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Research paper

Association between the hearing aid and mental health outcomes in people with hearing impairment: A case-control study among 28 European countries

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ABSTRACT

Background: Hearing loss affects over 1.5 billion individuals globally, with significant implications for mental health. This study investigates the association between hearing aid use and mental health outcomes, by particularly focusing on depression and unmet mental health needs (UMHN), across a diverse international sample.

Methods: Utilizing data from the third wave of the European Health Interview Survey (EHIS), this study involved 17,660 participants with hearing impairment from 28 countries. The study examined the association between hearing aid use and mental health outcomes, including the likelihood of moderate and severe depression and UMHN due to lack of contact with general practitioners (GPs) and mental health specialists. Logistic regression models, adjusted for socio-demographic characteristics, health risk behaviours, and other relevant variables, were employed. Inverse probability weights were used to mitigate potential selection bias.

Results: Hearing aid usage was associated with significantly lower likelihoods of moderate depression (Odds Ratio [OR] = 0.58, 95%CI = [0.54, 0.63]) and severe depression (OR = 0.61, 95%CI = [0.55, 0.69]), compared to non-usage. Hearing aid usage was also associated with reduced UMHN due to lack of GP contact for moderate (OR = 0.82, 95%CI = [0.75, 0.89]) and severe depression (OR = 0.75, 95%CI = [0.59, 0.95]). The depression risk reductions were greater among females and higher-educated subgroups but lower in individuals aged ≥65 years. Income level and rurality also impacted UMHN due to the lack of GP contact. No associations were found between hearing aids and UMHN due to the lack of mental health specialist contact.

Conclusions: Hearing aid adoption showed protective associations against mood disorders and lowered unmet primary mental healthcare needs. Tailoring intervention strategies to vulnerable sociodemographic profiles could optimize mental health benefits among those with hearing loss. Integrating hearing health services within mental healthcare delivery frameworks is vital amidst the rising global burden.

1. Background

Hearing loss is a growing global health issue. At present, over 1.5 billion individuals, accounting for 20 % of the world's population, are affected by hearing loss (https://www.who.int/news-room/fact-sheets/detail/deafness-and-hearing-loss#:~:text=It%20is%20estimated%20that%20by,%2D%20and%20middle%2Dincome%20countries, n.d.; World Health Organization, 2021). Additionally, a significant portion, exceeding 5 % of the global population, need rehabilitation services for moderate or severe hearing loss (https://www.who.int/news-room/fact-sheets/detail/deafness-and-hearing-loss#:~:text=It%20is%20estimated%20that%20by,%2D%20and%20middle%2Dincome%20countries, n.d.; World Health Organization, 2021). It is projected that by the year 2050, around 2.5 billion people may experience varying levels of hearing loss, with at least 700 million (1 in 10) of them likely needing hearing rehabilitation services (https://www.who.int/news-room/fact-

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sheets/detail/deafness-and-hearing-loss#:~:text=It%20is%20estimated%20that%20by,%2D%20and%20middle%2Dincome%20countries, n.d.; World Health Organization, 2021).

The influence of hearing loss is extensive, impairing sound detection, speech recognition, and overall communication capabilities. This impairment often leads to reduced participation in social and communicative activities, adversely affecting quality of life and mental health (West et al., 2023; Barbosa et al., 2023; Huang et al., 2022; Lawrence et al., 2021; Bigelow et al., 2020; Warren et al., 2023; Borre et al., 2023). Additionally, individuals with hearing loss face greater challenges in accessing healthcare services and encounter heightened mortality risks (Mick et al., 2014; Mikkola et al., 2016; Tan et al., 2022; Zhang et al., 2023). Economically, the unaddressed burden of hearing loss carries a substantial cost, estimated at US$ 980 billion annually and globally, encompassing healthcare expenditure, productivity loss, and societal impacts (McDaid et al., 2021).

While hearing aids do not fully restore normal auditory function or address the underlying causes of hearing loss, they significantly aid in sound detection and speech understanding, enhancing the user's engagement in daily activities (Cox et al., 2014). Despite established links between hearing loss and mental health deterioration (West et al., 2023; Barbosa et al., 2023; Huang et al., 2022; Lawrence et al., 2021; Bigelow et al., 2020), the literature presents inconsistent evidence regarding the mitigation effect of hearing aids on mental health (Atef et al., 2023; Tavanai et al., 2023; Spreckley et al., 2020; Mahmoudi et al., 2019; Brewster et al., 2022; Acar et al., 2011; Shukla et al., 2021; Ye et al., 2022; Tsimpida et al., 2022; Crealey and O'Neill, 2020; Dawes et al., 2015). Additionally, there is a paucity of research identifying which demographic groups benefit most from the use of hearing aids (Brewster et al., 2022). Similarly, while challenges in accessing healthcare are noted among the hearing-impaired (Bigelow et al., 2020; Mick et al., 2014; Mikkola et al., 2016; Baratedi et al., 2022), the association between hearing aid use and the reduction of unmet mental health needs remains underexplored. These research gaps are particularly relevant considering the increasing prevalence of hearing loss and the necessity for precise, targeted interventions (Brewster et al., 2022).

This study aims to fill these gaps by analysing data from a survey covering 28 countries and 31,1385 participants. Our objectives were to examine whether hearing aid use is associated with improved mental health and reduced unmet mental health needs, and if so, to identify the groups that benefit most from such interventions.

2. Methods

2.1. Study design and participants

We utilized data from the third wave of the European Health Interview Survey (EHIS), conducted from January 2018 to September 2020. The EHIS, a periodic cross-sectional survey, captures data representative of each participating country (*Eurostat: European Health Interview Survey (EHIS wave 3) — methodological manual*, 2020). The third wave included all 28 European Union states, plus Iceland, Norway, Serbia, the United Kingdom, and Turkey. The EHIS employed a two-stage stratified cluster sampling method, based on the Census Database, at both national and regional levels (*Eurostat: European Health Interview Survey (EHIS wave 3) — methodological manual*, 2020). Stratification was based on administrative regions and individual residences. Initially, clusters were selected proportionally to their size, followed by systematic household selection (*Eurostat: European Health Interview Survey (EHIS wave 3) — methodological manual*, 2020). The survey targeted individuals aged 15 years and older residing in these selected households, who were then engaged in face-to-face interviews and asked to complete self-administered questionnaires (*Eurostat: European Health Interview Survey (EHIS wave 3) — methodological manual*, 2020). To maintain conceptual consistency across diverse linguistic contexts, modifications to certain survey items were implemented, tailoring them to the linguistic nuances of each national language (*Eurostat: European Health Interview Survey (EHIS wave 3) — methodological manual*, 2020). Items collected by EHIS included sociodemographic factors, health status, lifestyle habits, and utilization of healthcare services. Detailed information on the sample characteristics from the third wave of EHIS, along with the distribution of prevalence rates across these characteristics, are available in elsewhere (*Eurostat: European Health Interview Survey (EHIS wave 3) — methodological manual*, 2020).

In this study, eligible participants were those who have a hearing impairment, including those who use hearing aids or those who reported "a lot of difficulty" or "cannot do at all" for two questions: "Do you have difficulty hearing what is said in a conversation with one other person in a noisier room?" and "Do you have difficulty hearing what is said in a conversation with one other person in a quiet room?". The threshold for "a lot of difficulty" or "cannot do at all" was adopted from UNICEF's guidelines for assessing disability (de Castro et al., 2023). To minimize potential bias from other sensory impairments (Zhang et al., 2022; Rong et al., 2020), participants with visual disabilities—defined as those who reported "a lot of difficulty" or "cannot do at all" for question "Do you have difficulty seeing even when wearing your glasses or contact lenses?"—were excluded. Participants whose responses were provided by a proxy were also excluded. Additionally, exclusions were made for participants with missing value on mental health assessments (detailed as follows) and health care utilization. The detailed process of participant selection is illustrated in Fig. 1.

The data are publicly available. The use of secondary de-identified data made this study exempt from institutional review board review. Participants in the original studies gave informed consent and each study was approved by relevant institutional ethics review committees at the country level involved in data collection.

2.2. Key measures

Mental health status was reflected by the depressive symptoms in this study. Depressive symptoms of clinical relevance were evaluated using the 8-item version of the Patient Health Questionnaire (PHQ-8), a self-administered survey based on eight of the nine symptom criteria of depression from the Diagnostic and Statistical Manual of Mental Disorders, 4th edition (DSM-IV) (*Eurostat: European Health Interview Survey (EHIS wave 3) — methodological manual*, 2020; Arias-de la Torre et al., 2021). The PHQ-8 is composed of eight Likert-scale items, each rated from zero (not at all) to three (nearly every day). It aligns with the DSM-IV criteria for a major depressive episode, covering a two-week period, excluding the ninth criterion related to suicidal thoughts. The total PHQ-8 score, ranging from zero to 24, is the sum of all item responses. In this study, a PHQ-8 score of 10 to 19 was indicative of clinically moderate depressive symptoms (Kroenke et al., 2009; Wu et al., 2020). This threshold is known for its high sensitivity and specificity (over 85 %) in detecting depression (Manea et al., 2012). Similarly, a PHQ-8 score of 20 or more was indicative of severe depressive symptoms (Kroenke et al., 2001).

Unmet mental health needs (UMHN) was reflected by four variables: had moderate depression (PHQ-8 $\geq$ 10 and PHQ $<$ 20) but no contact with general practitioners (GPs); had moderate depression but no contact with psychologist, psychotherapist, or psychiatrist; had severe depression (PHQ-8 $\geq$ 20) but no contact with GPs; and had severe depression but no contact with psychologist, psychotherapist, or psychiatrist. The inclusion of the GP in this assessment is significant, given that GPs are often the primary point of access for individuals seeking mental health care (Rocks et al., 2020).

2.3. Covariates

We examined the following socio-demographic variables: age (15–19, 20–64, and 65 or over), sex (male vs. female), residential setting (cities, towns and suburbs, rural areas, or not stated), citizenship status

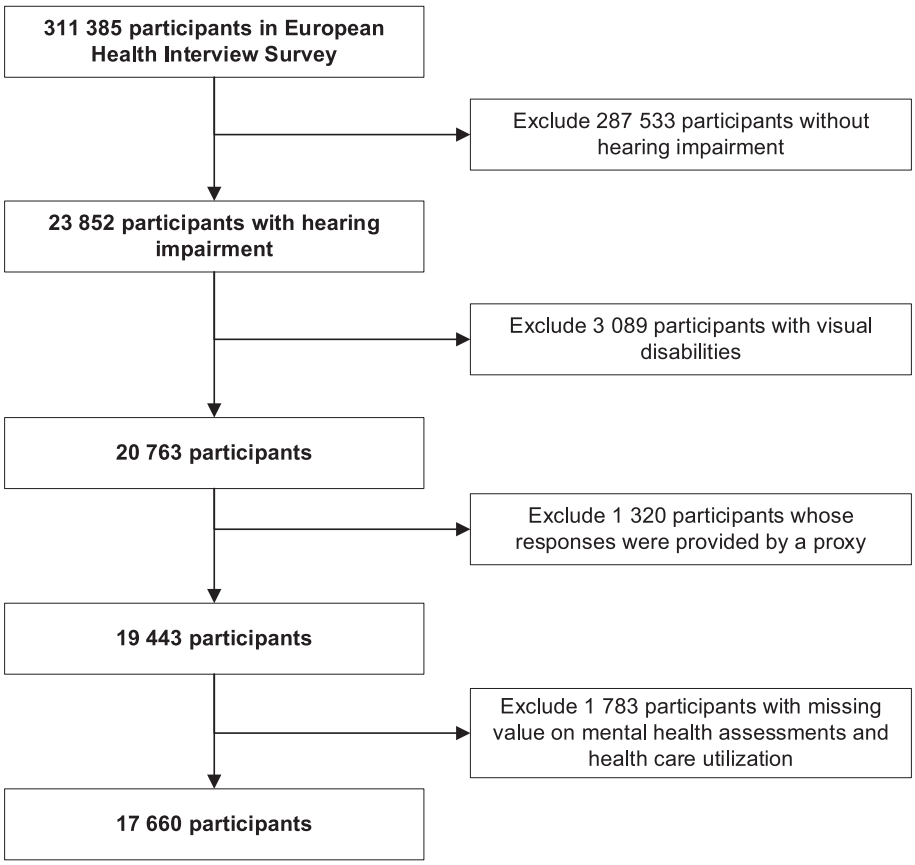

Fig. 1. STROBE diagram showing the selection of the participants.

(local or not), education attainment (lower secondary or lower, upper secondary or post-secondary education, vs. tertiary education or above), labour status (employed, unemployed, retired, or other), living alone (yes or no), and household income. The latter was determined based on the quintile of net monthly equivalised income, as provided in the EHIS directly, with a detailed methodology available elsewhere (*Eurostat: European Health Interview Survey (EHIS wave 3) — methodological manual*, 2020).

We also investigated health risk behaviours, including smoking (no smoking, occasional smoking, or frequent smoking), alcohol consumption (no alcohol, occasional drinking, or frequent drinking), and physical activity (PA) (yes or no). PA was assessed through the European Health Interview Survey-Physical Activity Questionnaire. This questionnaire encompasses work-related PA, transport-related PA, aerobic PA, and muscle-strengthening PA, with a detailed formula categorizing PA as "yes" or "no" found elsewhere (Finger et al., 2015).

Additional variables considered as potential risk or protective factors for mental health or access to mental health care were also examined, including: Body mass index (Smith et al., 2023; de Wit et al., 2022), calculated by dividing the self-reported weight (kg) by the square of the height (m). To explain the level of BMI, we used the standards of WHO: underweight (<18.5), health weight (≥18.5, <25), overweight (≥25, <30), and obesity (≥30) (Flegal et al., 2005); Long-standing health problem (Pilling et al., 2009), measured by question of "Do you have any long-standing illness or health problem? Long-standing means illnesses or health problems which have lasted, or are expected to last, for 6 months or more", with responses of yes or no; Activities limitations (Han et al., 2021) in the last six months, measured by question of "Are you limited because of a health problem in activities people usually do?" With responses of "not limited at all", "limited but not severely", or "severely limited"; Number of chronic diseases (Bobo et al., 2022), a sum of number of diseases in the past 12 months on 15 types of diseases, including "asthma", "chronic bronchitis, chronic obstructive pulmonary disease or emphysema", "myocardial infarction (heart attack) or chronic consequences of myocardial infarction", "coronary heart disease or angina pectoris", "high blood pressure", "stroke (cerebral haemorrhage, cerebral thrombosis) or chronic consequences of stroke", "arthrosis (arthritis excluded)", "low back disorder or other chronic back defect", "neck disorder or other chronic neck defect", "diabetes", "allergy, such as rhinitis, eye inflammation, dermatitis, food allergy or other (allergic asthma excluded)", "cirrhosis of the liver", "urinary incontinence, problems in controlling the bladder", "kidney problems", and "high blood lipids"; Bodily pain (Nassiri Kigloo et al., 2023), measured by question of "How much bodily pain have you had during the past 4 weeks?" with six responses from none to severe; and Social support (Chen et al., 2022), measured by Oslo social support scale (OSSS-3). The total score of the OSSS-3 spans from 3 to 14, and can be divided into three categories: a score range of 3–8 indicates poor social support, 9–11 suggests moderate social support, and 12–14 reflects a high level of social support (Kocalevent et al., 2018).

2.4. Statistical analysis

We reported categorical variables as numbers (percentage), and continuous variables as mean (standard deviation). Differences between groups were assessed via two-tailed *t*-tests (for continuous variables) and chi-square tests (for categorical variables).

To investigate the associations between hearing aid use and mental health outcomes, as well as UMHN, logistic regression models were employed, adjusting for socio-demographic characteristics, health risk behaviours, and potential risk or protective factors listed in the covariates section. Recognizing that the decision to use hearing aids is influenced by a variety of factors (Jorgensen and Novak, 2020), unlike in Randomized Controlled Trials (RCTs), there was a potential selection

bias in estimating the association of hearing aid use. To mitigate this bias, the logistic models were further refined using inverse probability weights (IPWs). IPWs, a development of the propensity score method, were employed to calculate the conditional likelihood of receiving a hearing aid treatment or intervention (Willems, 2014). These weights were calculated from propensity scores obtained through a separate logistic regression model predicting hearing aid usage, incorporating the same covariates as the primary logistic models. Additionally, we conducted group comparisons of both pre- and post-application of IPW, using standardized mean differences (SMDs). SMDs are calculated as the mean difference divided by the standard deviation of the variable, with an absolute value >0.1 signifying a significant imbalance (Stuart et al., 2013).

To identify which socio-demographic groups benefit most from such hearing aid intervention, we additionally conducted models incorporating an interaction term between socio-demographic factors and hearing aid usage.

Missing values for the study variables ranged from 0.09 % (for bodily pain) to 5.4 % (for household income), and to 12.9 % (for alcohol consumption). We implemented 13 multiple imputations by chained equations to avoid biases due to missing data (van Buuren and Groothuis-Oudshoorn, 2011).

We conducted a sensitivity analysis, by repeating the analysis without missing values imputation.

All analyses were performed using R (version 4.3.0). We report two-sided p values and 95 % confidence intervals (CIs) throughout. $p < 0.05$ was considered to be statistically significant.

3. Results

We included 9739 individuals who used hearing aids and 7921 individuals who did not (Fig. 1). Of these participants, 66.5 % were aged 65 or above, and 50.1 % were female. There were some differences in the basic characteristics of individuals between the two groups (Table 1). Individuals in the hearing aid user group tended to be older ($p < 0.001$), male ($p = 0.002$), city-dwelling ($p < 0.001$), holding local citizenship ($p < 0.001$), and with a higher education degree ($p < 0.001$) and higher income levels ($p < 0.001$). Hearing aid user group also had a higher proportion of retired individuals ($p < 0.001$), non-smoking ($p < 0.001$), normal weight ($p < 0.001$) as well as more frequent alcohol consumption ($p < 0.001$), greater engagement in physical activity ($p < 0.001$), fewer long-standing health conditions ($p < 0.001$), less activity limitations ($p < 0.001$), fewer chronic diseases ($p < 0.001$), less bodily pain ($p < 0.001$), and lower social support ($p < 0.001$). No significant difference was found in the proportion of individuals living alone between the two groups ($p = 0.153$). After IPW adjustment, the basic characteristics between the two groups were well balanced (SMDs $\leq$ 0.009).

After adjusting for potential confounders, including socio-demographic factors (age, sex, residential setting, citizenship status, educational level, labour status, living situation, and household income), health risk behaviours (smoking status, alcohol use, and physical activity), and other relevant variables (BMI, long-standing health conditions, activity limitations, number of chronic diseases, bodily pain, and social support), the study found significant associations for individuals using hearing aids compared to those not using them (Fig. 2). Specifically, hearing aid users had a reduced likelihood of moderate depression (Odds Ratio [OR] = 0.58, 95 % CI: [0.54, 0.63]), and severe depression (OR = 0.61, 95 % CI: [0.55, 0.69]) (Fig. 2). Additionally, this group showed a lower likelihood of experiencing UMHN due to no contact with a GP for moderate depression (OR = 0.82, 95 % CI: [0.75, 0.89]) and UMHN due to no contact with GP for severe depression (OR = 0.75, 95 % CI: [0.59, 0.95]) (Fig. 2). There were no significant associations found for UMHN due to no contact with mental health specialists for moderate or severe depression (OR = 0.99, 95 % CI: [0.85, 1.16] and OR = 0.93, 95 % CI: [0.71, 1.21], respectively) (Fig. 2).

Table 1
Basic characteristics. Data are shown as mean (SD) for continuous variables and number (percentage) for categorical variables. p values reflect unweighted group comparison, and were extracted from two-tailed *t*-tests (for continuous variables) and chi-square tests (for categorical variables). SMD, standardized mean difference between groups; IPW, inverse probability weighting.

	Hearing aid		p value	SMD before IPW	SMD after IPW
	No usage (*N* = 7921)	Usage (*N* = 9739)			
Age					
15–19	100 (1.3 %)	141 (1.4 %)	<0.001	0.207	0.007
20–64	2974 (37.5 %)	2715 (27.9 %)			
65 and over	4847 (61.2 %)	6883 (70.7 %)			
Sex (=female)	4074 (51.4 %)	4778 (49.1 %)	0.002	0.047	0.002
Residential setting					
Cities	2294 (29.0 %)	3147 (32.3 %)	<0.001	0.088	0.005
Towns and suburbs	2525 (31.9 %)	3115 (32.0 %)			
Rural areas	2726 (34.4 %)	3109 (31.9 %)			
Not stated	376 (4.7 %)	368 (3.8 %)			
Local citizenship (=TRUE)	7422 (93.7 %)	8990 (92.3 %)	<0.001	0.055	0.001
Education attained					
Lower secondary or lower	3767 (47.6 %)	3539 (36.3 %)	<0.001	0.238	0.002
Upper-secondary or post-secondary education	2636 (33.3 %)	3675 (37.7 %)			
Tertiary education or above	1518 (19.2 %)	2525 (25.9 %)			
Labour status					
Employed	1922 (24.3 %)	1987 (20.4 %)	<0.001	0.143	0.006
Unemployed	232 (2.9 %)	189 (1.9 %)			
Retired	4613 (58.2 %)	6320 (64.9 %)			
Other	1154 (14.6 %)	1243 (12.8 %)			
Living alone (=yes)	2395 (30.2 %)	3043 (31.2 %)	0.153	−0.022	0.004
Household income					
Low 25 % quintile	1796 (22.7 %)	1974 (20.3 %)	<0.001	0.119	0.007
2	2030 (25.6 %)	2296 (23.6 %)			
3	1624 (20.5 %)	1970 (20.2 %)			
4	1403 (17.7 %)	1824 (18.7 %)			

(*continued on next page*)

Table 1 (*continued*)

	Hearing aid		p value	SMD before IPW	SMD after IPW
	No usage (*N* = 7921)	Usage (*N* = 9739)			
Top 25 % quintile	1068 (13.5 %)	1675 (17.2 %)			
Smoke					
No smoking	6626 (83.7 %)	8394 (86.2 %)	<0.001	0.071	0.004
Occasional smoking	259 (3.3 %)	279 (2.9 %)			
Frequent smoking	1036 (13.1 %)	1066 (10.9 %)			
Alcohol consumption					
No alcohol	2823 (35.6 %)	2915 (29.9 %)	<0.001	0.125	0.009
Occasional drinking	2464 (31.1 %)	3180 (32.7 %)			
Frequent drinking	2634 (33.3 %)	3644 (37.4 %)			
Physical activity (=yes)	3835 (48.4 %)	5402 (55.5 %)	<0.001	−0.142	−0.005
BMI					
Underweight (<18.5)	1475 (18.6 %)	1399 (14.4 %)	<0.001	0.143	0.002
Healthy weight (≥18.5, <25)	2274 (28.7 %)	3203 (32.9 %)			
Overweight (≥25, <30)	2630 (33.2 %)	3443 (35.4 %)			
Obesity (≥30)	1542 (19.5 %)	1694 (17.4 %)			
Long-standing health (=yes)	6053 (76.4 %)	6297 (64.7 %)	<0.001	0.260	0.002
Activities limitations					
Not limited at all	2730 (34.5 %)	4895 (50.3 %)	<0.001	0.340	0.004
Limited but not severely	3228 (40.8 %)	3286 (33.7 %)			
Severely limited	1912 (24.1 %)	1487 (15.3 %)			
Not stated	51 (0.6 %)	71 (0.7 %)			
Number of chronic diseases					
None	1002 (12.6 %)	2022 (20.8 %)	<0.001	0.236	0.005
1–2	2804 (35.4 %)	3494 (35.9 %)			
≥3	4115 (52.0 %)	4223 (43.4 %)			
Bodily pain					
None	1595 (20.1 %)	3289 (33.8 %)	<0.001	0.371	0.003
Mild	2055 (25.9 %)	2817 (28.9 %)			
Moderate or severe	4271 (53.9 %)	3633 (37.3 %)			
Social support					
Poor social support	6114 (77.2 %)	8017 (82.3 %)	<0.001	0.132	0.003
Moderate social support	1737 (21.9 %)	1679 (17.2 %)			
Strong social support	70 (0.9 %)	43 (0.4 %)			
Score of PHQ-8	13.57 (5.26)	11.40 (4.23)	<0.001	0.456	0.201
PHQ-8 ≥ 10	4842 (61.1 %)	4868 (50.0 %)	<0.001	0.226	0.132
PHQ-8 ≥ 20	1075 (13.6 %)	558 (5.7 %)	<0.001	0.268	0.108
PHQ-8 ≥ 10 but no contact with general practitioners	2371 (49.0 %)	2238 (46.0 %)	0.003	0.060	0.091
PHQ-8 ≥ 10 but no contact with mental health specialists	4433 (91.6 %)	4527 (93.0 %)	0.009	−0.054	0.002
PHQ-8 ≥ 20 but no contact with general practitioners	438 (40.7 %)	174 (31.2 %)	<0.001	0.200	0.129
PHQ-8 ≥ 20 but no contact with mental health specialists	775 (72.1 %)	421 (75.4 %)	0.163	−0.076	0.036

The association between the use of hearing aids and a reduced likelihood of moderate depression was found to be stronger in females (OR = 0.82, 95%CI [0.70, 0.96]) and in individuals with an educational level of upper secondary or post-secondary (OR = 0.80, 95%CI [0.67, 0.95]). Conversely, the association was less pronounced in individuals aged 65 or older (OR = 1.61, 95%CI [1.36, 1.90]) and among retired individuals (OR = 1.59, 95%CI [1.32, 1.91]) (Table 2).

The association between the use of hearing aids and a decreased likelihood of severe depression was more pronounced among individuals belonging to the middle-upper household income level (OR = 0.64, 95%CI [0.43, 0.96]), but less pronounced in individuals aged 65 or older (OR = 1.39, 95%CI [1.06, 1.81]) (Table 2).

The association between hearing aid use and a reduced likelihood of UMHN due to no GP contact for moderate depression was more pronounced in individuals with upper secondary or post-secondary education (OR = 0.75, 95 % CI: [0.62, 0.91]) and those with tertiary education or higher (OR = 0.78, 95 % CI: [0.61, 0.98]). In contrast, this association was less pronounced among residents of towns and suburbs (OR = 1.33, 95 % CI: [1.07, 1.66]) and among those with local citizenship (OR = 2.05, 95 % CI: [1.42, 2.95]) (Table 2).

Despite no significant association between hearing aid use and the likelihood of UMHN due to the lack of specialist contact for moderate depression, certain demographic groups displayed different associations. Specifically, individuals residing in rural areas (OR = 1.67, 95 % CI: [1.10, 2.53]) and those with upper secondary or post-secondary education (OR = 1.78, 95 % CI: [1.23, 2.59]) who used hearing aids showed a higher likelihood of experiencing UMHN due to lacking specialist contact for moderate depression. On the other hand, retired individuals who used hearing aids were associated with a lower likelihood of encountering this UMHN (OR = 0.66, 95 % CI: [0.45, 0.96]) (Table 2).

The association between the use of hearing aids and a reduced

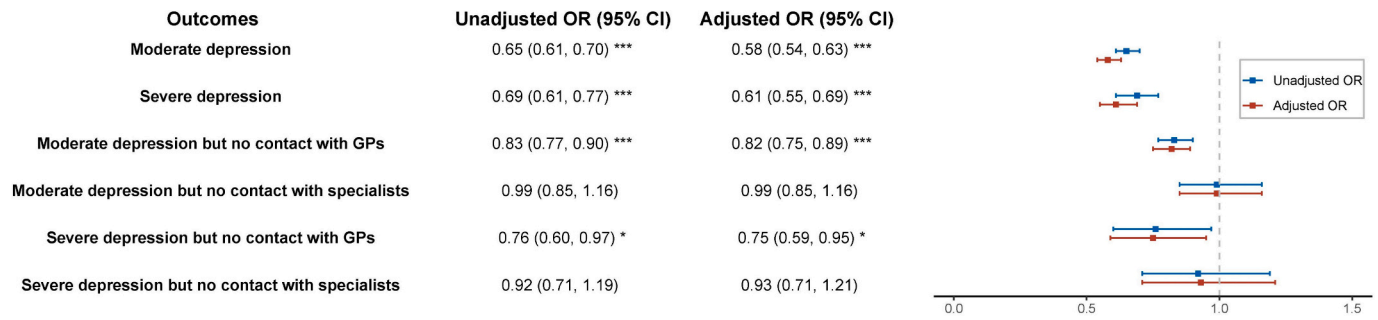

Fig. 2. Association of hearing aid use with the mental health outcomes as well as corresponding unmet mental health needs. Data extracted from IPW weighted logistic regression models, with corresponding outcomes as the dependent variable and hearing aid use as the key predictor. Covariates controlled for included socio-demographic factors (age, sex, residential setting, citizenship status, educational level, labour status, living situation, and household income), health risk behaviours (smoking status, alcohol use, and physical activity), and other relevant variables (BMI, long-standing health conditions, activity limitations, chronic disease count, body pain, and social support). OR, Odds ratio. CI, confidence interval. IPW, inverse probability weights. ***p < 0.001, **p < 0.01, *p < 0.05.

likelihood of UMHN due to no GP contact for severe depression was found to be more pronounced among individuals with higher income levels (p values <0.05) (Table 2).

The sensitive analysis without missing value imputation in Sup Fig. 1 and Sup Table 1 confirmed the above results.

4. Discussion

4.1. Statement of principal findings

This large, multi-country case-control study conducted across 28 countries with over 17,000 participants provided critical insights into the association between hearing aid use and mental health outcomes in individuals with hearing impairments. The findings revealed that hearing aid adoption is associated with about 40 % reduction in risk for moderate and severe depression, as well as about 20 % reduction in the likelihood of experiencing UMHN due to lack of contact with a GP for moderate and severe depression. Notably, the reduction in major depression risk was more substantial in females and those with upper secondary or higher education, but less so in individuals over 65 and retirees. Similarly, the decrease in severe depression was more marked in those with middle to upper household income, but less so in older adults. The likelihood of reduced UMHN due to lack GP contact for moderate depression was higher in individuals with higher education levels, yet lower in town/suburb residents and those with local citizenship. Similarly, the association with reduced UMHN due to lack GP contact for severe depression was stronger among wealthier individuals. No significant associations were observed for UMHN due to lack of contact with mental health specialists. Nevertheless, rural residents and those with upper secondary education using hearing aids showed an increased likelihood of UMHN due to lack of specialist contact for moderate depression, while retired hearing aid users had a reduced risk of this UMHN.

4.2. Interpretation

The finding that hearing aid use reduced the likelihood of moderate and severe depression aligns with past evidence linking hearing loss rehabilitation to mood improvements (Barbosa et al., 2023; Lawrence et al., 2021; Bigelow et al., 2020). Significantly, our research highlighted the varied associations of hearing aids across diverse demographic categories. The more pronounced reduction in major depression risk among females and individuals with at least upper secondary education, suggesting a heightened benefit of hearing aids in these groups. This may be attributable to their distinct social and professional spheres, which potentially heighten their vulnerability to the adverse consequences of hearing loss (Dobie and Van Hemel, 2004; Nachtegaal et al., 2009; Shankar et al., 2011). In such populations, hearing aids may play a pivotal role in preserving crucial social interactions and occupational functionality, which are essential components for mental well-being (Mick et al., 2014; Prieur Chaintre et al., 2024). In contrast, the weaker association in individuals over 65 and retirees might be linked to the complex aetiology of depression within these older demographics. Among older populations, internal factors, including neurocognitive variations, may obstruct the optimal mental health benefits attainable through auditory rehabilitation (Guo et al., 2023). These insights provide a substantial advancement in our understanding, offering crucial implications for healthcare practitioners in customizing hearing aid prescriptions to maximize mental health benefits across varied population segments.

We also found that hearing aid users have a reduced likelihood of experiencing UMHN due to the absence of GP contact. This finding resonated, to some extent, with the greater healthcare access barriers among those with hearing loss (Mikkola et al., 2016). This reduction in UMHN suggests that hearing aids may serve a dual purpose: not only improving auditory function but also acting as a facilitating measure to access primary healthcare for mental health issues. This suggests integrating hearing aids in the broader healthcare framework, especially in mental health management, would be beneficial. The variations in the association of hearing aids across different groups – more pronounced in those with higher education and wealthier individuals – can be understood in terms of awareness and accessibility. Educated individuals may have heightened awareness of their mental health needs and coupled with increased access to seek appropriate healthcare services (Steele et al., 2007; Araya et al., 2003). In contrast, the lesser benefit seen in town/suburb residents may indicate persistent inequities in access to care even when marginalized hearing-impaired subsets adopt hearing aid (Eubank et al., 2022; Haggerty et al., 2014). Targeting outreach and screening to detect those remaining cases of unmet needs could help address gaps. Further, the lesser benefit seen in those with local citizenship and wealthier individuals may indicate differing attitudes towards mental health and hearing loss management measures. This demographic group might rely on broader social networks and community activities, beyond GP visits, to address their mental health concerns (Corrigan et al., 2014; Im, 2018). This aspect emphasizes the need for a multifaceted approach to address mental health needs, one that considers the diverse societal and cultural dynamics influencing health-seeking behaviours.

Our investigation revealed insignificant associations between hearing aid use and UMHN due to the absence of engagement with mental health specialists for moderate and severe depression. These findings diverge from the expected outcome where hearing aids might reduce UMHN by improving social engagement. The absence of a significant association implies that while hearing aids may contribute to managing certain facets of mental health associated with hearing impairment, they are potentially inadequate for addressing the complexities of mental

Table 2
Sociodemographic disparities on the association between hearing aid use and mental health outcomes as well as corresponding unmet mental health needs. Results extracted from IPW weighted logistic regression models, with corresponding outcomes as the dependent variable and hearing aid use, related sociodemographic variables, and their interaction items as the key predictor. Data only show the results of ORs and 95 % confidence intervals (CI) for interaction items. Covariates controlled for included socio-demographic factors (age, sex, residential setting, citizenship status, educational level, labour status, living situation, and household income), health risk behaviours (smoking status, alcohol use, and physical activity), and other relevant variables (BMI, long-standing health conditions, activity limitations, chronic disease count, body pain, and social support). IPW, inverse probability weights.

Variable	Moderate depression	Severe depression	Moderate depression but no contact with GPs	Moderate depression but no contact with specialists	Severe depression but no contact with GPs	Severe depression but no contact with specialists
Age						
=15–19 × hearing aid use (=yes)	0.59 (0.31, 1.12)	0.38 (0.09, 1.54)	0.59 (0.24, 1.45)	0.57 (0.19, 1.77)	8.22 (0.52, 130.68)	0.18 (0.01, 3.57)
=20–64 × hearing aid use (=yes)	Reference	Reference	Reference	Reference	Reference	Reference
=65 and over × hearing aid use (=yes)	1.61 (1.36, 1.90)***	1.39 (1.06, 1.81)*	1.18 (0.97, 1.42)	0.72 (0.51, 1.00)	1.16 (0.71, 1.88)	0.80 (0.47, 1.37)
Sex (=female) × hearing aid use (=yes)	0.82 (0.70, 0.96)*	0.93 (0.73, 1.19)	1.12 (0.94, 1.33)	0.95 (0.69, 1.32)	1.04 (0.64, 1.68)	0.94 (0.54, 1.63)
Residential setting						
=Cities × hearing aid use (=yes)	Reference	Reference	Reference	Reference	Reference	Reference
=Towns and suburbs × hearing aid use (=yes)	1.09 (0.89, 1.32)	0.83 (0.61, 1.13)	1.33 (1.07, 1.66)**	1.22 (0.83, 1.79)	0.96 (0.54, 1.71)	0.62 (0.32, 1.21)
=Rural areas × hearing aid use (=yes)	1.10 (0.90, 1.34)	0.74 (0.54, 1.00)	1.01 (0.81, 1.25)	1.67 (1.10, 2.53)*	1.07 (0.59, 1.93)	0.67 (0.34, 1.34)
=Not stated × hearing aid use (=yes)	1.03 (0.71, 1.50)	1.21 (0.56, 2.64)	1.30 (0.78, 2.17)	1.53 (0.62, 3.79)	4.45 (0.97, 20.40)	–
Local citizenship (=TRUE) × hearing aid use (=yes)	1.18 (0.88, 1.60)	1.40 (0.81, 2.41)	2.05 (1.42, 2.95)***	0.74 (0.39, 1.41)	1.37 (0.52, 3.63)	2.47 (0.88, 6.97)
Education attained						
=Lower secondary or lower × hearing aid use (=yes)	Reference	Reference	Reference	Reference	Reference	Reference
=Upper-secondary or Post-secondary education × hearing aid use (=yes)	0.80 (0.67, 0.95) *	1.15 (0.87, 1.50)	0.75 (0.62, 0.91)**	1.78 (1.23, 2.59)**	1.29 (0.75, 2.22)	1.28 (0.71, 2.32)
=Tertiary education or above × hearing aid use (=yes)	0.88 (0.72, 1.07)	0.91 (0.65, 1.29)	0.78 (0.61, 0.98)*	1.39 (0.92, 2.10)	1.03 (0.54, 1.98)	1.21 (0.58, 2.53)
Labour status						
=Employed × hearing aid use (=yes)	Reference	Reference	Reference	Reference	Reference	Reference
=Unemployed × hearing aid use (=yes)	1.01 (0.59, 1.74)	0.90 (0.39, 2.04)	1.32 (0.71, 2.45)	0.97 (0.40, 2.40)	1.42 (0.38, 5.33)	0.33 (0.06, 1.70)
=Retired × hearing aid use (=yes)	1.59 (1.32, 1.91)***	1.39 (0.97, 1.99)	1.14 (0.91, 1.43)	0.66 (0.45, 0.96)*	1.24 (0.62, 2.48)	1.10 (0.54, 2.24)
=Other × hearing aid use (=yes)	1.17 (0.89, 1.52)	1.32 (0.86, 2.02)	1.01 (0.74, 1.38)	0.96 (0.59, 1.55)	0.97 (0.44, 2.16)	1.44 (0.65, 3.19)
Living alone (=yes) × hearing aid use (=yes)	1.14 (0.95, 1.35)	1.05 (0.82, 1.36)	1.00 (0.83, 1.20)	0.83 (0.59, 1.17)	0.91 (0.56, 1.50)	0.89 (0.50, 1.57)
Household income						
=Low 25 % quintile × hearing aid use (=yes)	Reference	Reference	Reference	Reference	Reference	Reference
=2 × hearing aid use (=yes)	1.13 (0.89, 1.43)	1.01 (0.74, 1.40)	1.00 (0.78, 1.29)	0.78 (0.49, 1.24)	2.10 (1.16, 3.81)*	0.96 (0.48, 1.94)
=3 × hearing aid use (=yes)	1.03 (0.81, 1.32)	0.93 (0.64, 1.33)	1.08 (0.83, 1.40)	1.38 (0.84, 2.25)	2.42 (1.17, 5.01)*	1.07 (0.47, 2.46)
=4 × hearing aid use (=yes)	0.99 (0.78, 1.28)	0.64 (0.43, 0.96)*	0.93 (0.70, 1.23)	0.69 (0.42, 1.14)	1.35 (0.61, 2.98)	0.92 (0.38, 2.23)
=Top 25 % quintile × hearing aid use (=yes)	1.11 (0.86, 1.43)	0.94 (0.60, 1.47)	1.00 (0.74, 1.35)	1.35 (0.79, 2.31)	2.82 (1.19, 6.66)*	1.15 (0.46, 2.91)

*** $p < 0.001$.
** $p < 0.01$.
* $p < 0.05$.

health issues that necessitate specialized intervention. In contrast to previous studies that have often emphasized the positive benefits of hearing aids on general mental health and social participation (Atef et al., 2023; Spreckley et al., 2020; Mahmoudi et al., 2019; Brewster et al., 2022; Acar et al., 2011; Shukla et al., 2021; Tsimpida et al., 2022; Ferguson et al., 2017), these findings highlight the limitations of hearing aids in addressing specific mental health challenges. This contributes to a more comprehensive understanding of the role of hearing aids in mental health care, underscoring the potential insufficient integration of hearing aids with broader mental health services, if were, especially for moderate to severe depression. Moreover, the increased likelihood of such UMHN among rural residents and those with upper secondary education is noteworthy. This phenomenon might be influenced by factors such as limited accessibility to mental health specialists in rural localities or an overreliance on social networks and community support systems, which could overshadow the need for professional mental health services (Eubank et al., 2022; Haggerty et al., 2014; Corrigan et al., 2014; Im, 2018). This suggests a gap in mental health service delivery or a disparity in health-seeking behaviour among these groups. Conversely, the reduced risk of such UMHN among retired hearing aid users could be related to different factors, such as more time to seek mental health care or more likely to be given mental care due to co-morbidity. This aspect of the findings highlights the diversity in health-seeking behaviours and access to mental health care across different life

stages and social groups.

The findings from this study have meaningful implications for clinical practice, health policy, and future research. For clinical practice, the results emphasize the importance of taking a personalized approach when prescribing hearing aids, considering each individual's sociodemographic profile and mental health needs. It advocates for more multidimensional mental healthcare pathways that encompass specialized psychiatric care alongside rehabilitative services like hearing aids. From a health policy perspective, the study underscores the necessity of integrating hearing aids into broader healthcare and mental health management strategies. This integration is particularly relevant for females and those with higher educational attainment, as they exhibit a more pronounced benefit from hearing aids in mitigating depression risks. Additionally, policies should aim to reduce disparities in healthcare access, particularly in rural areas where there is an increased likelihood of UMHN due to the lack of contact with mental health specialists. This calls for targeted outreach and screening initiatives to identify and bridge gaps in mental health service delivery. From a research perspective, the findings highlight the need for further exploration into the complex interplay between hearing loss, the use of hearing aids, and mental health outcomes across diverse demographic groups. Future studies should investigate the underlying mechanisms that contribute to the variable impact of hearing aids on mental health, with a focus on exploring effective strategies to enhance their benefits across all segments of the population. Additionally, research should delve into the reasons behind the limited impact of hearing aids in addressing specific mental health challenges, particularly those requiring specialist intervention, and how these limitations can be overcome.

4.3. Strength and limitations

This study had important strengths. First, this study utilized a large, multicounty dataset encompassing over 17,000 participants across 28 European countries. This substantial sample size lends reliability and generalizability to the findings. Second, the use of a standardized dataset allows for consistency in measures across diverse contexts. Third, the analysis accounts for a comprehensive set of potential confounders including sociodemographic factors, health behaviours, and other risk variables. This allows for isolating the impact of hearing aid use on mental health outcomes. Fourth, the study employs rigorous methodologies including IPW adjustments to minimize selection bias as well as multiple imputations for missing data. Finally, this study moves beyond examining overall associations to identifying specific groups gaining the most mental health benefits from hearing aids. This provides precise, tailored insights to guide interventions.

Some limitations are worth noting. First, the cross-sectional nature of the data limits causal inference about the benefit of hearing aid use on mental health. Second, the self-reported measures may be subject to reporting bias. Third, some nuances related to hearing aid use, such as consistency of usage, technological specifications, and subjective satisfaction were not explored. Fourth, the mental health measures were limited to depression and unmet needs, and implications for other conditions remain unclear. Fifth, the lack of data on participants' daily hearing aid usage. Previous research suggests that the extent of hearing aid use can influence the magnitude of improvements in social engagement, communication, and quality of life (Ferguson et al., 2017). Without data on daily usage patterns, it is challenging to fully understand how hearing aids contributed to the reduced risks of depression and unmet mental health needs. Future studies should collect detailed information on hearing aid adherence to better elucidate the impact of usage patterns on mental health outcomes in individuals with hearing impairment. Sixth, the absence of objective hearing assessments, such as pure-tone audiometry, to determine participants' hearing loss severity. The EHIS dataset relied on self-reported measures of hearing difficulty, which may be subject to bias, particularly among those with severe depressive symptoms who might exaggerate hearing loss challenges. Objective hearing data would have enabled a more precise analysis of the association between hearing loss and mental health outcomes. Future studies should include objective hearing measures to better understand the complex interplay between hearing impairment, hearing aid use, and mental well-being. Finally, while the large European sample allows for generalized insights, findings may not directly extend to populations elsewhere with differing healthcare infrastructures. Further research using longitudinal data, objective clinical measures, details on hearing aid characteristics, a wider range of mental health indicators, and samples from other global regions would help validate and extend these results.

5. Conclusion

In conclusion, this large multicounty study offers valuable insights into the association between hearing aid adoption and mental health outcomes among those with hearing impairment. The findings reveal meaningful associations between hearing aid usage and reduced risks of moderate and severe depression, as well as lowered likelihood of unmet mental healthcare needs due to lack of general practitioner contact for those with moderate to severe depression. Notably, the variations across sociodemographic factors in terms of these associations highlight important nuances regarding which subgroups stand to gain the greatest mental health benefits from hearing rehabilitation. As the global burden of hearing loss continues mounting, these results advocate for more personalized and demographically-targeted hearing loss intervention strategies, underpinned by deeper integration of hearing health services within mental healthcare systems.

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CRediT authorship contribution statement

Liansheng Zhang: Writing – review & editing, Writing – original draft. **Jiazhou Yu:** Writing – review & editing, Validation. **Huanyu Zhang:** Writing – review & editing. **Shanquan Chen:** Validation, Software, Methodology.

Declaration of competing interest

LZ and all other others declare no conflict of interest with this work.

Data availability statement

The data are publicly available and can be accessed here (https://ec.europa.eu/eurostat/web/microdata/european-health-interview-survey).

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Appendix A. Supplementary data

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