddressed hearing loss.

Crucially, the analysis was hampered the absence of country-specific data, especially from low- and middle-income countries; nevertheless, it provides a realistic but conservative illustration of the costs associated with unaddressed hearing loss.

Interventions to address hearing loss:

A review of available literature reveals the cost–effectiveness of various interventions with respect to hearing loss. These include:

- **Prevention**
  - Evidence suggests that prevention of hearing loss through early identification and management of otitis media is highly cost-effective.
  - A significant proportion of hearing loss is attributable to noise exposure. Directing health resources towards measures for prevention of noise-induced hearing loss is thus an appropriate option.
- **Screening programmes**. Overall, early identification of hearing loss through screening of newborns, schoolchildren and adults over 50 years of age is found to be cost-effective.
  - In neonates, universal screening strategy yields good economic returns in the long term. However, it is important to minimize the false-positives and to establish a tracking system for optimal benefit.
  - Screening of schoolchildren is shown to be an economically attractive intervention for mitigation of hearing loss.
- **Hearing devices**
  - Use of hearing aids is shown to be cost-effective, especially use is continuous and accompanied by audiological rehabilitation.

- Cochlear implants are shown to be most cost-effective when fitted unilaterally and at an early age. However, even when implants are fitted later in life, or provided in both ears, the benefits exceed the costs incurred. Although no studies were found that assessed the cost–effectiveness of captioning services and sign language interpretation, evidence suggests that these interventions are effective in making information accessible to deaf and hard of hearing people.

Conclusions

- This initial analysis shows that unaddressed hearing loss poses substantial costs to the health-care system and to the economy as a whole.
- Current estimates show that most global health-care and education costs linked to hearing loss are incurred in low- and middle-income countries.
- Public health interventions for prevention and early identification of hearing loss are cost-effective.
- Provision of hearing devices is a cost-effective strategy, especially when used regularly and supported with rehabilitation services.

Recommendations

- Hearing loss must be addressed as a public health issue.
- There is a need for policy-makers to allocate resources for, and plan strategically to promote, access to ear and hearing care.
- Public health strategies should address prevention, screening and early intervention of hearing loss.
- Country-specific data on the cost of unaddressed hearing loss and cost–effectiveness of interventions should be gathered to strengthen available evidence.

1. Introduction

An estimated 360 million people around the world have some form of hearing loss (Olusanya, Neumann & Saunders, 2014), most of whom live in low- and middle-income countries where they lack access to appropriate ear and hearing care services. Hearing loss poses a significant challenge in the lives of those affected and their families: it affects communication and language learning and is associated with lower academic achievement and fewer job opportunities. Unless suitable care is made available, the inevitable exclusion from communication causes feelings of loneliness, isolation and frustration; in elderly individuals it may also lead to cognitive decline.

Today, the causes of hearing loss are well known and preventive strategies have been identified. The technology is available to detect hearing loss at the earliest stage of development, and intervention techniques are well established. Early intervention programmes have been implemented in many parts of the world and are improving access to ear and hearing care services. People who have hearing loss are acquiring communication skills and can have the same opportunities in life as their hearing peers. Nevertheless, millions still lack access to the required interventions and face the adverse consequences of hearing loss.

A survey by the World Health Organization reported that only a handful of countries – mostly high-income countries – have developed strategies to address hearing loss (WHO, 2013). Other health priorities competing for limited resources were identified as the main barriers to provision of ear and hearing care services in underserved populations.

Knowledge of the economic costs associated with any health problem such as hearing loss, and of potential costs that might be avoided, is a powerful tool for policy-makers in planning the best use of their health-care budgets. It is the purpose of this WHO report to provide policy-makers with that tool, offering a conservative take on the global costs posed by unaddressed hearing loss. The report also reviews the cost–effectiveness of interventions to address hearing loss, with the aim of making a case for investment in this health issue.

2. Developing the report

Through this report we propose to make a case for addressing hearing loss, to policymakers who may be considering the relevance of hearing loss as a public health issue. For effective use of resources, the two key questions are likely to be posed.

- What is the cost of not addressing hearing loss?
- Is it cost-effective to provide interventions that mitigate the adverse impact of hearing loss?

In order to answer these questions, published estimates of the costs of living with hearing loss were reviewed over the period 2015–2016. After identifying over 1600 references in literature, nearly 450 studies were reviewed and of these, 50 met the criteria for inclusion in an initial review of literature. These were studies and reports focussed on costs associated with not taking action for hearing loss. Studies focussed on costs of interventions alone were excluded from the initial review. Through this an understanding was gained of the costing methods used and key aspects of direct, indirect and intangible costs relating to hearing loss.

A subsequent analysis provided a first picture of the global costs of hearing loss. The analysis takes account of the reported prevalence of hearing loss in various regions of the world and considers different aspects of its impact. Where feasible, a financial value is assigned to these aspects, including the direct costs typically incurred within the health-care system, as well as non-health costs such as those for special educational support and adaptation for children with unaddressed hearing loss. The analysis also highlights other aspects of cost, including the adverse impact of hearing loss on the individual's potential to contribute to the economy through participation in paid work. Finally, the report considers some of the broader societal impacts of hearing loss and incorporates these into estimates of global cost; details of the methodology of cost analysis and key assumptions are provided in section 3.2

As a next step, available evidence on the cost–effectiveness of interventions for hearing loss was studied in 2016, with a focus on measures aimed at preventing hearing loss, identifying it early, and providing suitable interventions, such as hearing aids, to those requiring them. Although over 500 references were identified, only 36 were found to fit the inclusion criteria as they reported original research findings. The evidence was critically reviewed and key outcomes are described in section 3.3 of this report.

3. Analysis of global costs of unaddressed hearing loss

(by Dr David McDaid and Dr A-La Park)

3.1 Types of cost assessed

The different types of cost associated with hearing loss were assessed during the analysis:

- **Direct costs** – typically, the costs associated with hearing loss incurred by health-care systems. Other direct costs may be incurred outside the health system, such as the costs of special educational support for children and of suitable adaptations.
- **Indirect costs** – include productivity losses and refer to the cost of individuals being unable to contribute to the economy because of absence from paid or voluntary work, education or home responsibilities.
- **Intangible/societal costs** – refer to the stigma experienced by families experiencing hearing loss, as well as the grief associated with the loss both of the ability to hear sound and of all the experiences related to sound.

The cost analysis was carried out following a review of literature on the costs to the health-care and education systems of hearing loss in children and adults. It was assumed that no costs were incurred to treat people with mild hearing loss. The lack of uniformity in access to hearing aids and implants across regions was considered and the actual costs of these devices were excluded from the global estimates.

3.2 Key considerations

3.2.1 Hearing loss prevalence

Data on hearing loss in the population were taken from the 2015 Global Burden of Disease (GBD) database. Published estimates of hearing loss for eight different regions of the world, categorized by five age groups (0–4, 5–14, 14–49, 50–69, and 70+ years) and by sex were then applied to these prevalence estimates (Stevens et al., 2013). Annex 1 provides definitions of severity of hearing loss that were used throughout this report. Annex 2 provides a list of countries in each region. A total of 195 countries and territories were included in the analysis; data from Palau and from Saint Kitts and Nevis were unavailable.

These prevalence rates are assumed to apply to all countries and territories that are grouped within the eight regions. The analysis further assumes that no costs are associated with mild hearing loss. All costs are calculated for moderate or higher degrees of hearing loss, i.e. hearing level greater than 35 dB in the better-hearing ear. Further, it is conservatively assumed that any additional costs of supporting children and young people

within the education system are incurred only in the case of those with at least moderately severe hearing loss (greater than 50 decibels).

3.2.2 Direct costs

Mean costs to health-care and education systems were estimated from studies (published up to 2016) of the direct costs of hearing loss. Only studies that looked at hearing loss of nonspecific cause were included, rather than studies of specific causal or risk factors such as otitis media or hazardous noise. Studies were excluded if the annual medical costs of all hearing loss could not be derived from papers.

In respect of health-care system costs, the analysis looks at costs incurred in the absence of provision of hearing aids and implants. This exclusion from the baseline analysis reflects the fact that financial and other barriers often limit access to these technologies in low- and middle-income countries.

In the absence of earlier estimates of the global direct cost of hearing loss, an approach similar to that used for estimating costs of dementia and visual impairment (Wimo, Jonsson & Winblad, 2006; Wimo et al., 2011; Access Economics, 2010) was applied to this analysis. This approach assumes that the ratio of annual direct health-care costs to gross domestic product (GDP) per capita spent on health and education services to address hearing will be similar in all countries. Following this method, direct (market price) health-care system costs can be imputed by making using of country-specific GDP per capita values and then calculating the average ratio of annual costs to GDP per capita. These GDP per capita values are given in purchasing power parity (PPP) adjusted 2015 international dollars, making use of estimates published by the World Bank; in a few cases 2014 rather than 2015 values had to be used.

Values for the United States overseas territories were obtained from the Bureau for Economic Affairs of the US Department of Commerce. The latest available values from the Central Intelligence Agency (CIA) World Fact Book were used for seven countries/territories for which World Bank estimates were not available (Andorra, Democratic People's Republic of Korea, Eritrea, Greenland, Somalia, Syrian Arab Republic and Taiwan, China). All other costs in local currencies have been converted to 2015 international dollars ($) using the International Monetary Fund (IMF) World Economic Outlook GDP Deflator Index and implied PPP conversion rate.

3.2.3 Indirect costs

Indirect costs include peoples' productivity losses due to absenteeism from work as well as income lost by family member(s) caring for a disabled child. A global estimate of indirect costs requires country-specific data on the state of labour markets and levels of participation by individuals with hearing loss. In the absence of such data, a conservative

estimate of productivity costs at global level has been prepared, with the assumption that productivity losses can be incurred only in countries that have near-full employment. The loss of work years in a working population aged 15–64 years with hearing loss is compared with a population without hearing loss. The costs of loss of work years is equivalent to PPP-adjusted GDP per capita, assuming individuals will be excluded from work for a full year.

Productivity loss is assumed to be equivalent to the difference between the rate of participation in the workforce by adults (here defined as those aged 15–64 years) with at least moderately severe levels of hearing difficulty and the rate of participation by the general working age population. To be conservative, this employment gap is taken from labour force survey data for the United Kingdom – an example of a high-income country with both highly developed regulations on employment discrimination and support for individuals with disabilities, including hearing loss.

3.2.4 Intangible/societal costs

The intangible/societal costs represent the value that an individual would place on any action or outcome – in this case, prevention of the hearing loss or of the disability it causes. This value reflects the level of accessibility, adaptation and social inclusion for people with disabilities in various countries.

- In the absence of such detailed information, one DALY (disability-adjusted life year) is valued very conservatively at PPP-adjusted country GDP per capita.
- To avoid double counting, these figures are then presented net of the costs of exclusion from the labour force.

3.3 Results

3.3.1 Health sector costs in children

Twenty studies provided information on the costs of hearing loss among children up to 14 years of age. However, the studies tended to focus specifically on the costs associated with children who received various forms of implants rather than all children who experienced hearing loss (Cheng et al., 2000; Schulze-Gattermann et al., 2002; Barton et al., 2006b; Semenov et al., 2013; Saunders et al., 2015). They also tended to provide incidence-based lifetime cost estimates rather than annual costs to health-care systems (Keren et al., 2002; Honeycutt et al., 2004). An analysis covering a number of low- and middle-income African countries provided estimates of lifetime costs associated with cochlear implants and maintenance but not of other health-care costs associated with hearing loss (Emmett et al., 2015). For this report, the estimate of the costs of hearing loss was therefore based on the findings of two studies, one from Australia and the second from the United Kingdom (Table 1).

The Australian study provided an estimate of total health-care costs in 2005 for 3.55 million Australians of all ages with some form of hearing loss (Access Economics, 2006). The estimate was broken down by sex and by five age groups, including children aged 0–14 years, and took account of differences in the severity of hearing loss. It made use of health-care expenditure linked to hearing loss from national hospital morbidity and case mix data, applying this to Australian population estimates in 2005 to estimate total costs. Total mean health-care cost of hearing loss per child for 10 268 children with moderate or greater hearing loss was estimated to be $9412 (10 392 Australian dollars at 2005 prices), of which some 54% was for use of allied health professionals including audiologists and speech therapists. The estimate did not include the costs of implants and hearing aids, which were identified separately and could thus be excluded from the cost estimate here.

In the United Kingdom study, one-year health costs for 120 children aged 7–9 years with permanent hearing loss over 40 dB were compared with costs for 63 children with normal hearing (Schroeder et al., 2006). Health and social care costs included emergency hospital visits, inpatient and outpatient care, social care services, maintenance costs for devices such as hearing aids, cochlear implants (assuming a 60-year implant life), loop systems and special alarm clocks/smoke alarms. Much of the cost data relied on self-report of costs and resource use by parents; mean annual costs were significantly higher by $2580 (£1368 at 2003 prices) per hearing-impaired child for the use of community health services, with a further small but significant difference of $228 (£121 at 2003 prices) per annum for the use of hospital outpatient services. There were no significant differences for most specialist health-care costs between the two groups. The estimates were much lower than in the Australian study, which may reflect much of the cost for speech therapy and audiology being incurred at younger ages. This estimate of additional costs is also closer to that

reported in an Italian study: the annual direct medical costs of prelingual bilateral neurosensorial hearing loss that prevented speech development were estimated in 2007 to be $1113 (€757 at 2007 prices) for children aged up to 7 years and $895 (€609 at 2007 prices) for children aged 7–18 (Bubbico et al., 2007).

Table 1. Studies used for estimate of the health care costs of hearing loss in children

Country	Population covered	Annual health-care costs of hearing loss per person (2015 int'l $)	Observations
Australia (Access Economics, 2006)	Children from birth to 14 years	9412	Makes use of national hospital morbidity and case mix data. Assumes costs apply to a population of 10 268 children with at least mild hearing loss. Does not include cost of fitting hearing aids and cochlear implants
United Kingdom (Schroeder et al., 2006)	Children aged 7–9 years	2808	Based on parental self-report of health and social care resource use costs including emergency hospital visits, inpatient and outpatient care, community and social care services, and use of equipment, including ongoing costs of hearing aids, cochlear implants, loop systems and special alarm clocks/smoke alarms

Global health costs for children with hearing loss were then estimated for two scenarios:

- Scenario A – making use of the higher Australian estimate alone, as this was based on medical record use.
- Scenario B: blending the Australian with the lower United Kingdom estimates, which relied on self-reported use of services.

Since no comparable estimates of health-care system costs were available, the global analysis assumes that the same share of GDP per capita is allocated to health-care costs for hearing loss as seen in the two scenarios. This is then combined with GBD 2015 data on the prevalence of hearing loss in each country to provide estimates of country-specific health-care costs. Although children account for only 3% of the total population affected by hearing loss, they incur much more substantial costs than adults. This reflects not only the level of

health-care costs but also the fact that children are more likely than adults to receive health-care service support for hearing loss.

In scenario A, the estimated global cost of childhood hearing loss to health-care systems in 2015 is $45.8 billion. If the blended lower share of GDP for health-care costs in scenario B is used, this cost falls to $24 billion. This will be an underestimate of total costs, however, as it takes no account of the costs of hearing devices and cochlear implants. If Australian assumptions on both the assumed use and costs of cochlear implants alone were included, global costs would increase to $47.3 billion. Table 2 shows the breakdown of these costs across eight different regions, indicating that more than 80% of all these costs are incurred outside the high-income group of countries. Table 3 shows the 10 countries that contribute most to the global health-care costs of hearing loss for children. China and India combined account for almost 31% of all costs, followed by the United States accounting for almost 9% of costs.

Table 2. Global health-care sector costs for children aged 0–14 years with at least moderate hearing loss

Region	Prevalence of at least moderate hearing loss in children 0–14 years (2015 GBD Study)	Health system cost – scenario A ($, thousands)	Health system cost – scenario B ($, thousands)	Percentage of global child health-care hearing costs
High-income	938 451	9 031 351	4 733 435	19.69%
Central/eastern Europe and central Asia	784 206	2 937 270	1 539 457	6.40%
Sub-Saharan Africa	6 468 234	4 629 128	2 426 179	10.09%
Middle East and north Africa	1 154 316	3 973 253	2 082 428	8.66%
South Asia	6 646 697	7 792 690	4 084 239	16.99%
Asia-Pacific	2 091 953	4 158 945	2 179 751	9.07%
Latin America and Caribbean	1 667 713	5 130 530	2 688 970	11.19%
East Asia	2 718 326	8 207 332	4 301 557	17.90%
World	*22 469 896*	*45 860 499*	*24 036 016*	*100%*

Table 3. Health-care sector costs for hearing-impaired children: top 10 countries contributing to global costs

Country	Prevalence of at least moderate hearing loss in children 0–14years (2015 GBD Study)	GDP per capita (2015 $)	Health system cost – scenario A ($, thousands)	Percentage of global child health-care hearing costs	Health system cost – scenario B ($, thousands)
China	2 629 638	14 450	7 860 592	17.14%	4 119 827
India	5 020 742	6 101	6 336 233	13.82%	3 320 893
United States	347 840	56 116	4 037 850	8.80%	2 116 284
Indonesia	833 843	11 058	1 907 347	4.16%	999 662
Nigeria	1 325 525	6 004	1 646 292	3.59%	862 841
Brazil	514 518	15 391	1 638 106	3.57%	858 550
Mexico	386 279	17 269	1 379 883	3.01%	723 213
Russian Federation	247 568	24 451	1 252 230	2.73%	656 308
Saudi Arabia	72 295	53 539	800 688	1.75%	419 650
Pakistan	771 721	5 011	799 935	1.74%	419 255

3.3.2 Costs in adults

To estimate the costs to the health-care sector for adults with hearing loss aged 15 and older, four studies were identified, from Australia, the Netherlands, the United Kingdom and the USA. They differ substantially in their methods, leading to very different estimates as shown in Table 4. Ultimately the studies done in Australia and the Netherlands were suitable for use. The United Kingdom study that reported on the direct costs of hearing loss in adults between the ages of 22 and 65 years in 2013 was excluded, as it looked only at the impact of the use of primary care and social care services and not at any other health-care use associated with hearing loss (Archbold et al., 2015) A brief report from the USA that provided an estimate of the health system costs of hearing loss for the over-65s in 2002 was also excluded (Stucky, Wolf & Kuo, 2010). The authors assumed that direct medical costs would be equivalent to the average cost of an initial year of hearing loss rather than trying to estimate changing costs depending on length of condition or severity; this mean that the cost estimates are much higher at $1668.11 ($1292.23 at 2002 prices) than those seen in either the Australian or Dutch studies.

Table 4. Studies estimating the health-care costs of hearing loss for adults

Country	Adult population covered	Annual health-care costs of hearing loss per person (2015 $)	Observations
Australia (Access Economics, 2006)	Young people and adults aged 15+ years	134.32	Covers health-care costs including use of hearing aids and cochlear implants
Netherlands (Nachtegaal et al., 2010)	Adults aged 18–65 years	1071.12	Covers use of primary, secondary, occupational and complementary contacts only
United Kingdom (Archbold et al., 2015)	Adults aged 22–65 years	44.58	Covers general practitioner and social care costs only
USA (Stucky, Wolf & Kuo, 2010)	Adults aged over 65 years	1668.11	Covers all health-care costs but estimate is based on initial year of treatment rather than mean cost of treatment

The Australian study used to inform estimates of the costs for children also provides detailed information on the total health-care costs in 2005 for young people and adults aged 15 years and over. The mean cost per adult with hearing loss was estimated to be $134.32 (148.29 Australian dollars at 2005 prices), including costs for hearing aids and use of cochlear implants by some of the population. This is now equivalent to 0.003% of GDP per capita in Australia in 2015.

The Dutch study relied on a questionnaire completed every month for six months by 1295 individuals aged between 18 and 65 years with and without hearing loss, collected as part of the Dutch National Longitudinal Study on Hearing (Nachtegaal et al., 2010). Significant differences in costs between the hearing-impaired and non-impaired groups were $1071 (€403 at 2007 prices). This is equivalent to 0.022% of GDP per capita in the Netherlands in 2015.

Two scenarios were used in the present analysis. Scenario A makes use of the Australian cost estimate alone, and scenario B blends the Australian and higher Dutch cost estimates. For other countries where no comparable estimates of health-care system cost are available, the analysis assumes the same share of GDP per capita is allocated to health-care costs for hearing loss. This is then combined with GBD 2015 data on the prevalence of hearing loss in each country to provide estimates of country-specific health-care costs.

In scenario A, the estimate of the global cost of hearing loss in adults to health-care systems in 2015 is $21.4 billion; if the blended share of GDP for health-care costs in scenario B is

used, this figure increases to $83.8 billion. These costs are lower than for children, reflecting the lower level of resource allocation to adults relative to children within health-care systems. Table 5 shows the breakdown of these costs across eight different regions, indicating that nearly 43% of these costs fall on the high-income countries. Table 6 shows the 10 countries with the highest individual contributions to the global health-care costs. Most are high-income countries, reflecting the potentially very low levels of funding as measured as a share of GDP per capita that are assumed to be allocated to hearing loss in this analysis. China and India combined account for more than 26% of all costs and the United States for 16%.

Table 5. Global health-care sector costs for individuals aged 15 years and over with at least moderate hearing loss

Region	Prevalence of at least moderate hearing loss in individuals aged 15+ years (2015 GBD Study)	Health system cost – scenario A ($, thousands)	Health system cost – scenario B $, thousands)	Percentage of global adult health-care hearing costs
High-income	68 898 706	9 208 295	35 935 014	42.86%
Central/eastern Europe and central Asia	36 764 655	2 190 543	8 548 508	10.20%
Sub-Saharan Africa	35 539 165	415 715	1 622 312	1.93%
Middle East and north Africa	15 474 150	841 129	3 282 472	3.91%
South Asia	91 389 297	1 559 616	6 086 341	7.26%
Asia-Pacific	35 044 078	1 087 243	4 242 923	5.06%
Latin America and Caribbean	34 026 666	1 578 553	6 160 242	7.35%
East Asia	105 086 625	4 604 395	17 968 474	21.43%
World	*422 223 343*	*21 485 488*	*83 846 285*	*100%*

Table 6. Costs to the health-care sector for hearing-impaired adults aged 15 years and over: top 10 countries contributing to global costs

Country	Prevalence of at least moderate hearing loss in individuals aged 15+ years (2015 GBD Study)	GDP per capita (2015 $)	Health system cost – scenario A ($, thousands)	Percentage of global adult health-care hearing costs	Health system cost –scenario B ($, thousands)
China	101 506 695	14 450	4 330 031	20.15%	16 897 779
United States	21 031 484	56 116	3 483 996	16.22%	13 596 160
India	72 345 713	6 101	1 302 906	6.06%	5 084 540
Japan	11 394 023	37 322	1 255 338	5.84%	4 898 907
Russian Federation	13 889 037	24 451	1 002 533	4.67%	3 912 346
Germany	6 303 835	47 377	881 640	4.10%	3 440 566
Brazil	12 264 855	15 391	557 239	2.59%	2 174 602
France	4 263 834	39 631	498 841	2.32%	1 946 709
Italy	4 653 018	36 030	494 901	2.30%	1 931 331
United Kingdom	4 024 012	41 459	492 491	2.29%	1 921 927

3.3.3 Costs to the education sector

The principal cost to education systems is for the additional support – over and above the standard education costs – to help a child remain integrated within a regular school or alternatively to be educated in a school dedicated to children with hearing difficulties. These costs will vary from country to country, according to the number of years of schooling a child can expect to receive. In 2014, for instance, the expected number of years of primary and secondary schooling for children in countries classified as high-income by the World Bank was 12.67 compared with a mean of 8.8 in low-income countries (UNESCO, 2016). Most of the countries with the lowest number of expected years of schooling are in sub-Saharan Africa (Table 7).

Table 7. Countries with lowest expected years of schooling for all children, 2015[a]

Country	Expected years in primary/secondary school, both sexes
South Sudan	4.75
Eritrea	4.81
Niger	5.83
Djibouti	6.62
Mali	7.00
Pakistan	7.74
Burkina Faso	7.99
Senegal	8.47
Mauritania	8.51
Côte d'Ivoire	8.69

[a]Source: UNESCO, 2016.

Given these differences in duration of schooling the estimate of costs used in this model assumes that all children have the opportunity to attend school between the ages of 5 and 14 years. Special educational support for preschool children within and outside the education sector is available in some countries and represents another element of cost, although the availability of such support around the world is impossible to determine

Conservatively, costs for young people aged 15–18 years are not included even though many will attend school, particularly in high-income countries. The costs of educational support for young people attending higher education, including university, have also been excluded from the estimate: these costs are highly country-specific and cannot easily be determined at a global level.

The analysis also conservatively assumes that special educational support is provided only to children with at least moderately severe hearing loss; most of the studies that were identified focused on this population. The direct costs to education systems of supporting children with this level of hearing loss are often greater than the costs incurred by health systems.

Eighteen studies looked at the impacts on education systems – for instance, the costs of providing education within specialist schools for the deaf, especially for children with congenital or prelingual onset of hearing loss. Some of these studies were excluded from

consideration for this global costing model because they focused only on narrow segments of the population, e.g. children with severe to profound hearing loss (Cheng et al., 2000; Mohr et al., 2000; Schulze-Gattermann et al. 2002; Saunders et al., 2015), or on a very small number of cases (Francis et al., 1999) or because they had been superseded by more recent estimates (O`Neill et al., 2001). A study from China reported the estimated mean costs of special education over nine years for children who had not been subject to neonatal screening or treated subsequently for permanent congenital and early-onset hearing loss were $42 300, or $4700 per annum (Huang et al., 2012). The paper was not specific, however, on the severity of hearing loss associated with these costs and was therefore excluded from consideration of education costs. Costs to the education sector in high-income settings are thus a composite of estimates of costs from five sources: four studies (two from the United Kingdom, one each from Australia and Italy) plus calculated costs in the United States drawing on information cited in a study and survey data. Table 8 summarizes these sources of information.

These five sources include an estimate from the United Kingdom that was based on a cross-sectional survey involving the teachers of nearly 9000 children using special educational services; the costs of compulsory education for children with at least moderately impaired hearing, with and without cochlear implants, were estimated (Barton et al., 2006a). It covered the costs of placement in mainstream nursery/primary or secondary school settings, of the use of special education services, and of support from teachers, learning assistants, community support workers, sign language tutors, nursery nurses, speech and language therapists and other professionals. The most conservative estimate suggested an annual cost for special education services of $19 398 (£10 234 at 2003 prices). Excluding the average cost of school attendance for any child of $7489 (£5212 at 2015 prices) (DfE, 2016), the mean additional annual cost per hearing-impaired child aged between 4 and 16 years was $11 909.

Another United Kingdom study reported special education-related costs to be the key element of differences in costs between children born with bilateral permanent childhood hearing loss (PCHL) and a similar cohort of children without hearing loss in southern England (Schroeder et al., 2006). The one-year health and education costs for 120 children with PCHL and a mean age of 7.9 years were compared with those for 63 children with normal hearing and a mean age of 8.1 years. The cost data relied heavily on self-report of costs and resource use by parents. Mean annual education costs for each child with hearing loss were estimated to be $20 445 (£10 841 at 2003 prices) compared with $6644 (£3523 at 2003 prices) for a child without hearing loss. In non-parametric bootstrapped analysis, the mean difference in education costs between hearing-impaired and non-impaired children was estimated to be $13 731 (£7281 at 2003 prices).

Table 8. Studies estimating costs to the education sector of hearing loss

Country	Population covered	Annual costs to education sector of hearing loss per pupil (2015 $)	Observations
Australia (Access Economics, 2006)	All children with at least mild hearing loss	5 075	Mean additional costs to the education system for children in mainstream and special schools
Italy (Colletti et al., 2011)	Congenitally and prelingually deaf children up to age 10 years	4 610	Mean additional costs for educational support in mainstream schools
United Kingdom (Barton et al., 2006a)	Children aged 4–16 years with bilateral permanent hearing loss greater than 40 dB attending nursery, primary or secondary schools	11 909	Costs in mainstream nursery, primary or secondary school settings, plus use of special education services, and support costs for teachers, learning support assistants, community support workers, sign language tutors, nursery nurses, speech and language therapists and other professionals
United Kingdom (Schroeder et al., 2006)	Children aged 7–9 years with bilateral permanent hearing loss greater than 40 dB	13 731	Costs in mainstream primary or secondary school settings, plus use of special education services/ residential services, and cost of support from teachers and learning support assistants
USA (GRI, 2011; Semenov et al., 2013; NCES, 2016)	Children aged 3 years and over with all levels of hearing loss included in survey of educational settings	8 235	Makes used of published US Department of Education estimate of market costs for different types of educational placement and support for hearing-impaired children

An Italian analysis reported the impact on the costs of education of earlier cochlear implantation (Colletti et al., 2011). Mean education expenses were $8963 per annum for children who did not receive an implant until they were between 6 and 7 years of age compared with $4353 for children who received an implant in their first year of life. However, this analysis appears to look only at educational costs within mainstream school settings. Analysis in Australia, taking account of children in mainstream and special schools with all levels of hearing loss, reported mean additional costs to the education system per child of 5603 Australian dollars (2005 prices) annually (Access Economics, 2006).

Annual costs from the US Department of Education for different types of educational placement and support for hearing-impaired children were reported in a study looking at the impact of the costs of cochlear implantation in young children in the USA (Semenov et al., 2013). These data were combined with 2010 survey data on the placement of students with all levels of hearing loss in different school settings in the USA (GRI, 2011) to estimate the additional mean cost per student as $8235 more than the average annual education cost of $11 011 (NCES, 2016).

Another study was identified that looked at the 10-year costs of education for severely and profoundly hearing-impaired children in six sub-Saharan African countries – Kenya, Malawi, Nigeria, Rwanda, South Africa and Uganda (Emmett et al., 2015) – but information on the extent to which these services are available for all children with moderate and greater levels of hearing loss in Africa, without significant financial cost to families, is very limited. Certainly, restrictions on opportunities for hearing-impaired children to access school have been cited in several low- and middle-income countries (UNESCO, 2014). The study revealed the annual cost of education in a residential school for the deaf in South Africa to be $6419 per child. However, these schools are available to only a minority of children and may be fee-paying. Moreover, this figure takes no account of the routine costs of providing an education for any child. The costs of special education for those with hearing loss are substantially lower in the other five African countries, but access to this education still appears to be limited; for example, one recent news article indicates that Malawi has only six schools for children with severe hearing loss (Clark et al., 2015). The estimate of costs as a share of GDP per capita consistently provided lower, more conservative estimates of costs in these countries. These lower estimates were therefore used with caution, given the lack of information on access to education as well as a lack of information on the routine costs of schooling.

Using the results of the five studies included in Table 8, about 0.18% of GDP per capita would be spent on additional education sector costs for individuals with at least moderately severe hearing loss. This same share of GDP per capita was applied to all other countries: overall, the additional costs to support the education of children aged 5–14 years with at least moderately-severe levels of hearing loss can be conservatively estimated at $3.9 billion.

Table 9 shows the breakdown of these costs across the eight different regions. It indicates that, if spending in all countries reflects GDP per capita in the studies included in the model, more than 83% of costs fall with the high-income grouping of countries, reflecting the higher prevalence of more severe levels of hearing loss in low- and middle-income countries.

The 10 countries that account for the greatest portion of global education sector costs of hearing loss are listed in Table 10. China and India account for one third of all costs; only one country from the high-income group – USA – features in the list. Critically, however, the actual education sector costs in countries will depend on the extent to which children have the opportunity to participate in education, and it is noted that there is little detailed information on this outside high-income country settings.

Table 9. Global education sector costs for children aged 5–14 years with at least moderately severe hearing loss

Region	Prevalence of at least moderately severe hearing loss in children aged 5–14 years	Education system cost ($, thousands)	Percentage of global child health-care hearing costs
High-income	78 996	658 944	16.83%
Central/eastern Europe and central Asia	71 349	233 620	5.97%
Sub-Saharan Africa	606 247	374 041	9.55%
Middle East and north Africa	112 768	342 863	8.76%
South Asia	722 801	741 255	18.94%
Asia-Pacific	212 428	369 285	9.43%
Latin America and Caribbean	173 753	467 038	11.93%
East Asia	275 527	727 634	18.59%
World	*2 253 869*	*3 914 681*	*100%*

Table 10. Costs to the education sector for hearing-impaired children aged 5–14 years: top 10 countries contributing to global costs

Country	Prevalence of hearing loss in children aged 5–14 years (2015 GBD Study)	GDP per capita (2015 $)	Education system cost ($, thousands)	Percentage of global child health-care hearing costs
China	265 942	14 450	693 426	0.1771%
India	554 480	6 101	610 384	0.1559%
USA	28 081	56 116	284 338	0.0726%
Indonesia	82 993	11 058	165 593	0.0423%
Brazil	56 218	15 391	156 124	0.0399%
Nigeria	122 067	6 004	132 242	0.0338%
Mexico	40 187	17 269	125 222	0.0320%
Russian Federation	21 938	24 451	96 794	0.0247%
Saudi Arabia	7 534	53 539	72 786	0.0186%
Pakistan	74 910	5 011	67 731	0.0173%

3.3.4 Productivity losses

Reduced participation of hearing-impaired individuals in the workforce accounts for a much higher share of the total costs of hearing loss than health or education sector costs. Hearing loss has multiple impacts on participation in employment: rates of employment are lower than for people without disabilities (Woodcock & Pole, 2008; Rydberg, Gellerstedt & Danermark, 2010; Jung & Bhattacharyya, 2012; Pierre et al., 2012; Stam et al., 2013; Garramiola-Bilbao & Rodriguez-Alvarez, 2016) and hearing loss is also a reason for early retirement (Helvik, Krokstad & Tambs, 2012). Research also points to career opportunities and levels of income being restricted because of hearing loss (Hogan et al., 2009). Moreover, the impact on participation in employment is likely to be greater if participation in education is curtailed (Woodcock & Pole, 2008; Garramiola-Bilbao & Rodriguez-Alvarez, 2016).

In Australia, the employment rate for people with hearing loss was 11% lower than that for the general population. The cost of this employment gap was estimated to be $5.7 billion (6.67 billion Australian dollars at 2005 prices) (Access Economics, 2006).

Various studies in the United Kingdom have estimated the costs of productivity losses. Using a prevalence-based approach to determine the level of hearing loss, the Commission on

Hearing Loss (ILC-UK, 2014) estimated productivity losses to be $36.4 billion (£24.8 billion at 2013 prices). Another study estimated losses of $3135 (£2136 at 2013 prices) per person – totalling almost $6 billion in 2013 – as a consequence of reduced earning for hearing-impaired individuals in employment (Archbold et al., 2015). An earlier United Kingdom study estimated the costs due to lost employment and reported a loss of $33 billion for all those experiencing hearing loss and of $25 billion if the estimate was restricted to individuals who did not use hearing aids (Shield, 2006).

A global estimate of at least some of the productivity losses related to hearing loss would require detailed information on participation rates in employment by hearing-impaired individuals relative to the general working-age population in all countries. However, this information is not available; the employment gap is likely to vary greatly, and is probably lowest in countries that have taken the most progressive steps to promote inclusion in the workforce.

In the absence of country-specific information, a conservative estimate of productivity costs at global level has been prepared for illustrative purposes, using the assumption that productivity losses can be incurred only in countries that have near-full employment. From a societal perspective, reduced rates of participation in employment have an economic cost only in conditions of full employment. In practice, "full employment" does not mean a zero unemployment rate – there will always be fluctuations in employment status; there is no agreement on a definition of full employment, but it has been equated with unemployment rates between 3% and 6%. For the purposes of this analysis, full employment was assumed in all countries with unemployment rates of 6% or less. Thus, if individuals with hearing loss are excluded from the labour market in these countries, productivity losses are incurred. No productivity losses are assumed to be incurred in other countries. Assumptions on the rate of unemployment and the participation of adults (aged 15–64 years) in employment in the working population were taken from ILO statistics for all countries for 2015 (ILOSTAT. Employment to Population Ratio 2015, 2016; ILOSTAT. Unemployment Rate, 2016).

The analysis also assumes that losses are due only to unemployment and premature retirement; it does not take account of any impacts on productivity during employment and further assumes that there are no productivity losses due to mortality. Productivity loss is assumed to be equivalent to the difference in the rate of participation in the workforce by adults (15–64 years) with at least moderately severe hearing loss compared with the rate of participation by the general working-age population.

To be conservative, this employment gap is taken from 2015 Labour Force Survey data in the United Kingdom – an example of a high-income country with highly developed regulations on employment discrimination, as well as support for individuals with disabilities, including hearing loss. The employment rate for "all working age people who are not classified disabled and/or work-limiting disabled" was estimated to be 79.3%; this compared with a rate of 64.9% for "working age disabled people who report their main

health problem as difficulty in hearing" (Tomlinson, 2015), which translates into a gap of 18% in the employment rates between the two groups. The costs of exclusion from the labour force are here assumed to be equivalent to PPP-adjusted GDP per capita; it is assumed that individuals will be excluded from work for a full year.

Seventy-three countries had unemployment rates of 6% or less in 2015. Many high-income countries, such as France, Greece and the Netherlands, were deemed not to have full employment and were excluded from this analysis. Global and country-specific factors influence the number of countries that have low unemployment rates. Total productivity losses using this approach are estimated to be almost $105 billion (Table 11); 71% of costs are outside the high-income region. This illustrative estimate is probably conservative as it does not take account of productivity losses among people with mild or moderate hearing loss. If moderate hearing loss is also assumed to have an impact on employment participation, productivity losses in this model would increase to more than $402 billion. In addition to these productivity losses, governments will also incur administration costs associated with providing any social welfare benefits to individuals who are out of work as a result of their hearing loss. (The value of the benefits themselves would not be considered a cost from a societal perspective but, effectively, a transfer payment between different members of society via the country's taxation system.)

Table 12 shows the 10 countries with the highest individual contributions in the illustrative analysis of global productivity costs of hearing loss. China accounts for more than one third of all productivity costs,[1] followed by the United States and then India. The values for the United Kingdom in Table 11 illustrate how potentially conservative this global estimate is: estimated productivity costs of almost $2 billion are considerably lower than the estimates discussed earlier in this report. However, more country-specific data are needed to determine the full extent of productivity losses.

[1] In fact this estimate is low as GDPs in the Hong Kong and Macao Special Administrative Regions of China are higher than GDP per capita in mainland China.

Table 11. Illustrative global productivity losses due to at least moderately severe hearing loss in individuals aged 15–64 years

Region	Prevalence of moderately severe plus hearing loss in individuals aged 15–64 years	Productivity costs ($, thousands)	Percentage of global productivity costs
High-income	5 773 196	30 115 025	28.70%
Central/eastern Europe and central Asia	3 243 370	8 585 116	8.18%
Sub-Saharan Africa	5 046 689	1 713 628	1.63%
Middle East and north Africa	310 339	2 220 428	2.12%
South Asia	20 829 200	11 481 003	10.94%
Asia-Pacific	6 764 459	8 956 213	8.54%
Latin America and Caribbean	2 461 866	4 078 223	3.89%
East Asia	20 690 857	37 772 657	36.00%
World	*65 119 976*	*104 922 293*	*100%*

Table 12. Illustrative productivity costs for at least moderately severe hearing impaired adults (15–64 years): top 10 countries contributing to global costs

Country	Unemployment rate – ILO estimates and projections (%)	Prevalence of moderately severe hearing loss, 15–64 years	Total productivity costs	Percentage of total productivity costs
China	4.6	20 328 284	36 077 358	34.38%
United States	5.3	2 969 823	17 794 313	16.96%
India	3.5	16 713 456	9 601 605	9.15%
Russian Federation	5.8	2 598 384	6 898 693	6.58%
Japan	3.3	1 065 159	4 137 773	3.94%
Indonesia	5.8	3 058 083	3 895 441	3.71%
Germany	4.6	610 725	3 024 283	2.88%
Mexico	4.3	1 351 599	2 522 259	2.40%
Thailand	1.1	1 111 825	2 329 015	2.22%
United Kingdom	5.5	439 312	1 959 656	1.87%

3.3.5 Societal/intangible costs

The intangible costs of hearing loss are social and individual experiences attached to the disability expressed in monetary terms. Although it is hard to place a value on stigma, grief and social exclusion, one way of expressing this is to enumerate the quality-adjusted or disability-adjusted life years. Alternatively, surveys can be conducted to gather information on how much individuals are willing to invest to avoid the adverse health impacts of a disease or disability. The values thus obtained vary according to the degree of accessibility (to education, communication, employment, etc.), adaption and social inclusion that exists for individuals with disabilities in different countries.

Intangible costs for hearing loss are rarely estimated but can dominate overall costs. In a study by Shield (2006), a monetary value was placed on lost quality of life due to hearing loss in adults in the European Union and in Europe as a whole (excluding the Russian Federation and Turkey) in 2004. With each quality-adjusted life year lost assumed to have a value (in 2003) of €44 000, the total cost of hearing loss in Europe was estimated at $421 billion (€284 billion at 2003 prices). In Australia, the monetary value of the total number of disability-adjusted life years (DALYs), where each DALY was valued at $50 800 after excluding health and productivity losses, was $10.2 billion (11.3 billion Australian dollars at 2005 prices).

In principle, the same approach can be used at a global level but requires a detailed evaluation of willingness to pay to avoid hearing loss in different countries. In the absence of such detailed information for most countries, the analysis for illustrative purposes indicates what the costs of hearing loss might be if one DALY were valued very conservatively at PPP-adjusted country GDP per capita. To avoid double counting, these figures are presented net of the costs of exclusion from the labour force as well as of use of health and education systems.

Table 13 shows net costs of DALYs after excluding productivity costs. More than 47% of the global costs of $573 billion are incurred in high-income region countries. China has the highest share (15.27%) of total intangible costs, closely followed by the United States (14.36%), which has a smaller DALY burden valued at a higher relative rate of GDP per capita.

Table 13. Illustrative global costs of DALYs all ages due to hearing loss

Region	Intangible costs (S, thousands)	Percentage of total intangible costs
High-income	270 812 007	47.22%
Central/eastern Europe and central Asia	53 043 833	9.25%
Sub-Saharan Africa	13 646 792	2.38%
Middle East and north Africa	26 211 852	4.57%
South Asia	42 714 604	7.45%
Asia-Pacific	25 556 456	4.46%
Latin America and Caribbean	48 229 973	8.41%
East Asia	93 281 921	16.27%
World	*573 497 438*	*100.00%*

3.3.6 Other costs: informal care and communication-related

Hearing loss will also contribute to productivity losses by family members and friends who spend time providing additional support to people with impaired hearing. One Australian analysis estimated costs of $2.7 billion for informal care received from family and friends (assumed to be 5.75 hours every week). Most obviously, these costs are likely to be incurred by the parents of young children. However, there is insufficient information to allow anything to be said in this analysis about the incremental level of informal unpaid care and support linked to hearing status at global level.

Further costs relate to measures to promote inclusion though improved communication. For instance, costs are associated with the provision of modified telephones suitable for hearing-impaired individuals and of digital hearing aids that can now connect directly to mobile phones; some of these may be borne by the public purse but costs will often be payable by families. Public and private-sector broadcasters may have to comply with national requirements relating to television access services, including subtitling (close captioning) and on-screen sign language interpretation of a proportion of programming. These costs will be highly country-specific and depend partly on national regulations and legislation related to disability; they were not included in the global estimates.

3.3.8 Overall costs

This conservative analysis clearly indicates that unaddressed hearing loss poses a high cost burden to economies throughout the world. The overall cost is the sum of all direct, indirect and societal costs and is estimated at between 750 and 790 billion international dollars.

Table 14 brings together estimates of the global costs of health and education costs for 2015. Using health-care costs for scenario A these amount to $71.2 billion; for scenario B the figure is $111.8 billion. Of these costs, 73% and 63% are incurred outside the high-income region for scenarios A and B respectively. The costs in Table 14 do not include the costs of hearing aids and cochlear implants but are the costs incurred for the provision of services within the health-care and education systems. The estimate of the costs to the education sector is conservative as it accounts for the costs incurred by children aged 5–14 years with at least moderately severe hearing loss; it does not include the costs related to support for communication.

Estimating informal care and intangible costs, such as the costs of social exclusion and grief, presents a particular challenge, but these are important elements of global cost, and country-specific data are required. Table 15 illustrates the impact of their inclusion in the overall societal costs of hearing loss. The illustrative cost estimates Table 15 are certainly very conservative but may add at least $104 billion to productivity losses. The informal care costs and intangible costs will depend crucially on the monetary values attached to the avoidance of a year lived with disability in different countries. In the current estimates, country-specific GDP per capita has been used; this may over- or undervalue the costs, and country-specific – or at least region-specific – data need to be collected if these costs are to be better identified and quantified.

Table 14. Total health (at least moderate hearing loss) and education (at least moderately severe loss) sector costs

Region	Education costs ($, thousands)	Total health sector costs ($, thousands)		Total health sector and education costs ($, thousands)		Total health sector and education costs (as % of total health and education costs)	
		Scenario A	Scenario B	Scenario A	Scenario B	Scenario A	Scenario B
High-income	658 944	18 239 646	40 668 449	18 898 590	41 327 393	26.52%	36.97%
Central/eastern Europe and central Asia	233 620	5 127 813	10 087 965	5 361 433	10 321 585	7.52%	9.23%
Sub-Saharan Africa	376 433	5 044 843	4 048 491	5 421 275	4 424 924	7.61%	3.96%
Middle East and north Africa	340 472	4 814 382	5 364 900	5 154 854	5 705 372	7.23%	5.10%
South Asia	741 255	9 352 306	10 170 580	10 093 562	10 911 835	14.16%	9.76%
Asia-Pacific	369 285	5 246 188	6 422 674	5 615 473	6 791 958	7.88%	6.08%
Latin America and Caribbean	467 038	6 709 082	8 849 211	7 176 120	9 316 249	10.07%	8.33%
East Asia	727 634	12 811 727	22 270 031	13 539 361	22 997 665	19.00%	20.57%
World	*3 914 681*	*67 345 987*	*107 882 301*	*71 260 668*	*111 796 982*	*100.00%*	*100.00%*

Table 15. Illustrative combined direct, indirect and intangible costs of hearing loss ($ '000s)

Region	Total health costs ($, thousands)		Education costs ($, thousands)	Productivity costs ($, thousands)	Intangible costs ($, thousands)	All costs ($, thousands)		Percentage of all costs	
	Scenario A	Scenario B				Scenario A	Scenario B	Scenario A	Scenario B
High-income	18 239 646	40 668 449	658 944	30 115 025	270 812 007	319 825 622	342 254 425	42.66%	43.31%
Central/eastern Europe and central Asia	5 127 813	10 087 965	233 620	8 585 116	53 043 833	66 990 382	71 950 534	8.94%	9.11%
Sub-Saharan Africa	5 044 843	4 048 491	376 433	1 713 628	13 646 792	20 781 696	19 785 344	2.77%	2.50%
Middle East and north Africa	4 814 382	5 364 900	340 472	2 220 428	26 211 852	33 587 134	34 137 652	4.48%	4.32%
South Asia	9 352 306	10 170 580	741 255	11 481 003	42 714 604	64 289 169	65 107 442	8.58%	8.24%
Asia-Pacific	5 246 188	6 422 674	369 285	8 956 213	25 556 456	40 128 141	41 304 627	5.35%	5.23%
Latin America and Caribbean	6 709 082	8 849 211	467 038	4 078 223	48 229 973	59 484 316	61 624 445	7.93%	7.80%
East Asia	12 811 727	22 270 031	727 634	37 772 657	93 281 921	144 593 939	154 052 243	19.29%	19.49%
World	*67 345 987*	*107 882 301*	*3 914 681*	*104 922 293*	*573 497 438*	*749 680 398*	*790 216 713*	*100.00%*	*100.00%*

4. Cost–effectiveness of intervention

Available evidence was reviewed to assess the cost–effectiveness of interventions to prevent, identify and manage hearing loss.

4.1 Prevention

Just two articles relating to strategies for prevention of hearing loss were available. Baltussen & Smith (2009) looked at the cost–effectiveness of selected interventions for prevention of hearing loss in Africa and Asia; they suggest that passive screening for identification and treatment of otitis media is the most efficient preventive measure in these regions. In Australia, 37% of hearing loss is the result of exposure to excessive noise, which is preventable (Access Economics, 2006). Suitable interventions to raise awareness of, and develop policy for, reduction of noise-induced hearing loss can be a cost-effective option for prevention.

4.2 Screening programmes

Screening for hearing loss is a cost-effective strategy, but the most beneficial screening techniques to be used depend on the country and its existing infrastructure. In developed provinces of China, for example, universal screening was shown to be feasible because the infrastructure for its implementation already existed. In developing areas of the country, however, neonatal screening by targeted otoacoustic emissions is the more realistic approach (Tobe et al., 2013).

In neonates, it has been shown that universal screening achieves a good economic effect in the long term (see model by Huang et al., 2012) and that the cost–effectiveness of hospital-based (Bevilacqua et al., 2010) and community-based screening models in newborns does not differ significantly (Grill et al., 2006). Interestingly, family costs and cost per case associated with a newborn hearing screening programme in England (Uus, Bamford & Taylor, 2006) are considerably less than the costs of distraction screening tests performed by health visitors on infants around 8 months of age. Universal screening is also cost-effective (Kezirian et al., 2001; Hessel et al., 2003) if false-positives can be minimized (Kemper & Downs, 2000), and it has higher potential for long-term cost-saving when compared with no screening or selective screening (Keren et al., 2002). The implementation of a tracking system within a newborn hearing screening programme improves its cost–effectiveness.

Other significant benefits are associated with early detection and treatment of infants with hearing loss, such as increased productivity as a result of better language skills (Langer et al., 2012) and improvements in health-related quality of life (Burke, Shenton & Taylor, 2012).

Screening of schoolchildren for hearing loss has been shown to be a cost-effective and economically attractive intervention. However, targeted screening could be more accurate and cost-effective than universal screening, especially when children have already been identified with hearing loss at a school-entry hearing check. Annual screening of schoolchildren is an effective method for early identification and management of otitis media (Baltussen & Smith, 2009).

For 60- to 70-year-old adults with hearing loss, screening would provide a cost-effective way to improve quality of life, with a one-stage audiometric screen being more cost-effective than a two-stage strategy (Morris et al., 2012). In adults with hearing disabilities, screening focused on identifying individuals with significant hearing loss (i.e. hearing level >35 dB) would be effective and give better outcomes (Davis et al., 2007). In addition, it has been reported (Liu et al., 2011) that the tone-emitting otoscope is a more cost-effective means of screening elderly people for hearing loss than the hearing handicap questionnaire strategy.

4.3 Hearing aids

A cost–utility analysis conducted by Abrams et al. (2002) compares the cost–effectiveness of hearing aids alone with that of hearing aids combined with short-term post-fitting audiological rehabilitation. In adults with mild sensorineural hearing loss, results showed the greater cost–effectiveness of hearing aids plus post-fitting rehabilitation. This was confirmed by another study in the Netherlands (Joore et al., 2003), which showed fitting of hearing aids to be cost-effective. However, comparison of utility scores before and after provision of hearing aids revealed that the cost–effectiveness of the aids varies with the instrument used to measure utility (Barton et al., 2004).

4.4 Cochlear implants

A study comparing quality of life and cost–utility of unilateral vs bilateral cochlear implants reported greater cost–effectiveness for bilateral cochlear implants compared with unilateral implants in patients with profound hearing loss. Additional improvements in quality of life were seen after patients received the second implant (Bichey & Miyamoto, 2008). However, cost–utility scenarios by Summerfield et al. (2002) demonstrated significant improvement with bilateral implantation, making it a cost-effective choice. Treatment of post-lingual deaf adults with cochlear implants improves quality of life at a reasonable direct cost and appears to produce net savings (Bichey et al., 2002; Lee et al., 2006). Overall, cochlear implants have a large and significant positive impact on health-related quality of life and speech perception (Klop et al., 2008). Drennan, Banerjee & Garrison (2015) have reported that cochlear implantation in 1-year old children, in India would be cost-effective and significantly improve their quality of life. Cheng et al. (2000) showed that cochlear implants in children are very effective and Summerfield et al. (2010) reported that bilateral implantation is not only cost-effective but also associated with improved quality of life. However, some reports have shown that the cost–effectiveness of cochlear implants

declines with age (see UK Cochlear Impact Study Group, 2004). Chen, Amoodie & Mittmann (2014) looked at the cost and cost–effectiveness of bilateral cochlear implants in Canada; it was their observation that the major improvement in quality of life came from the first implant, and that the cost–effectiveness of bilateral compared with unilateral implantation is not much different. In reviewing cost–benefit, cost–utility and cost–effectiveness, it appears that, in the United States, each US$ 1 invested in treating a hearing-impaired child with cochlear implants yields a return of US$ 2.07 (Penaranda et al., 2012). A study by Monteiro et al. (2012) showed that the overall costs of cochlear implantation were exceeded by the personal (quality of life) and economic benefits (positive change in employment status post-implantation and significant increase in annual income). In their study they found that people with untreated hearing loss earn 50–70% less in Canada.

Looking at the economic costs of congenital bilateral permanent childhood hearing loss Schroeder et al. (2006) noted that the annual health, social and broader societal cost is related to the severity of loss and is inversely related to language abilities after adjustment for severity. The high cost associated with prelingual onset of severe to profound hearing loss suggests interventions aimed at children, such as early identification and treatment, may yield substantial dividends. American data reported by Mohr et al. (2000) suggest that, if early investment can shift just an additional 10% of prelingually deaf children into mainstream education, the return on investment would more than double.

5. Conclusions and recommendations

Based on the available evidence and analysis, the following conclusions are reached and recommendations made:

5.1 Conclusions

- This initial analysis shows that unaddressed hearing loss poses substantial costs to the health-care system and to the economy as a whole.
- Current estimates show that most global health-care and education costs linked to hearing loss are incurred in low- and middle-income countries.
- Public health interventions for prevention and early identification of hearing loss are cost-effective.
- Provision of hearing devices is a cost-effective strategy, especially when used regularly and supported with rehabilitation services.

5.2 Recommendations

- Hearing loss must be addressed as a public health issue.
- There is a need for policy-makers to allocate resources for, and plan strategically to promote, access to ear and hearing care.
- Public health strategies should address prevention, screening and early intervention of hearing loss.
- Country-specific data on the cost of unaddressed hearing loss and cost–effectiveness of interventions should be gathered to strengthen available evidence.

6. References

Abrams H, Chisolm TH, McArdle R (2002). A cost-utility analysis of adult group audiologic rehabilitation: are the benefits worth the cost? J Rehabil Res Dev. 39(5):549–58.

Access Economics (2006). Listen Hear! The economic impact and cost of hearing loss in Australia: a report. Melbourne: Cooperative Research Centre for Cochlear Implant and Hearing Aid Innovation.

Access Economics (2010). The global economic cost of visual impairment. Report for AMD Alliance International. Canberra: Access Economics.

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 technologies. Nottingham, The Ear Foundation.

Armstrong M (2016). Automatic recovery and verification of subtitles for large collections of video clips. London: British Broadcasting Corporation (White Paper WHP 323).

Baltussen R, Smith A (2009). Cost-effectiveness of selected interventions for hearing impairment in Africa and Asia: a mathematical modelling approach. Int J Audiol. 48:144–58.

Bamford J, Fortnum H, Bristow K, Smith J, Vamvakas G, Davies L et al. (2007). Current practice, accuracy, effectiveness and cost-effectiveness of the school entry hearing screen. Health Technol Assess. 11(32):1–168.

Barton GR, Bankart J, Davis AC, Summerfield QA (2004). Comparing utility scores before and after hearing-aid provision. Appl Health Econ Health Policy. 3(2):103–5.

Barton GR, Stacey PC, Fortnum HM, Summerfield AQ (2006a). Hearing-impaired children in the United Kingdom, II: Cochlear implantation and the cost of compulsory education. Ear Hear. 27(2):187–207.

Barton GR, Stacey PC, Fortnum HM, Summerfield AQ (2006b). Hearing-impaired children in the United Kingdom, IV: cost-effectiveness of pediatric cochlear implantation. Ear Hear. 27(5):575–88.

Bevilacqua MC, Alvarenga K, Costa OA., Moret A (2010). The universal newborn hearing screening in Brazil: from identification to intervention. Int J Pediatr Otorhinolaryngol. 74(5):510–5.

Bichey BG, Miyamoto RT (2008). Outcomes in bilateral cochlear implantation. Otolaryngol Head Neck Surg. 138(5):655–61.

Bichey BG, Hoversland JM, Wynne MK, Miyamoto RT (2002). Changes in quality of life and the cost-utility associated with cochlear implantation in patients with large vestibular aqueduct syndrome. Otol Neurotol. 23(3):323–7.

Bubbico L, Bartolucci MA, Broglio D, Boner A (2007). Costi sociali della sordita pre-linguale [Societal cost of pre-lingual deafness]. Ann Ig. 19(2):143–52.

Burke MJ, Shenton RC, Taylor MJ (2012). The economics of screening infants at risk of hearing impairment: an international analysis. Int J Pediatr Otorhinolaryngol. 76(2):212–8.

Chen J, Amoodie H, Mittmann N (2014). Cost-utility analysis of bilateral cochlear implantation in adults: a health economic assessment from the perspective of a publicly funded program. Laryngoscope. 124(6):1452–8.

Cheng AK, Rubin HR, Powe NR, Mellon NK, Francis HW, Niparko JK (2000). Cost-utility analysis of the cochlear implant in children. JAMA. 284(7):850–6.

Clark J (2015). Malawian students travel to Manchester to save country from hearing loss pandemic. In: Mancunian Matters [website]. Manchester: Mancunian Matters (http://www.mancunianmatters.co.uk/content/021074524-malawian-students-travel-manchester-save-country-hearing-loss-pandemic, accessed 14 February 2017).

Colletti L, Mandalà M, Shannon RV, Colletti V (2011). Estimated net saving to society from cochlear implantation in infants: a preliminary analysis. Laryngoscope. 121(11):2455–60.

ILC-UK (2014). Commission on Hearing Loss: final report. London: International Longevity Centre-UK.

Davis A, Smith P, Ferguson M, Stephens D, Gianopoulos I (2007). Acceptability, benefit and costs of early screening for hearing disability: a study of potential screening tests and models. Health Technol Assess. 11(42):1–294.

DfE (2016). Expenditure by local authorities and schools on education, children and young people's services in England, 2014–15. London: Department for Education (SR63/2016).

Drennan WR, Banerjee S, Garrison L (2015). Estimating cost-effective device prices for Pediatric Cochlear implantation in India [abstract]. Value Health. 18(3):A183.

Emmett SD, Tucci DL, Smith M, Macharia IM, Ndegwa SN, Nakku D et al. (2015). GDP matters: cost effectiveness of cochlear implantation and deaf education in sub-Saharan Africa. Otol Neurotol. 36(8):1357–65.

Francis HW, Koch ME, Wyatt JR, Niparko JK (1999). Trends in educational placement and cost-benefit considerations in children with cochlear implants. Arch Otolaryngol Head Neck Surg. 125(5):499–505.

GRI (2011). Regional and National Summary Report of Data from the 2009–10 Annual Survey of Deaf and Hard of Hearing Children. Washington, DC: Gallaudet Research Institute, Gallaudet University.

Garramiola-Bilbao I, Rodriguez-Alvarez A (2016). Linking hearing impairment, employment and education. Public health. 141:130–5.

Grill E, Uus K, Hessel F, Davies L, Taylor R, Wasem J et al. (2006). Neonatal hearing screening: modelling cost and effectiveness of hospital- and community-based screening. BMC Health Serv Res. 6:14.

Helvik AS, Krokstad S, Tambs K (2013). Hearing loss and risk of early retirement. The HUNT study. Eur J Public Health. 23(4):617–22.

Hessel F, Grill E, Schnell-Inderst P, Siebert U, Kunze S, Nickisch A et al. (2003). Economic evaluation of newborn hearing screening: modelling costs and outcomes. Ger Med Sci. 1:Doc09.

Hogan A, O'Loughlin K, Davis A, Kendig H (2009) Hearing loss and paid employment: Australian population survey findings. Int J Audiol. 48(3):117–22.

Honeycutt A, Dunlap L, Chen H, al Homsi G (2004). Economic costs associated with mental retardation, cerebral palsy, hearing loss, and vision impairment – United States, 2003. MMWR Morb Mortal Wkly Rep. 53(3):57–9.

Huang LH, Zhang L., Tobe RY, Qi FH, Sun L, Teng Y et al. (2012). Cost-effectiveness analysis of neonatal hearing screening program in China: should universal screening be prioritized? BMC Health Serv Res. 12:97.

ILOSTAT (2016). Employment to population ratio 2015. In: Key indicators of the labour market. Ninth edition. Available at www.ilo.org/ilostat Geneva: ILO

ILOSTAT (2016). Unemployment rate. Available at www.ilo.org/ilostat Geneva: ILO

Joore MA, van der Stel H, Peters H, Boas GM, Anteunis L (2003). The cost effectiveness of hearing-aid fitting in Netherlands. Arch Otolaryngol Head Neck Surg. 129(3):297–3-4.

Jung D, Bhattacharyya N (2012). Association of hearing loss with decreased employment and income among adults in the United States. Ann Otol Rhinol Laryngol. 2012;121(12):771–5.

Kemper AR, Downs SM (2000). A cost effectiveness analysis of newborn hearing screening strategies. Arch Pediatr Adolesc Med. 154(5):484–8.

Keren R, Helfand M, Homer C, McPhillips H, Lieu TA (2002). Projected cost-effectiveness of statewide universal newborn hearing screening. Pediatrics 110(5): 855–64.

Kezirian EJ, White KR, Yueh B, Sullivan SD (2001). Cost and cost-effectiveness of universal screening for hearing loss in newborns. Otolaryngol Head Neck Surg,124(4):359–67.

Klop WM, Boermans P, Ferrier M, van den Hout W, Stiggelbout A, Frijns J (2008). Clinical relevance of quality of life outcome in cochlear implantation in postlingually deafened adults. Otol Neurotol. 29(5):615–21.

Langer A, Brockow I, Nennstiel-Ratzel U, Menn P (2012). The cost-effectiveness of tracking newborns with bilateral hearing impairment in Bavaria: a decision-analytic model. BMC Health Serv Res. 12:418.

Lee H, Park E, Kim HJ, Choi J, Kim H (2006). Cost-utility analysis of cochlear implants in Korea using different measures of utility. Acta Otolaryngo. 126(8):817–23.

Liu C, Collins MP, Souza PE, Yueh B (2011). Long-term cost-effectiveness of screening strategies for hearing loss. J Rehabil Res Dev. 48(3):235–44.

Mohr PE, Feldman JJ, Dunbar JL, McConkey-Robbins A, Niparko JK, Rittenhouse RK et al. (2000). The societal costs of severe to profound hearing loss in the United States. Int J Technol Assess Health Care. 16(4):1120–35.

Monteiro E, Shipp D, Chen J, Nedzelski J, Lin V (2012). Cochlear implantation: a personal and societal economic perspective examining the effects of cochlear implantation on personal income. J Otolaryngol Head Neck Surg. 41(Suppl 1):S43–8.

Morris AE, Lutman ME, Cook AJ, Turner D (2012). An economic evaluation of screening 60- to 70-year-old adults for hearing loss. J Public Health (Oxf). 35(1):139–46.

Nachtegaal J, Heymans MW, van Tulder MW, Goverts ST, Festen JM, Kramer SE (2010). Comparing health care use and related costs between groups with and without hearing impairment. Int J Audiol. 49(12):881–90.

NCES (2016). Digest of education statistics. Total and current expenditures per pupil in public elementary and secondary schools: selected years, 1919–20 through 2012–13. Washington DC: National Center for Education Statistics, Institute of Education Sciences.

O'Neill C, Archbold SM, O'Donoghue GM, McAlister DA, Nikolopoulos TP (2001). Indirect costs, cost-utility variations and the funding of paediatric cochlear implantation. Int J Pediatr Otorhinolaryngol. 58(1):53–7.

Olusanya BO, Neumann KJ, Saunders JE (2014). The global burden of disabling hearing impairment: a call to action. Bull World Health Organ. 92(5):367–73.

Penaranda A, Mendieta JC, Perdomo JA, Aparicio ML, Marín LM, García JM et al. (2012). Beneficios económicos del implante coclear para la hipoacusia sensorineural profundal

[Economic benefits of the cochlear implant for treating profound sensorineural hearing loss]. Rev Panam Salud Publica. 31(4):325–31.

Pierre PV, Fridberger A, Wikman A, Alexanderson K (2012). Self-reported hearing difficulties, main income sources, and socio-economic status; a cross-sectional population-based study in Sweden. BMC Public Health. 12:874.

Rydberg E, Gellerstedt LC, Danermark B (2010). The position of the deaf in the Swedish labor market. Am Ann Deaf. 155(1):68–77.

Saunders JE, Barrs DM, Gong W, Wilson BS, Mojica K, Tucci DL (2015). Cost effectiveness of childhood cochlear implantation and deaf education in Nicaragua: a disability adjusted life year model. Otol Neurotol. 36(8):1349–56.

Schroeder L, Petrou S, Kennedy C, McCann D, Law C, Watkin PM et al. (2006). The economic costs of congenital bilateral permanent childhood hearing impairment. Pediatrics. 117(4):1101–12.

Schulze-Gattermann H, Illg A, Schoenermark M, Lenarz T, Lesinski-Schiedat A (2002). Cost-benefit analysis of pediatric cochlear implantation: German experience. Otol Neurotol. 23(5):674–81.

Semenov YR, Yeh ST, Seshamani M, Wang NY, Tobey EA, Eisenberg LS et al. (2013). Age-dependent cost-utility of pediatric cochlear implantation. Ear Hear. 34(4):402–12.

Shield B (2006). Evaluation of the social and economic costs of hearing impairment. Brussels: Hear-it.

Stam M, Kostense PJ, Festen JM, Kramer SE (2013). The relationship between hearing status and the participation in different categories of work: demographics. Work. 46(2):207–19.

Stevens G, Flaxman S, Brunskill E, Mascarenhas M, Mathers CD, Finucane M (2013). Global and regional hearing impairment prevalence: an analysis of 42 studies in 29 countries. Eur J Public Health. 23(1):146–52.

Stucky SR, Wolf KE, Kuo T (2010). The economic effect of age-related hearing loss: national, state, and local estimates, 2002 and 2030. J Am Geriatr Soc. 58(3):618–9.

Summerfield AQ, Marshall DH, Barton GR, Bloor KE (2002). A cost utility scenario analysis of bilateral cochlear implantation. Arch Otolaryngol Head Neck Surg. 128(11):1255–62.

Summerfield AQ, Lovett RE, Bellenger H, Batten G (2010). Estimates of the cost-effectiveness of pediatric bilateral cochlear implantation. Ear Hear. 31(5):611– 24.

Tobe RG, Mori R, Huang L, Xu L, Han D, Shibuya K (2013). Cost-effectiveness analysis of a national neonatal hearing screening program in China: conditions for the scale-up. PLoS One, 8(1):e51990.

Tomlinson J (2015). Employment: Disability: Written question – 1718. 17 June 2015. London: Hansard (http://www.parliament.uk/business/publications/written-questions-answers-statements/written-question/Commons/2015-06-09/1718/, accessed 15 February 2017).

UK Cochlear Implant Study Group (2004). Criteria of candidacy for unilateral cochlear implantation in postlingually deafened adults II: cost-effectiveness analysis. Ear Hear. 25(4):336–60.

UNESCO (2014). Teaching and learning: achieving quality for all. Education for All Global Monitoring Report 2013/14. Paris: United Nations Educational, Scientific and Cultural Organization (http://unesdoc.unesco.org/images/0022/002256/225660e.pdf, accessed 15 February 2017).

UNESCO (2016). School life expectancy by level of education. Paris: United Nations Educational, Scientific and Cultural Organization (http://data.uis.unesco.org/index.aspx?queryid=147, accessed 15 February 2017).

Uus K, Bamford J, Taylor R (2006). An analysis of the costs of implementing the National Newborn Hearing Screening Programme in England. J Med Screen, 13(1):14–9.

Wimo A, Jonsson L, Winblad B (2006). An estimate of the worldwide prevalence and direct costs of dementia in 2003. Dement Geriatr Cogn Disord. 21(3):175–81.

Wimo A, Jönsson L, Gustavsson A, McDaid D, Ersek K, Georges J et al. (2011). The economic impact of dementia in Europe in 2008 – cost estimates from the Eurocode project. Int J Geriatr Psychiatry. 26(8):825–32.

Woodcock K, Pole JD (2008). Educational attainment, labour force status and injury: a comparison of Canadians with and without deafness and hearing loss. Int J Rehabil Res. 31(4):297–304.

WHO (2013). Multi-country assessment of national capacity to provide hearing care. Geneva: World Health Organization (available at http://www.who.int/pbd/publications/WHOReportHearingCare_Englishweb.pdf).

7. Annexes

Annex 1

A1. Hearing impairment categories

Hearing impairment level	Better ear hearing level (decibels)	Hearing in a quiet environment	Hearing in a noisy environment
Unilateral	<20 in the better ear; >=35 in the worse ear	Does not have problems unless sound is near poorer hearing ear	May have real difficulty following/taking part in a conversation
Mild	20 - 34	Does not have problems hearing what is said	May have real difficulty following/taking part in a conversation
Moderate	35 - 49	May have difficulty hearing a normal voice	Has difficulty hearing and taking part in conversation
Moderately Severe	50 - 64	Can hear loud speech	Has great difficulty hearing and taking part in conversation
Severe	65 - 79	Can hear loud speech directly in one's ear	Has very great difficulty hearing and taking part in conversation
Profound	80 - 94	Has great difficult hearing	Cannot hear any speech

Note: Hearing impairment categories are defined using the better ear hearing threshold in decibels averaged over frequencies 0.5, 1, 2 and 4 kHz (dBHL)

Annex 2

A2. List of countries and regions used in analysis*

Subregion	Countries
East Asia region	
East Asia	China (including Hong Kong SAR and Macau SAR), Democratic People's Republic of Korea, Taiwan
Asia Pacific region	
Southeast Asia	Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Maldives, Myanmar, Philippines, Sri Lanka, Thailand, Timor-Leste, Viet Nam
Oceania	American Samoa, Cook Islands, Fiji, French Polynesia, Guam, Kiribati, Marshall Islands, Micronesia (Federated States of), Nauru, Northern Mariana Islands, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Vanuatu
South Asia region	
South Asia	Afghanistan, Bangladesh, Bhutan, India, Nepal, Pakistan
Central / Eastern Europe and Central Asia region	
Central Asia	Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Mongolia, Tajikistan, Turkmenistan, Uzbekistan
Central Europe	Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Hungary, Montenegro, Poland, Romania, Serbia, Slovakia, Slovenia, Macedonia (Former Yugoslav Republic of)
Eastern Europe	Belarus, Estonia, Latvia, Lithuania, Moldova, Russian Federation, Ukraine
Middle East and North Africa region	
North Africa and Middle East	Algeria, Bahrain, Egypt, Iran (Islamic Republic of), Iraq, Jordan, Kuwait, Lebanon, Libyan Arab Jamahiriya, Morocco, Occupied Palestinian Territory, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, Tunisia, Turkey, United Arab Emirates, Yemen
Sub-Saharan Africa region	
Central Africa	Angola, Central African Republic, Congo, Democratic Republic of the Congo, Equatorial Guinea, Gabon
East Africa	Burundi, Comoros, Djibouti, Eritrea, Ethiopia, Kenya, Madagascar, Malawi, Mauritius, Mozambique, Rwanda, Seychelles, Somalia, South Sudan, Sudan, Uganda, United Republic of Tanzania, Zambia
Southern Africa	Botswana, Lesotho, Namibia, South Africa, Swaziland, Zimbabwe
West Africa	Benin, Burkina Faso, Cameroon, Cape Verde, Chad, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, São Tomé and Príncipe, Togo
Latin America and Caribbean region	
Andean Latin America	Bolivia, Ecuador, Peru
Central Latin America	Colombia, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Venezuela (Bolivarian Republic of)
Southern Latin America	Argentina, Chile, Uruguay
Tropical Latin America	Brazil, Paraguay

Caribbean	Antigua and Barbuda, Bahamas, Barbados, Belize, Bermuda, British Virgin Islands, Cuba, Dominica, Dominican Republic, Grenada, Guyana, Haiti, Jamaica, Netherlands Antilles, Puerto Rico, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago
High-income region	
Asia-Pacific, high-income	Brunei Darussalam, Japan, Republic of Korea, Singapore
Australasia	Australia, New Zealand
North America, high-income	Canada, United States of America
Western Europe	Andorra, Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Greenland, Iceland, Ireland, Israel, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom

*Global burden of disease data were not available for St Kitts and Nevis or Palau. The analysis assumes that Macau and Hong Kong Special Administrative Regions of China and included in the China data.