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Trends and driving factors of age-related hearing loss and severity over 30 years: a cross-sectional study

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Abstract

Background Age-related hearing loss (AHL) is a modifiable risk factor for chronic disability and cognitive decline in adults over 60 years globally. Despite its preventable nature, long-term trends (1992-2021) in AHL burden and its demographic, socioeconomic, occupational noise exposures, and geographic drivers remain underexplored, limiting targeted intervention strategies.

Methods This observational study analyzed age-standardized prevalence and years lived with disability (YLDs) for AHL among adults aged ≥60 years using the Global Burden of Disease Study 2021 (1992-2021). Data were stratified by sex, age, region, and nation, with demographic decomposition to isolate population aging effects and Bayesian spatiotemporal regression to quantify modifiable drivers (e.g., occupational noise). Temporal trends were evaluated by calculating annual average percentage change (AAPC) with 95% confidence intervals (CI).

Results From 1992 to 2021, AHL-related prevalence and YLDs showed an upward trend globally ($AAPC_{prevalence}$ = 0.14 [95% CI: 0.13, 0.14]; $AAPC_{YLDs}$ = 0.17 [95% CI: 0.15, 0.20]). There was a downward trend in the YLDs of AHL from 1992 to 1995 ($AAPC_{YLDs}$ = -0.08 [95% CI: -0.19, 0.04]). Regionally, while most regions showed an increasing trend in AHL prevalence, 1990-2019, some regions still showed a decreasing trend ($AAPC_{Western\ sub\text{-}Saharan\ Africa}$ = -0,22 [95% CI: -0.37, -0.08]). In 2021, in the countries with middle socio-demographic index (SDI) levels, the older the population, the higher the prevalence and YLDs of AHL. Furthermore, the burden of AHL varies by age and sex and has unique temporal and spatial features. Notably, higher SDI levels correlated with reduced occupational noise-attributable burdens, while adults aged 70-74 years exhibited the highest occupational noise-driven YLDs.

Conclusion The global burden of AHL continues to rise, which is a growing problem for countries with medium SDI levels. Occupational noise exposure emerges as a critical modifiable risk factor, particularly in rapidly industrializing economies, highlighting the urgent need to prioritize workplace hearing protection programs and targeted noise

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control policies tailored to regional contexts. These interventions are especially vital for older men in low-resource settings and medically underserved countries to mitigate preventable disability and address health inequities.

Keywords Age-related hearing loss, Occupational noise exposure, Socio-demographic index, Disability-adjusted life years, Burden, Trends

Introduction

Age-related hearing loss (AHL), also known as senile presbycusis, is the most common sensory impairment in older persons and is currently the third most common cause of long-term disability in the senior population [1]. AHL is a progressive condition that affects the ability to hear high-frequency sounds, typically caused by the aging process and environmental factors, such as long-term noise exposure. It is characterized by a gradual loss of hearing, which can significantly impact an individual's quality of life and communication abilities [2]. According to the World Health Organization (WHO), the world's population aged 60 years and older is projected to reach 2.1 billion by 2050, nearly doubling from 2015 [3], with one in four older adults having disabling hearing loss [4]. Untreated hearing loss can prevent older persons from engaging in even the most basic forms of communication, which can exacerbate feelings of social isolation, frustration, and loneliness [5–7]. Addressing hearing loss in older adults is a major challenge due to the gradual nature of the condition, the complexity of identifying early signs, and the lack of access to necessary interventions, such as hearing aids and hearing healthcare, especially in low-resource settings [8, 9]. These effects can also exacerbate concomitant conditions like frailty, falls [10], and late-onset depression [11]. There is mounting evidence that early cognitive decline and dementia are linked to hearing loss in old age, and that the severity of hearing loss is a predictor of a bad prognosis in Alzheimer's patients [12]. Two-thirds of adults 60 years of age and older are expected to reside in low- and middle-income nations by 2050 [2]. These nations frequently lack the infrastructure, human resources, regulations, and awareness necessary to address hearing loss and manage the disease's burden. Moreover, these challenges are compounded by the stigma around hearing loss, where affected individuals may not seek the necessary help due to societal attitudes or lack of awareness about the available treatments [8]. The Corona Virus Disease 2019 (COVID-19) pandemic mask use created barriers to facial and acoustic information, underscoring the importance of hearing in older adults. A greater reliance on visual information to compensate for AHL, which also affects speech recognition functions [13], further exacerbating the health burden of hearing loss in the elderly population.

Untreated AHL not only has negative consequences on the individual but also carries large economic implications. In 2002 alone, the estimated total cost of treating hearing loss in individuals over 65 was $8.2 billion; by 2030, that figure is expected to rise to $51.4 billion [14]. It follows that older people will bear a disproportionate share of the large and rising health, social, and economic expenses associated with AHL. Addressing these costs requires understanding the full scope of AHL's impact and identifying effective, cost-efficient intervention strategies that can be widely implemented. Determining the actual magnitude of the health burden of AHL among the elderly worldwide as well as its historical trends is therefore imperative. In order to give a thorough description of the burden of disease associated with AHL among older adults at the global, regional, and national levels over the past 30 years and the next 19 years, including prevalence, years of life lived with disability (YLDs), and other factors, this study makes use of the Global Burden of Diseases, Injuries, and Risk Factors Study 2021 (GBD 2021) [15]. Since noise is a major modifiable risk factor for hearing loss [16], we assessed the impact of noise exposure and incorporated a grading system for hearing loss severity, distinguishing our study from others. Help to promote health and well-being, reduce health disparities among older adults, and guide future policies and treatments for effectively managing these conditions on a global scale. This study aims to highlight the challenge of mitigating AHL in aging populations and offers evidence to inform global health policies, promote health and well-being, and address health disparities among older persons.

Materials and methods

Data sources and study population

GBD 2021 quantifies health losses due to 371 diseases in 204 countries and territories, including measures of prevalence, disease severity, and death, which together constitute a comprehensive assessment of the burden of disease [15]. In the course of our research, we gathered information from the GBD 2021 database using the Global Health Data Exchange query tool (GHDx) (https://vizhub.healthdata.org/gbd-results/) regarding the prevalence of AHL and YLDs among older individuals in 204 countries between 1992 and 2021. To categorize hearing loss, the prevalence of AHL and YLDs by gender, age, socio-demographic index (SDI), location, nation, and risk factors was examined. A detailed description of the data sources is available in eMethod 1 of Supplement Material.

AHL, as defined by GBD, includes causes other than meningitis, chronic otitis media, or congenital factors, with presbycusis being the dominant cause, referring to the gradual hearing loss due to the breakdown of neurons in the inner ear as a result of aging, which was coded by the International Classification of Diseases (ICD)−9 codes H71-H75.83, H80-H80.93, H83-H83.93, H90-H91, H91.1-H91.93, H94-H94.83, Q16-Q16.9, and ICD-10 codes: H74-H75.83, H90-H91, H91.1-H91.93, H94-H94.83, Q16-Q16.9 [17]. A detailed description of the ICD code is available in eMethod 2 of Supplement Material. Hearing loss can be classified as mild (threshold 20–34 dB), moderate (threshold 35–49 dB), moderately severe (threshold 50–64 dB), severe (threshold 65–79 dB), profound (threshold 80–94 dB), and complete (threshold greater than 95 dB) [18]. These classifications were calculated based on the average pure tone hearing thresholds of the better ear at 0.5, 1, 2 and 4 kHz. Following the guidelines set forth by the WHO [19] and other research [20], we divided the population into six age groups: 60–64, 65–69, 70–74, 75–79, 80–84, and 85–89 years. We followed and completed the STROBE Guidelines.

Data analysis

First, we computed the 95% confidence intervals (CIs) and annual average percentage changes (AAPCs) using a linear regression model. In this model, the independent variable was each year, and the dependent variable was rates (such as the prevalence linked to AHL) on a logarithmic scale. A detailed description of the AAPC is available in eMethod 3 of Supplement Material.

Second, the regression model's estimated mean yearly percentage change was used to determine whether there had been any notable changes in the linear trend's slope. Time trends in the data were identified by joinpoints regression analysis, the simplest model that fits the data by connecting several different line segments on a logarithmic scale [21]. These line segments are made into joinpoints, where the simplest model (i.e., 0 joinpoints) is a straight line.

Third, global trends in the above metrics were also analyzed by sex, age, and SDI, which is a comprehensive indicator of the development status of a country or region. A detailed description of the SDI is available in eMethod 4 of Supplement Material.

Fourth, regional and national trends in the prevalence of AHL-related, YLDs were also explored using the same methodology described above.

Fifth, the exposure to risk factors and their attributable burdens were quantified by GBD comparative risk assessment by grading the severity of hearing loss according to criteria [22]. Occupational noise exposure is defined as the proportion of the population exposed to noise levels of 85+ decibels in the workplace, based on the population distribution across 17 economic activities (such as agriculture, hunting, forestry, fishing, mining, and quarrying) [23]. Estimating the burden of AHL due to occupational noise using a person population attributable fraction (PAF) as detailed in eMethod 5 of Supplement Material.

Sixth, the Bayesian age-period-cohort analysis (BAPC) model with integrated nested Laplace approximation (INLA), which demonstrated better coverage and precision than the APC model. In order to predict the number of TC cases, incidence rates, deaths and mortality rates from 2021 to 2040, we used the BAPC model with integrated nested laplace approximation to approximate the marginal posterior distributions, which avoids the mixing and convergence problems associated with the use of markov chain monte carlo simulation algorithms in the traditional bayesian approach mixing and convergence problems in traditional bayesian methods [24]. The impact of COVID-19 on AHL was finally analyzed by modeling the burden of COVID-19 and related outcomes in a hierarchy of mutually exclusive and collectively exhaustive causes [16]. Statistical analyses were performed using R software (version 4.1.2) and the linkedpoint regression program (version 4.9.0.0). Statistical significance was set at $P < 0.05$ (two-sided).

Results

Global trends

Globally, the AHL prevalence was 65828.75per 100,000 in 2021 and there was an overall increasing trend in both AHL-related prevalence and YLDs among older adults

Table 1 Global AAPCs in prevalence and YLDs of AHL in older adults aged 60–89 years, 1992-2021

	Prevalence		YLDs	
	AAPC (95% CI)	***p* value**	**AAPC (95% CI)**	***p* value**
1992-2001	0.11 (0.10 to 0.11)	<0.001	0.05 (0.03 to 0.08)	<0.001
2002-2011	0.07 (0.05 to 0.08)	<0.001	0.13 (0.07 to 0.18)	<0.001
2012-2021	0.25 (0.23 to 0.27)	<0.001	0.28 (0.20 to 0.35)	<0.001
1992-2021	0.14 (0.13 to 0.14)	<0.001	0.17 (0.15 to 0.20)	<0.001
2019-2021	0.21 (0.18 to 0.24)	0.008	0.05 (−0.39 to 0.49)	0.400

Abbreviation: *AAPC* average annual percentage change, *YLD* years of life lived with disability, *AHL* age-related hearing loss, *CI* confidence interval between 1992 and 2021 (AAPC=0.14 [95% CI: 0.13, 0.14]; AAPC=0.17 [95% CI: 0.15, 0.20], $P<0.01$) (Tables 1 and 2), but there was a decreasing trend in AHL-related YLDs between 1992 and 1995, and between 2005 and 2011 (AAPC = −0.08 [95% CI: −0.19 to 0.04]; AAPC = −0.04 [95% CI: −0.08 to 0.01], $P<0.01$) (Table S1). Between 1992 and 2021, AHL-related prevalence in older adults appeared to converge in 1999, 2010, 2014, and 2018, respectively (Fig. 1).

From 1992 to 2019, AHL-associated prevalence rates increased globally in both males and females (Table 2). Specifically, the AHL-associated prevalence rate per 100,000 population in males rose from 66936.26 to 68780.08 in 1992, AAPC = 0.09 [95% CI: 0.09, 0.10], and in females, the AHL-associated prevalence rate per 100,000 population rose from 60047.06 to 63193.14 in 1992, AAPC = 0.18 [95% CI: 0.16, 0.19]. AHL-associated YLDs in males and females showed the same trend. In a connected-point regression model, we found that the prevalence of AHL-associated YLDs in females increased most significantly between 2013 and 2017 (AAPC= 0.34 [95% CI: 0.29 to 0.39] (Table S2).

AHL-associated prevalence rates in older adults aged 60–89-year-olds showed an increasing trend between 1992 and 2019, with the most pronounced rise in ages 65-65 years (AAPC=0.21 [95% CI:0.19,0.23]), but with a brief decline between 2001 and 2008 (AAPC=−0.09 [95% CI: - 0.14, −0.04]). YLDs, on the other hand, showed an overall decreasing trend, with the most significant decrease between 1992 and 1995 (AAPC=−0.48 [95% CI: −0.58, - 0.39]) (Table S3). The greatest increase in AHL-associated prevalence between 1992 and 2021 was observed in middle- and high-level countries, and the greatest increase in AHL-associated prevalence in the linked regression model was observed in high-middle-level countries between 2015 and 2018 (AAPC=0.91 [95% CI: 0.67,1.15]) (Table S4).

Between 1992 and 2021, the region with the greatest change in AHL-related prevalence was Eastern sub-Saharan Africa, with the most significant change from 1995 to 1999 (AAPC=2.76 [95% CI: 1.14, 4.41]), and the greatest change in YLDs was East Asia region, which had the largest change from 2015 to 2019 (AAPC=1.15 [95% CI: 1.05, 1.26]) (Fig. 2, Tables 2, S6). The largest change in urban prevalence was in Eritrea, with the largest change from 1995 to 2000 (AAPC=2.94 [95% CI: 1.74, 4.15]), and the largest change in YLDs was in China and the Unite Republic of Tanzania (AAPC=0.36 [95% CI: 0.33, 0.39]; AAPC=0.36 [95%CI: 0.28, 0.43]) (Fig. 2, Tables S7, S8).

Classification of hearing loss

Prevalence and YLDs associated with different grades of hearing loss showed an overall increasing trend, but complete hearing loss was decreasing, with the most significant decreases in both prevalence and YLDs occurring between 2019 and 2021 (AAPC=−0.69 [95% CI: −0.79, −0.6]; AAPC=−0.70 [95% CI: −0.81, −0.58]), and both declines were greater for men than for women (Figures S1 - S4, Table S9). The prevalence of Complete hearing loss and YLDs decreased the most at the Low-middle SDI level, and most significantly from 2018 to 2021 (AAPC=−1.25[95%CI: −1.49, −1]) (Table S10). Regionally and nationally, the prevalence of complete hearing loss changed most significantly in tropical Latin America from 1996 to 1999 and in Uganda from 2019 to 2021 (Tables S11, S12).

Ageing, population and epidemiological change

AHL was most affected by demographic factors from 1992 to 2021, with prevalence and YLDs most affected by demographic factors at the middle SDI level and East Asia (92.15%;84.27%) (Fig. 3, Tables S13, S14). National, prevalence was most affected by demographic factors in Georgia (186.46%), and YLDs were most affected by demographic factors in Afghanistan (560.47%) (Table S15). The driver of different levels of hearing loss was population growth and the higher the level of hearing loss the more affected by aging (Figures S5 to S10).

Occupational noise exposure

Between 1992 and 2021, global AHL due to occupational noise exposure factors showed an increasing trend (AAPC=0.39 [95% CI: 0.37, 0.42]), with the highest changes in High SDI levels and East Asia region affected by occupational noise exposure (AAPC=0.26 [95% CI: 0.23, 0.29]; AAPC=0.49 [95% CI: 0.46, 0.51]) (Figures S11, S12, Table S16). The results of the COVID-19 impact on disease and predictive analysis are detailed in the Supplementary Material.

Impact of COVID-19

Globally, in both 2019 and 2021, Asia recorded the highest incidence rates for AHL. Most countries and regions experienced higher AHL incidence rates in 2019 compared to 1990 (Figure S13). Although the rates of moderately severe and severe hearing loss are relatively low on a global scale, these conditions contribute less significantly to the overall incidence of disability worldwide. (Figure S14, Figure S15)

Prognostic analysis

The global prevalence of AHL is projected to reach (66016.77/100,000 persons [95% UI: 42959.99 to 89073.55]) by 2040, with the prevalence rate continuing to increase but with a slowing trend (AAPC: 0.02 [95% CI: 0.02 to 0.03]). Notably, YLDs showed a downward

Table 2 Global AAPC in prevalence and YLDs of AHL stratified by sex, age, SDI and regional

	Prevalence						YLDs					
	1992		2021		1992-2021		1992		2021		1992-2021	
	Case number (95% UI)	Rate (per 100,000)	Case number (95% UI)	Rate (per 100,000)	AAPC (95% CI)	*P*	Case number (95% UI)	Rate (per 100,000)	Case number (95% UI)	Rate (per 100,000)	AAPC (95% CI)	*P*
Global	314447627.80 (283741143.90 to 347947500.50)	63201.63 (57022.13 to 69911.65)	699876300.60 (633931330.10 to 767891653.30)	65828.75 (59628.41 to 72227.60)	0.14 (0.13 to 0.14)	<0.001	10082885.50 (6728356.27 to 14407601.19)	2078.34 (1396.53 to 2954.36)	22993134.72 (15412031.75 to 32620166.45)	2184.04 (1468.18 to 3091.94)	0.17 (0.15 to 0.20)	<0.001
Sex												
Male	149817001.00 (135222017.90 to 165580180.80)	66936.26 (60400.77 to 73930.67)	339239937.80 (307171434.20 to 371985448.60)	68780.08 (62281.55 to 75401.78)	0.09 (0.09 to 0.10)	<0.001	4726927.75 (3138856.62 to 6792827.76)	2209.00 (1484.83 to 3144.17)	11046626.41 (7373418.034 to 15764776.32)	2288.83 (1537.42 to 3251.10)	0.12 (0.10 to 0.15)	<0.001
Female	164630626.80 (148516834.00 to 182385344.80)	60047.06 (54163.95 to 66512.17)	360636362.80 (326540451.00 to 396155899.60)	63193.14 (57220.39 to 69427.43)	0.18 (0.16 to 0.19)	<0.001	5355957.76 (3577171.36 to 7644656.91)	1972.90 (1321.10 to 2810.39)	11946508.32 (8036241.70 to 16919323.03)	2092.42 (1407.62 to 2963.33	0.21 (0.18 to 0.24)	<0.001
Age group, years												
60–64	86548937.41 (78359160.16 to 96031445.01)	52044.48 (47119.72 to 57746.60)	172763936.8 (156404375.50 to 191325025.00	53980.66 (48869.06 to 59780.13)	0.12 (0.09 to 0.15)	<0.001	2212579.25 (1388672.36 to 3301131.60)	1330.49 (835.05 to 1985.07)	4433690.25 (2766220.75 to 6601225.91)	1385.32 (864.31 to 2062.57)	0.13 (0.11 to 0.15)	<0.001
65–69	79449144.12 (71159789.37 to 88043399.61)	60516.00 (54202.04 to 67062.20)	177073252.90 (160067382.20 to 193887400.10)	64193.69 (58028.61 to 70289.26)	0.21 (0.19 to 0.23)	<0.001	2273129.56 (1456316.23 to 3342683.83)	1731.43 (1109.27 to 2546.11)	5121261.61 (3292997.93 to 7511638.70)	1856.59 (1193.80 to 2723.17)	0.25 (0.22 to 0.27)	<0.001
70–74	61953294.10 (56152382.02 to 68401267.17)	67778.99 (61432.60 to 74833.29)	145373807.10 (131564748.60 to 158479138.40)	70624.93 (63916.27 to 76991.71)	0.10 (0.10 to 0.20)	<0.001	2015391.30 (1336538.64 to 2902971.49)	2204.91 (1462.22 to 3175.95)	4790538.71 (3189135.66 to 6801491.79)	2327.32 (1549.33 to 3304.27)	0.20 (0.20 to 0.20)	<0.001
75–79	44969285.60 (40695590.56 to 49687182.08)	72822.58 (65901.83 to 80462.68)	99389397.75 (90727678.85 to 109003416.10)	75360.99 (68793.33 to 82650.72)	0.12 (0.11 to 0.13)	<0.001	1706283.05 (1185582.14 to 2352622.92)	2763.13 (1919.91 to 3809.80)	3827092.14 (2654204.34 to 5280839.25)	2901.85 (2012.52 to 4004.14)	0.17 (0.15 to 0.20)	<0.001
80–84	28502904.88 (25764558.40 to 31518432.33)	75993.54 (68692.65 to 84033.45)	68521596.26 (62207560.80 to 75239629.43)	78236.13 (71026.93 to 85906.60)	0.10 (0.09 to 0.11)	<0.001	1241876.60 (899487.043 to 1666756.29)	3311.05 (2398.18 to 4443.85)	3022735.37 (2198069.24 to 4042258.19)	3451.28 (2509.70 to 4615.34)	0.15 (0.13 to 0.17)	<0.001
85–89	13024061.67 (11609663.35 to 14265774.26)	78626.23 (70087.51 to 86122.44)	36754309.77 (32959584.16 to 39957044.25)	80386.85 (72087.26 to 87391.69)	0.08 (0.07 to 0.08)	<0.001	633625.76 (461759.86 to 841435.06)	3825.20 (2787.64 to 5079.74)	1797816.65 (1311403.82 to 2382712.62)	3932.08 (2868.22 to 5211.33)	0.10 (0.08 to 0.12)	<0.001
SDI												
High	83210484.45 (75246397.44 to 92034862.79)	56538.16 (51127.70 to 62529.46)	152752731.00 (137949234.70 to 169288990.80)	57035.28 (51515.58 to 63220.09)	0.03 (0.02 to 0.04)	<0.001	2579780.01 (1725895.87 to 3688095.17)	1738.96 (1160.90 to 2489.75)	4787395.75 (3212030.46 to 6833790.10)	1748.84 (1166.64 to 2506.88)	0.04 (0.00 to 0.08)	0.066
High-middle	81997056.27 (73829911.55 to 90818712.60)	63411.62 (57093.00 to 70199.25)	172808157.40 (156241057.70 to 188304464.00)	68792.13 (62210.82 to 74985.41)	0.28 (0.27 to 0.29)	<0.001	2578448.36 (1710731.52 to 3691808.17)	2056.37 (1375.01 to 2927.05)	5643536.83 (3767119.25 to 8015537.88)	2261.70 (1512.56 to 3208.22)	0.34 (0.31 to 0.37)	<0.001

Table 2 (continued)

	Prevalence						YLDs					
	1992		2021		1992-2021		1992	2021			1992-2021	
	Case number (95% UI)	Rate (per 100,000)	Case number (95% UI)	Rate (per 100,000)	AAPC (95% CI)	P	Case number (95% UI)	Rate (per 100,000)	Case number (95% UI)	Rate (per 100,000)	AAPC (95% CI)	P
Middle	88034973.15 (78993216.88 to 97506572.16)	70530.28 (63290.14 to 77999.98)	233676975.80 (210402018.60 to 254950024.60)	72048.05 (64902.72 to 78578.10)	0.07 (0.06 to 0.08)	<0.001	2779561.53 (1832934.73 to 3992123.54)	2338.44 (1563.43 to 3324.82)	7689484.52 (5139384.03 to 10896504.11)	2427.50 (1633.96 to 3424.16)	0.13 (0.11 to 0.15)	<0.001
Low-middle	45492033.37 (41206334.49 to 50326571.42)	63944.94 (57898.26 to 70813.35)	106406775.20 (96439016.44 to 118001271.30)	63986.12 (57973.53 to 70976.49)	0.00 (−0.01 to 0.01)	0.433	1571134.92 (1053208.13 to 2249834.01)	2312.58 (1571.32 to 3277.37)	3631740.51 (2442622.50 to 5191019.36)	2256.58 (1532.02 to 3201.90)	−0.09 (−0.11 to −0.06)	<0.001
Low	15359237.00 (13883873.96 to 17061321.76)	59504.98 (53794.09 to 66058.78)	33647335.08 (30369106.90 to 37380650.67)	61327.62 (55377.52 to 68078.59)	0.10 (0.08 to 0.11)	<0.001	562687.15 (375979.63 to 803674.15)	2301.46 (1563.47 to 3246.91)	1222002.95 (818425.20 to 1747103.38)	2328.02 (1578.69 to 3297.71)	0.04 (0.00 to 0.07)	0.068
GBD region												
East Asia	83445438.58 (73951247.62 to 93262184.31)	77016.44 (68289.23 to 85774.16)	224262686.70 (199897999.00 to 243417007.30)	81492.16 (72694.19 to 88498.88)	0.2 (0.18 to 0.22)	<0.001	2480900.16 (1610962.30 to 3591778.93)	2423.13 (1597.16 to 3468.95)	7272229.65 (4841391.13 to 10289090.06)	2682.69 (1793.17 to 3781.23)	0.35 (0.33 to 0.38)	<0.001
Oceania	236542.51 (209127.69 to 267228.18)	72094.08 (63699.00 to 81322.16)	562427.14 (497156.73 to 636631.74)	72780.23 (64330.44 to 82293.33)	0.02 (−0.02 to 0.06)	0.417	6671.16 (4280.13 to 9840.69)	2210.12 (1453.98 to 3202.34)	15852.17 (10231.90 to 23208.63)	2216.01 (1460.82 to 3196.65)	−0.01 (−0.06 to 0.04)	0.759
Central Asia	3399824.10 (3050388.41 to 3812293.69)	60218.87 (54019.22 to 67633.50)	5645739.33 (5083341.46 to 6302353.17)	60559.85 (54478.29 to 67767.51)	0.02 (0.02 to 0.02)	<0.001	109021.66 (71476.31 to 157898.57)	1993.35 (1315.01 to 2873.93)	175085.65 (114697.84 to 253406.44)	1985.42 (1317.34 to 2850.62)	−0.01 (−0.02 to −0.01)	<0.001
Central Europe	11966547.56 (10759202.96 to 13404298.52)	60728.36 (54591.57 to 68070.85)	17989533.05 (16165517.06 to 20169204.16)	60986.32 (54811.87 to 68332.05)	0.02 (0.01 to 0.03)	0.001	378805.13 (251248.05 to 546195.50)	1969.60 (1314.44 to 2827.61)	589065.08 (392069.58 to 845235.32)	1976.82 (1313.38 to 2839.87)	0.01 (−0.01 to 0.03)	0.318
Eastern Europe	36221562.08 (32954200.67 to 39805708.26)	61012.15 (54936.16 to 68402.52)	54885102.48 (49895439.21 to 60370033.14)	61276.78 (55166.30 to 68582.30)	0.02 (0.01 to 0.02)	<0.001	742486.38 (497662.78 to 1063207.58)	2062.33 (1389.89 to 2940.50)	949015.52 (635156.48 to 1356422.64)	2052.69 (1377.69 to 2929.43)	−0.02 (−0.02 to −0.01)	0.002
High-income Asia Pacific	15013559.68 (13617287.44 to 16730104.12)	56228.39 (50972.13 to 62670.86)	32700591.52 (29548383.45 to 36537446.88)	56381.85 (51058.50 to 62832.22)	0.01 (0.00 to 0.03)	0.067	425156.90 (280843.16 to 619290.91)	1613.46 (1069.11 to 2343.65)	993442.21 (665002.79 to 1429812.65)	1616.49 (1067.47 to 2351.59)	0.01 (0.00 to 0.030	0.099
Australasia	1946890.23 (1834687.39 to 2059421.97)	60957.31 (57382.38 to 64514.74)	4364432.71 (3893915.37 to 4834943.36)	63295.99 (56435.47 to 70196.16)	0.13 (0.12 to 0.14)	<0.001	57855.84 (39106.65 to 81405.63	1808.82 (1222.003 to 2547.89)	130752.53 (86180.00 to 187786.86)	1867.48 (1225.38 to 2690.80)	0.12 (0.10 to 0.15)	<0.001
Western Europe	22557418.57 (20314905.99 to 25271725.51)	46625.46 (42431.09 to 51203.06)	28648997.52 (25795552.34 to 32040503.59)	46591.06 (42409.70 to 51169.46)	−0.01 (−0.03 to 0.01)	0.529	1100717.90 (732286.68 to 1587971.91)	1388.51 (919.45 to 2009.01)	1725867.85 (1148859.20 to 2478299.22)	1393.33 (917.410 to 2014.49)	0.02 (0.00 to 0.04)	0.124
Southern Latin America	3293775.96 (2951858.31 to 3687002.57)	54738.07 (49026.64 to 61294.18)	6027899.57 (5403814.88 to 6761985.53)	54729.08 (49072.66 to 61370.25)	0.00 (−0.01 to 0.01)	0.766	104414.18 (69128.31 to 149860.63)	1758.96 (1168.49 to 2519.01)	192113.39 (127360.15 to 278360.59)	1730.20 (1144.79 to 2510.11)	−0.06 (−0.07 to −0.04)	<0.001

Table 2 (continued)

	Prevalence						YLDs					
	1992		2021		1992-2021		1992	2021			1992-2021	
	Case number (95% UI)	**Rate (per 100,000)**	**Case number (95% UI)**	**Rate (per 100,000)**	**AAPC (95% CI)**	***P***	**Case number (95% UI)**	**Rate (per 100,000)**	**Case number (95% UI)**	**Rate (per 100,000)**	**AAPC (95% CI)**	***P***
High-income North America	29783995.38 (26358955.20 to 33182658.62)	63279.92 (56000.91 to 70559.94)	51774350.59 (46027831.13 to 58142095.03)	60273.88 (53581.17 to 67670.57)	−0.16 (−0.20 to −0.12)	<0.001	1008427.28 (674284.96 to 1431179.87)	2116.63 (1409.45 to 3015.35)	1700905.29 (1146423.00 to 2414296.28)	1976.85 (1332.01 to 2806.77	−0.22 (−0.30 to −0.14)	<0.001
Caribbean	1954118.37 (1748454.30 to 2205947.54)	59098.01 (59098.01 to 66711.89)	3839824.15 (3443111.93 to 4330977.54)	59011.21 (52910.06 to 66558.77)	0.00 (−0.01 to 0.00)	0.401	64036.80 (42355.24 to 92511.13)	1945.47 (1288.24 to 2807.97)	124319.15 (82324.83 to 179389.04)	1911.74 (1266.17 to 2758.20)	−0.05 (−0.07 to −0.03)	<0.001
Andean Latin America	1312734.16 (1186554.23 to 1464839.20)	53249.91 (48091.43 to 59496.94)	3728106.51 (3365596.20 to 4173936.60)	53282.83 (48082.94 to 59684.53)	0.00 (0.00 to 0.01)	0.407	40771.90 (26712.05 to 59172.06)	1696.49 (1117.17 to 2454.26)	116017.96 (76754.14 to 167587.15)	1674.94 (1110.04 to 2415.86)	−0.04 (−0.06 to −0.02)	0.001
Cen-tral Latin America	5996886.28 (5386940.90 to 6756227.47)	59603.89 (53508.95 to 67215.22)	17784766.37 (15930843.51 to 20023662.84)	59546.43 (53314.50 to 67093.52)	0.00 (−0.01 to 0.00)	0.224	189248.03 (124851.27 to 273493.67)	1929.05 (1280.34 to 2776.88)	562298.23 (371311.62 to 812300.55)	1917.35 (1271.43 to 2761.94)	−0.02 (−0.03 to 0.00)	0.084
Tropi-cal Latin America	7544466.38 (6723012.60 to 8510530.91)	67280.10 (59931.46 to 75846.77)	20955035.65 (18677483.06 to 23645313.03)	67111.27 (59803.59 to 75706.15)	−0.01 (−0.05 to 0.03)	0.682	240241.83 (158617.77 to 346815.91)	2213.22 (1476.05 to 3171.95)	673383.79 (446636.85 to 966881.89)	2188.03 (1457.21 to 3132.07)	−0.04 (−0.13 to 0.05)	0.411
North Africa and Middle East	11069574.74 (10012801.39 to 12259912.82)	56813.88 (51389.97 to 62997.10)	28164978.73 (25459270.08 to 31200070.35)	56830.02 (51365.40 to 63014.50)	0.00 (0.00 to 0.00)	0.141	417074.76 (281571.23 to 594087.23)	2228.07 (1524.29 to 3146.26)	1021542.29 (686788.99 to 1464004.12	2125.65 (1444.60 to 3023.94)	−0.16 (−0.17 to −0.16)	<0.001
South Asia	42894397.60 (39007580.40 to 47408602.19)	64723.02 (58811.62 to 71674.18)	112394903.30 (102242914.20 to 124443965.80)	64817.63 (58927.15 to 71825.604)	0.01 (0.00 to 0.02)	0.135	1486827.41 (999262.81 to 2123934.49)	2362.82 (1612.10 to 3336.96)	3857476.50 (2606833.25 to 5491651.54)	2297.27 (1566.67 to 3248.14)	−0.09 (−0.12 to −0.06)	<0.001
Central sub-Saharan Africa	1332056.52 (1208196.30 to 1467679.80)	52715.58 (47873.80 to 58112.50)	2907835.79 (2635543.60 to 3203283.24)	52456.57 (47618.99 to 57775.60)	0.00 (−0.06 to 0.05)	0.859	49660.45 (32650.17 to 71749.69)	2118.31 (1426.17 to 3002.72)	108161.99 (71773.68 to 155724.00)	2095.14 (1414.40 to 2970.93)	−0.04 (−0.08 to 0.00)	0.076
Eastern sub-Saharan Africa	5086365.68 (4611703.91 to 5596523.82)	63374.19 (56136.42 to 71554.11)	9619882.67 (8744794.12 to 10548290.97)	70614.09 (61713.68 to 80113.66)	0.27 (−0.02 to 0.56)	0.067	204468.50 (134107.90 to 294566.32)	2553.17 (1704.16 to 3631.20)	479548.60 (313474.92 to 692325.53)	2827.76 (1874.64 to 4038.18)	0.26 (−0.01 to 0.53)	0.057
Southern sub-Saharan Africa	1628856.05 (1496072.70 to 1775320.16)	49545.44 (45495.46 to 54038.21)	3330280.77 (3068797.05 to 3614077.51)	50000.62 (46050.09 to 54306.82)	0.03 (0.02 to 0.05)	<0.001	52896.27 (35147.96 to 76103.92)	1668.26 (1118.01 to 2384.12)	104919.10 (69692.66 to 149968.94)	1652.50 (1109.40 to 2342.82)	−0.02 (−0.06 to 0.01)	0.203
Western sub-Saharan Africa	5365849.93 (4749929.66 to 6076784.43)	49592.83 (45028.10 to 54504.20)	12593898.21 (10992540.92 to 14344796.50)	46353.07 (42233.72 to 50733.52)	−0,22 (−0.37 to −0.08)	0.003	199316.16 (133188.94 to 283064.47)	2014.84 (1361.65 to 2836.93)	373014.08 (248377.77 to 528711.23)	1873.43 (1263.09 to 2629.04)	−0.23 (−0.35 to −0.11)	<0.001

Table 2 (continued)

	Prevalence						YLDs					
	1992		2021		1992-2021		1992	2021			1992-2021	
	Case number (95% UI)	**Rate (per 100,000)**	**Case number (95% UI)**	**Rate (per 100,000)**	**AAPC (95% CI)**	***P***	**Case number (95% UI)**	**Rate (per 100,000)**	**Case number (95% UI)**	**Rate (per 100,000)**	**AAPC (95% CI)**	***P***
Southeast Asia	22396767.43 (20060567.77 to 25010183.75)	74134.53 (66387.87 to 82720.10)	57695027.86 (51490532.37 to 64558872.53)	74749.59 (66698.63 to 83556.48)	0.01 (−0.02 to 0.04)	0.532	723886.80 (478279.01 to 1045961.12)	2504.75 (1678.00 to 3585.35)	1828123.67 (1206054.87 to 2642198.00)	2475.57 (1656.05 to 3547.00)	−0.05 (−0.07 to −0.04)	<0.001

Abbreviation: *AAPC* average annual percentage change, *YLD* years of life lived with disability, *SDI* sociodemographic index, *UI* uncertainty interval, *GBD* Global Burden of Disease Study

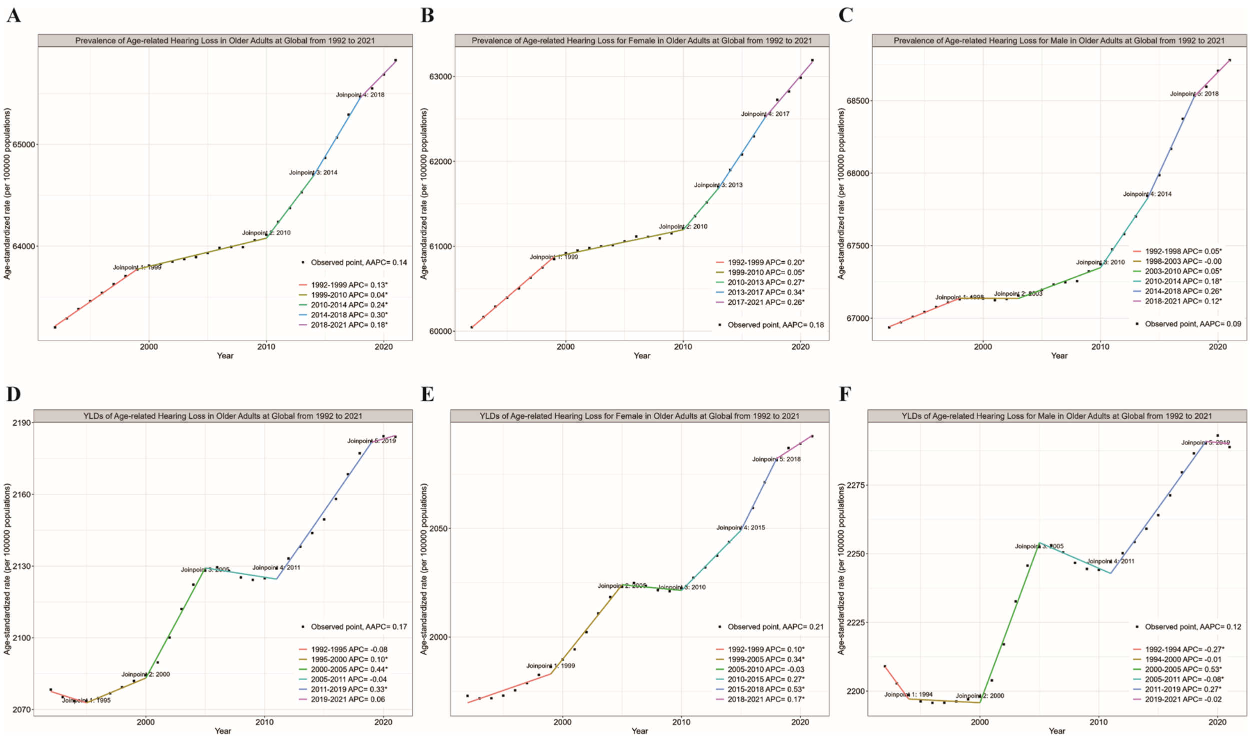

Fig. 1 Joinpoint regression analysis of global, female and male AHL burden among children and adolescents, 1992-2021. AHL: Age-related Hearing Loss, YLDs: Years Lived with Disability. **A**, **B** and **C** prevalence. **D**, **E** and **F** YLDs

trend (AAPC: −0.04 [95% CI: −0.04 to −0.03]). Between 2021 and 2040, AHL incidence and YLDs changed the most in complete hearing loss (AAPC: −0.9 [95% CI: −0.91 to −0.90]) (AAPC: −0.89 [95% CI: −0.89 to −0.88]) (Figures S16, S17, Table S17).

Discussion

This study, based on the GBD 2021 database, is the first to examine AHL prevalence and YLDs in individuals aged 60–89. It analyzes the impact of aging, demographic, and epidemiological factors on AHL globally, regionally, and nationally, showing a consistent increase in AHL prevalence and YLDs from 1992 to 2021, driven by population growth, aging, and disease severity. The 2021 World Health Assembly resolution highlighted the need for investment in ear and hearing health care, emphasizing prevention, management, and treatment of AHL, especially for at-risk populations [19, 24]. Joinpoint regression analyses showed a slowing rise in AHL prevalence and YLDs from 2019 to 2021, suggesting effective control of AHL in older adults during this period. However, occupational noise exposure continues to contribute to hearing loss, particularly among those exposed for extended periods [25]. Other factors like chronic diseases [26], ototoxic medications [27], and chemical exposures [28] also play a role but were not extensively evaluated. More research is needed to explore their long-term impacts. While AHL is linked to cognitive decline and considered a modifiable risk factor for dementia [29], other aging-related factors may also affect both hearing loss and cognitive decline, warranting further exploration of their complex relationship.

Joinpoint regression analyses showed that the prevalence rate associated with AHL continued to trend upward between 2005 and 2010, but the disability rate shifted from an original increase to a decrease. It is reassuring that both the prevalence of AHL and the rise in YLDs slowed from 2019 to 2021 compared with the previous period. While previous studies have shown that COVID-19 contributes to the onset of hearing loss [30, 31], the results suggest effective control of AHL in older adults globally during this period. However, it is important to note that despite attempts to mitigate occupational noise exposure, this risk factor continues to contribute to hearing loss, particularly among those who were exposed to noise for extended periods during their working years [25]. Additionally, other risk factors such as chronic non-communicable diseases [26], ototoxic medications [27], and chemical exposures [28] may also play a role in hearing loss, although these were not extensively evaluated in this study. Further research is needed to explore the long-term impacts of these factors.

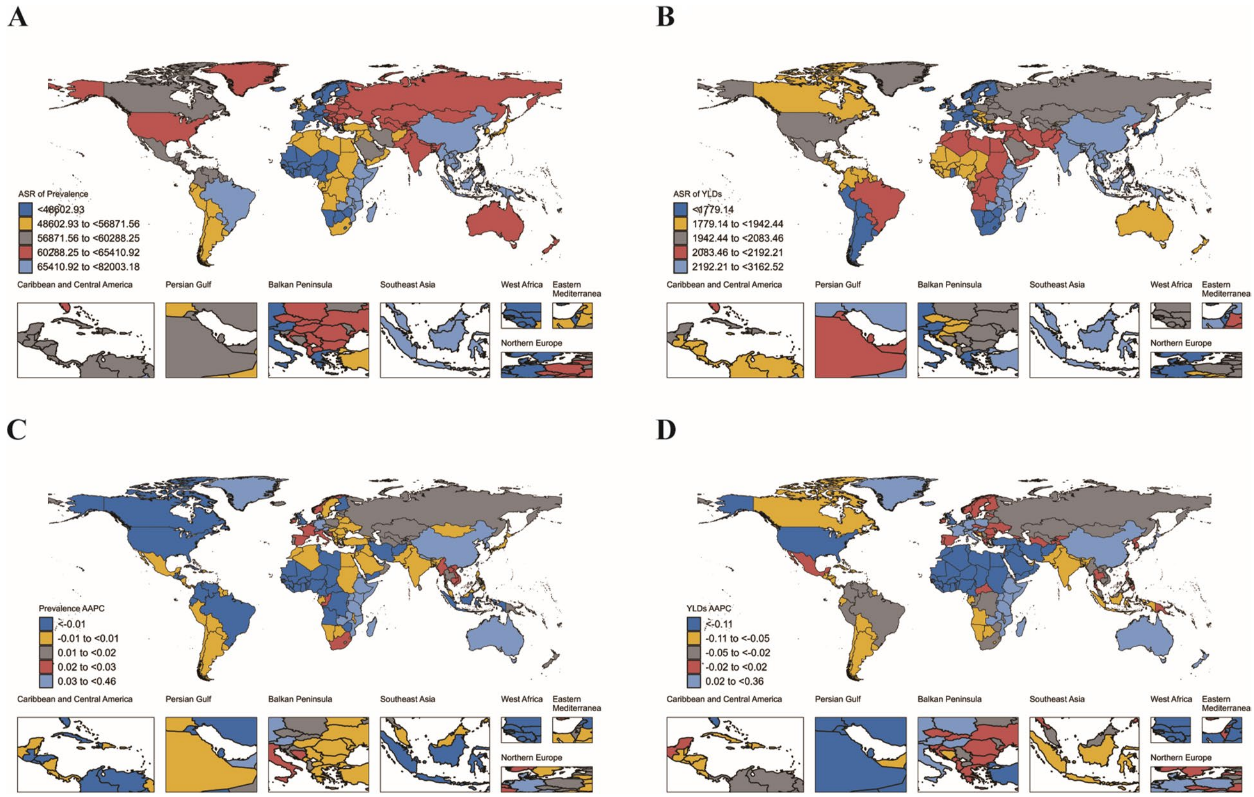

Fig. 2 Map of national ASR and AAPCs in AHL burden among older adults aged 60–89-year-olds, 1992-2021. ASR: Age-Standardized Rate, AAPCs: annual average percentage changes, AHL: Age-related Hearing Loss, YLDs: Years Lived with Disability. **A** ASR of prevalence. **B** ASR of YLDs. **C** AAPC of prevalence. **D** AAPC of YLDs

Although previous studies have shown a certain association between AHL and cognitive decline, and hearing loss is considered a modifiable risk factor for dementia [29], it is important to note that during aging, multiple factors other than hearing loss may simultaneously affect both hearing loss and cognitive decline. Therefore, while improving hearing health in older adults may significantly reduce the burden of hearing loss, more research is needed to explore the complex relationship between hearing loss and cognitive function.

AHL-related prevalence and YLDs among older adults in all age groups are on the rise globally between 1992 and 2021, with the greatest increase in the 65–69-year-old age group. Our results also showed a gradual increase in AHL-related prevalence and YLDs with increasing age, which may be associated with a slower gait and less activity in older adults [32–35]. There are also gender differences in AHL in older adults. We found that male older adults had higher prevalence and YLDs associated with AHL than women, and that men were more age-driven than women. This is consistent with previous studies indicating that men are more prone to hearing loss than women, particularly at higher frequencies, while women typically experience mild to moderate hearing loss, which tends to worsen at lower frequencies [36, 37]. Focusing on the health of older adults from a gender perspective as well as an age perspective and early attention to at-risk populations has considerable potential to reduce health disparities.

Older adults in low- and middle-income regions are disproportionately affected by AHL, with this trend expected to worsen. In 2021, Eastern sub-Saharan Africa exhibited higher AHL prevalence and YLDs, although both declined between 2019 and 2021, indicating some progress in prevention but highlighting ongoing challenges in addressing AHL among older populations [38]. Our findings suggest that India's low SDI, limited access to universal healthcare, under-resourced healthcare infrastructure, high technology costs, and uneven distribution of healthcare professionals contribute to the higher burden of AHL-related diseases [39, 40]. Additionally, 25–30% of elderly hearing aid users struggle with inadequate use due to the complexity of the devices [41], limiting their effectiveness in improving quality of life and reducing complications. More importantly, limited access to hearing aids in many parts of the world remains a significant barrier to addressing age-related hearing

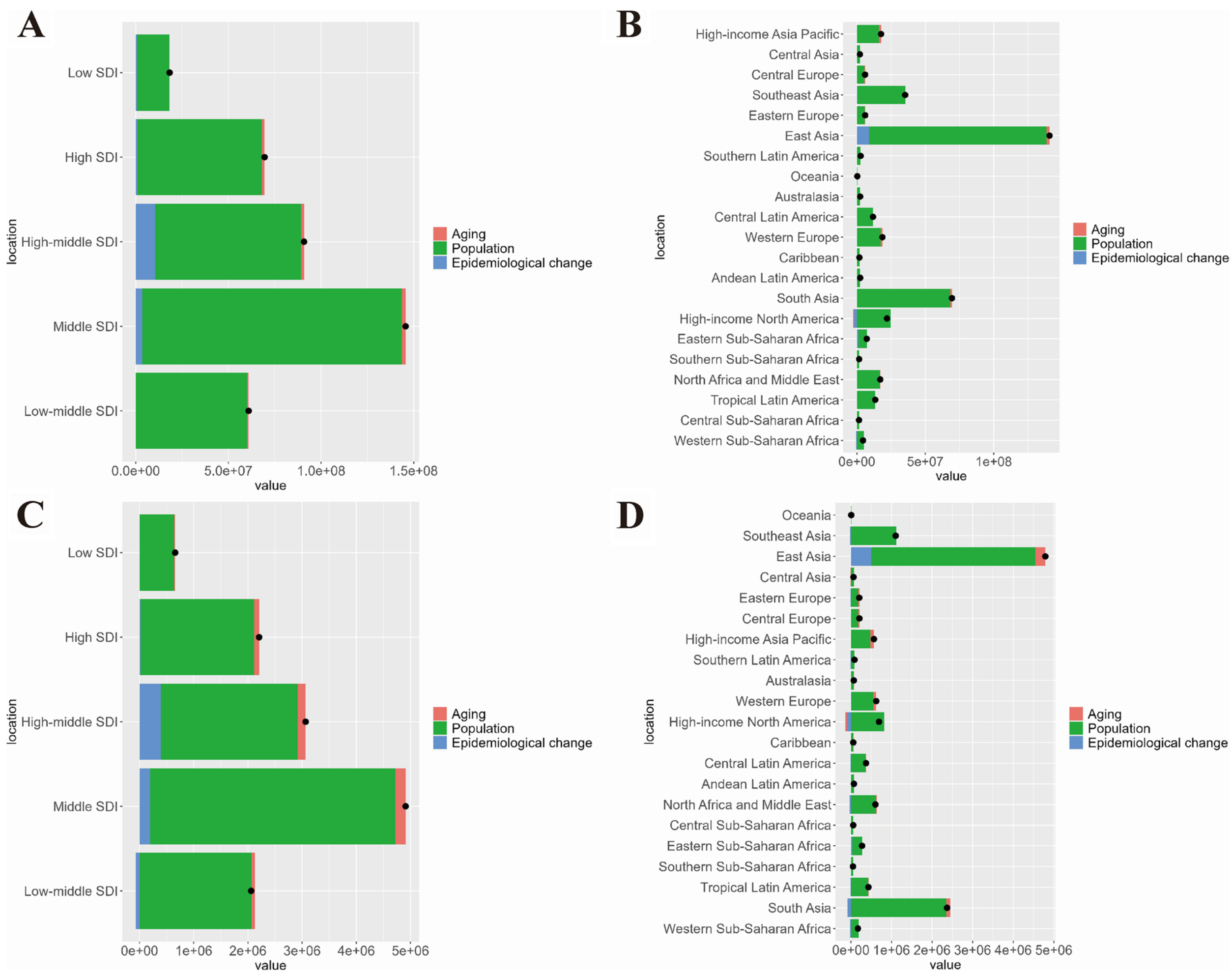

Fig. 3 Changes in AHL according to population-level determinants and epidemiological change by SDI quintiles and regions. AHL: Age-related Hearing Loss, SDI: Socio-Demographic Index. **A** and **B** prevalence. **C** and **D** YLDs

loss. Factors such as high costs, lack of availability, and limited access to trained professionals in low- and middle-income countries exacerbate this issue. Furthermore, delayed diagnosis is a critical concern. Many elderly individuals do not seek help for their hearing loss until it severely impacts their quality of life, and often attribute their condition to normal aging, resulting in missed opportunities for early intervention. Early diagnosis and intervention can significantly improve outcomes, and addressing the growing burden of hearing loss [24].

Aging is a primary cause of hearing loss [2], and age-related hearing damage exacerbates noise susceptibility, leading to a feedback loop between aging and hearing deterioration. Epidemiological studies have shown that the prevalence of hearing loss increases significantly with age, with estimates suggesting that nearly 1 in 3 adults over the age of 65 suffer from some degree of hearing impairment [18]. Additionally, factors such as occupational and environmental noise exposure [42, 43], chronic diseases (e.g., diabetes, hypertension) [44], and lifestyle choices (e.g., diet, stress, medication use) [45] interact with aging to contribute to moderate to severe hearing loss in older adults. The WHO has highlighted that hearing loss is not only a leading cause of disability but also a key contributor to increased all-cause and cause-specific mortality among older populations [19]. This complex interplay between aging, environmental factors, and health conditions underscores the importance of addressing hearing loss as part of broader public health initiatives aimed at improving the health and quality of life for older adults. However, the contribution of chronic diseases and lifestyle factors to moderate to severe hearing loss varies depending on individual differences. Therefore, reducing or eliminating the risk factors associated with AHL is crucial. Mild hearing loss is prevalent among AHL patients, suggesting that early screening and intervention could significantly alleviate the disease burden by addressing these risk factors. While the burden of AHL due to occupational noise is decreasing globally, from 1990 to 2019, the global age-standardized disability-adjusted life year rates (ASDR) for occupational noise-induced hearing loss (ONIHL) decreased by 1.72% [46], countries like Brazil have implemented widespread hearing protection measures, further reducing the AHL burden [47, 48]. Additionally, higher SDI countries tend to have lower AHL burdens due to better noise regulations and protective equipment use [49]. To mitigate hearing loss risk from noise exposure, it is essential to minimize exposure to loud sounds and integrate ear and hearing health care into national health plans. Protective measures like earplugs and earmuffs should be used, and regular hearing assessments should be conducted in noise-exposed occupations. Additionally, a systematized hearing conservation program should be implemented to effectively manage hearing health and prevent noise-induced hearing loss in the workplace.

Our study has some limitations. First, data from the GBD 2021 database, which does not use a standardized set of statistical methods across all countries and does not estimate uncertainty; Second, loss of data from countries with incomplete life systems, high quality country-level data, and little data from resource-poor countries; Third different diagnostic criteria for AHL in each country, and the data may be subject to error, which makes it easy to overdiagnose or underdiagnose; Fourth, this study relies entirely on the GBD database, as well as other global databases; Fifth, this study includes very few other causes of AHL, such as ototoxic hearing loss. Furthermore, GBD data do not encompass other potential influencing factors like genetic factors, environmental noise, chronic diseases (e.g., hypertension, diabetes), and medication use, which could have significant effects on hearing health in older populations. Future research could explore these additional factors and their interactions to better understand their combined impact on hearing loss.

Conclusion

Over the past three decades, there has been a sustained global increase in the prevalence of AHL and YLDs, highlighting the urgent need for targeted hearing screening, noise exposure prevention, and hearing aid use among older adults. Men are disproportionately affected by AHL compared to women, and older adults in regions with moderate SDI are particularly vulnerable. These findings underscore the necessity of allocating more healthcare resources to older men in these areas, indicating that future efforts to address the global burden of hearing loss should prioritize the physical healthcare needs of these populations.

Abbreviations

AHL	Age-related hearing loss
WHO	World Health Organization
COVID-19	Corona Virus Disease 2019
YLDs	Years of life lived with disability
GBD 2021	Global Burden of Diseases, Injuries, and Risk Factors Study 2021
GHDx	Global Health Data Exchange query tool
SDI	Socio-demographic index
CIs	Confidence intervals
AAPCs	Annual average percentage changes
CIs	Confidence intervals
WHA70.13	The 2021 World Health Assembly
WjRH	The World Report on Hearing

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12877-025-06066-6.

Supplementary Material 1: Figure S1. Joinpoint regression analysis of prevalence of AHL in older adults from 1992 to 2021 at global in mild hearing loss (A), moderate hearing loss (B), moderately severe hearing loss (C), severe hearing loss (D), profound hearing loss (E) and complete hearing loss (F) groups, stratified by impairment. Figure S2. Joinpoint regression analysis of YLDs of AHL in older adults from 1992 to 2021 at global in mild hearing loss (A), moderate hearing loss (B), moderately severe hearing loss (C), severe hearing loss (D), profound hearing loss (E) and complete hearing loss (F) groups, stratified by impairment. Figure S3. (A) The stacking rate of prevalence in older adults aged 60-89 years at global from 1992 to 2021 in mild hearing loss, moderate hearing loss and moderately severe hearing loss groups, stratified by impairment. (B) The stacking rate of prevalence in older adults aged 60-89 years at global from 1992 to 2021 in severe hearing loss, profound hearing loss and complete severe hearing loss groups, stratified by impairment. Figure S4. (A) The stacking rate of YLDs in older adults aged 60-89 years at global from 1992 to 2021 in mild hearing loss, moderate hearing loss and moderately severe hearing loss groups, stratified by impairment. (B) The stacking rate of YLDs in older adults aged 60-89 years at global from 1992 to 2021 in severe hearing loss, profound hearing loss and complete severe hearing loss groups, stratified by impairment. Figure S5. Changes in prevalence and YLDs (A, B) of AHL (C, D) in mild hearing loss group according to population-level determinants including aging, population growth and epidemiological change from 1992 to 2021 at the global level and by SDI quintiles and regions. Figure S6. Changes in prevalence and YLDs (A, B) of AHL (C, D) in moderate hearing loss group according to population-level determinants including aging, population growth and epidemiological change from 1992 to 2021 at the global level and by SDI quintiles and regions. Figure S7. Changes in prevalence and YLDs (A, B) of AHL (C, D) in moderately severe hearing loss group according to population-level determinants including aging, population growth and epidemiological change from 1992 to 2021 at the global level and by SDI quintiles and regions. Figure S8. Changes in prevalence and YLDs (A, B) of AHL (C, D) in severe hearing loss group according to population-level determinants including aging, population growth and epidemiological change from 1992 to 2021 at the global level and by SDI quintiles and regions. Figure S9. Changes in prevalence and YLDs (A, B) of AHL (C, D) in profound hearing loss group according to population-level determinants including aging, population growth and epidemiological change from 1992 to 2021 at the global level and by SDI quintiles and regions. Figure S10. Changes in prevalence and YLDs (A, B) of AHL (C, D) in complete hearing loss group according to population-level determinants including aging, population growth and epidemiological change from 1992 to 2021 at the global level and by SDI quintiles and regions. Figure S11. Occupational noise for AHL related DALYs, and AAPC, among older adults aged 60-89 years from 1992 to 2021 at global level (A) and stratified by SDI (B-F) and regional levels. Figure S12. (A) Occupational noise for AHL related DALYs among older adults from 1992 to 2021 at global level in age groups 60 to 64, 65 to 69 and 70 to 74. (B) Occupational noise for AHL related DALYs among older adults from 1992 to 2021 at global level in age groups 75 to 79, 80 to 84 and 85 to 89. (C) Occupational noise for AHL related YLDs among older adults from 1992 to 2021 at global level in age groups 60 to 64, 65 to 69 and 70 to 74. (D) Occupational noise for AHL related YLDs among older adults from 1992 to 2021 at global level in age groups 75 to 79, 80 to 84 and 85 to 89. Figure S13. Global distribution map of AHL of ASR of prevalence and YLDs in older adults aged 60-89 years, 1992, 2019, and 2021 at global. Figure S14. Global distribution map of ASR of prevalence and YLDs in older adults aged 60-89 years, 1992, 2019, and 2021 in mild hearing loss (A) and moderate hearing loss (B) and moderately severe hearing loss (C) groups, stratified by impairment. Figure S15. Global distribution map of ASR of prevalence and YLDs in older adults aged 60-89 years, 1992, 2019, and 2021 in severe hearing loss (A), profound hearing loss (B), complete hearing loss (C) groups. Figure S16. (A) The global change trends of rate and number of prevalence of AHL from 1992 to 2021, and its predicted trends between 2022 and 2040 in age groups 60 to 64, 65 to 69 and 70 to 74. (B) The global change trends of rate and number of YLDs of AHL from 1992 to 2021, and its predicted trends between 2022 and 2040 in age groups 60 to 64, 65 to 69 and 70 to 74. (C) The global change trends of rate and number of prevalence of AHL from 1992 to 2021, and its predicted trends between 2022 and 2040 in age groups 675 to 79, 80 to 84 and 85 to 89. (D) The global change trends of rate and number of YLDs of AHL from 1992 to 2021, and its predicted trends between 2022 and 2040 in age groups 75 to 79, 80 to 84 and 85 to 89. Figure S17. (A) The global change trends of rate and number of prevalence of AHL from 1992 to 2021, and its predicted trends between 2022 and 2040 in mild hearing loss, moderate hearing loss and moderately severe hearing loss groups. (B) The global change trends of rate and number of YLDs of AHL from 1992 to 2021, and its predicted trends between 2022 and 2040 in mild hearing loss, moderate hearing loss and moderately severe hearing loss groups. (C) The global change trends of rate and number of prevalence of AHL from 1992 to 2021, and its predicted trends between 2022 and 2040 in severe hearing loss, profound hearing loss, complete hearing loss groups. (D) The global change trends of rate and number of YLDs of AHL from 1992 to 2021, and its predicted trends between 2022 and 2040 in severe hearing loss, profound hearing loss, complete hearing loss groups.

Supplementary Material 2.

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Authors' contributions
Conceptualization, Methodology, Software [Fen-Fen Li, Zi-Yue Fu], Data curation, Roles/Writing - original draft [Ke Han, Bing-Yu Liang], Visualization, Investigation [Yan-Xun Han], Supervision [Ye-Hai Liu, Bu-Sheng Tong, Yu-Chen Liu].

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Data availability
The data utilized in this study can be found in the Global Burden of Diseases, Injuries, and Risk Factors Study 2021 (https://ghdx.healthdata.org/gbd-2021). The names of the repository/repositories and accession number(s) can be found in the article/Supplementary table.

Declarations

Ethics approval and consent to participate
Not applicable. Data was downloaded from the Global Health Data Exchange (GHDx) query tool (https://vizhub.healthdata.org/gbd-results/). While GBD data is open and transparent, no ethics are required for its use. All methods were carried out in accordance with relevant guidelines and regulations of the Declaration of Helsinki (https://www.wma.net/policies-post/wma-declaration-of-helsinki/). The GHDx data infrastructure ensures compliance with international data protection standards through rigorous de-identification processes prior to public release.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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