No evidence for a protective role of hearing aids for the risk of dementia in UK Biobank: a response to Jiang et al. (2023)

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Hearing loss is considered a major risk factor for dementia[1]. Due to the possibility of improving hearing with the use of hearing aids, the latter have garnered considerable attention as a potentially modifiable intervention to delay the onset of dementia. The provision of hearing aids to reduce the risk of dementia may also be clinically cost-effective, which not all lifestyle interventions fulfil[2]. In the absence of randomised controlled trials with a sufficiently long follow-up, observational designs have been invaluable in describing the population trends of hearing loss, hearing aid use, and dementia incidence, and in assessing the direction and strength of potential effects[3,4].

Jiang et al. (2023) [5] analysed the rate of dementia in users and non-users of hearing aids in the UK Biobank cohort. The study had an observational design, testing hearing loss and the use of hearing aids as exposures to modify the risk of dementia, and controlling for relevant confounders but unable to fully rule out selection effects. The authors found that those participants with hearing loss who used hearing aids at baseline did not exhibit a higher rate of dementia during follow-up compared to people without hearing loss (HR=1.04, 95% CI=0.98-1.10). Participants with hearing loss who did not use hearing aids at baseline did exhibit a higher rate of dementia when compared to people without hearing loss (HR=1.42, 95% CI=1.29-1.56). The interpretation was that among people with hearing loss, users of hearing aids were at lower risk of dementia than non-users, suggesting a potential role for hearing aid use in the prevention of dementia. The study received substantial coverage and led some to declare that the evidence for a causal role for hearing aids in the prevention of dementia was now "*as good as possible without randomised controlled trials*" [6].

In recent months, we tried and failed to reproduce the results by Jiang et al. using the same sample as the original study. First, we could not reproduce the numbers of missing observations as reported in the original paper – our numbers were considerably higher (**S1**). Second, we did not find the same proportions of dementia diagnoses in the different exposure groups as Jiang et al. (**S2-3**). Finally, we were unable to reproduce the main results – we found that before and after adjusting for confounders, hearing loss was significantly associated with the rate of dementia. Moreover, when comparing people with hearing loss using hearing aids to those without hearing loss, the rate of dementia was *greater* (HR=1.30, 95% CI=1.15-1.46) than when comparing people without hearing aids to those without hearing loss (HR=1.07, 95% CI=0.99-1.15). Our results differed from those of Jiang et al. also for Alzheimer's disease and vascular dementia. While we could not exactly recreate all covariates using the same coding as in the original paper – the authors did not describe some crucial steps in defining or recoding of those variables (**S4**) neither in the article nor upon requests – we performed multiple sensitivity analyses to confirm the robustness of our results, including varying the method to determine dementia and the dates of right-censoring. (**S5-7**). We wrote the code for data preparation and analysis anew because we could not access the code of the original paper. Our code is available at https://github.com/JuM24/hearing_dementia_UKB.

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Our results do not correspond well with hypotheses about the preventative potential of hearing aids. We also do not have a clear explanation for the direction of the effect. Selection bias inherent to the UK Biobank cohort[7], unadjusted confounding, measurement error, suboptimal operationalisation of the exposure, timing in the provision of hearing aids, and an unsystematic attempt at confounder adjustment[8] could be contributing factors.

Discrepancies such as those described in the present article could be more easily avoided if authors described in detail the definitions of new variables and transformations of existing variables, and published the code used to derive and analyse the data. We also stress that the work by Jiang et al. was not designed to assess causality. While another discovery of the co-occurrence of hearing aid use and a lower rate of dementia would be a reason for cautious optimism, claims of a definitive conclusion with hitherto published observational data are in our opinion premature. The association between hearing loss and dementia is complex and hearing aids may not be universally effective at reducing cognitive decline in all groups[9]. A causal role for the use of hearing aids in the risk of dementia is thus far from a settled issue.

We would welcome other teams with access to the data to check the discrepancies and Jiang et al. to respond to our observations. We encourage researchers, in the spirit of Open Science, to provide transparent accounts of their methodology by publishing their full code and any other relevant information to enhance reproducibility of research results.

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Supplementary appendix

S1: differences in data-cleaning.

The tables below display the discrepancies between our analysis and that by Jiang et al. (2023) [1] regarding numbers of observations removed due to various criteria (**left**) and the numbers of missing observations for each variable (**right**). In the left table, each row depicts the number of observations removed at each data-cleaning step (no shading) and the numbers of observations remaining in the sample prior to and after data cleaning (grey shading). The table on the right displays the numbers of missing observations for each variable that was used as a confounder in the analyses. Jiang et al. reported only the total number of missing observations across confounder variables. The numbers for our data cleaning are based on preparation for the default analysis (see **S5**).

Step	**Jiang et al.**	**Mur et al.**
Initial sample size	502,506	502,359
No hearing assessment	25,081	24,963
Dementia at baseline	283	217
Hearing aid use but no hearing loss		213
Missing confounder data	39,348	160,752
Final sample size	437,704	316,214
Variable	**Jiang et al.**	**Mur et al.***
Sex		0
Ethnicity		1,603
Education		5,016
Income		68,298
Deprivation		591
Smoking		1,773
Alcohol		418
Physical activity		17,886
BMI		2,494
Hypertension		194
Diabetes		0
CVD		942
APOE allele status		91,988
Total	39,438	160,752

*The total number of removed observations does not equal the sum of the missing observations across all variables, because one observation can be missing data for several variables.

S2: comparison of descriptive statistics between the two analyses. The numbers from our analyses in the third column are based on the data cleaning for the default analysis (**S5**).

Hearing	**Jiang et al. n (%)**	**Mur et al. n (%)**
Without hearing loss	325,882 (74)	236,239 (75)
Hearing loss without hearing aids	98,730 (23)	70,975 (22)
Hearing loss with hearing aids	13,092 (3)	9,000 (3)
Age at baseline, years		
40-49	102,116 (23)	79,483 (25)
50-59	167,409 (38)	108,211 (34)
60-69	168,179 (38)	127,147 (40)
>69		1,373 (1)
Sex		
Female	235,249 (54)	165,618 (52)
Male	202,455 (46)	150,596 (48)
Ethnicity		
White	416,131 (95)	300,796 (95)
Asian or Asian British	8,327 (2)	6,350 (2)
Black or Black British	6,135 (1)	4,537 (1)
Other	7,111 (2)	4,531 (1)
Income		
Level 1 (<£18,000)	97,236 (22)	67,132 (21)
Level 2 (£18,000-30,999)	106,630 (24)	79,658 (25)
Level 3 (£31,000-52,000)	113,589 (26)	83,989 (27)
Level 4 (>£52,000)	120,249 (27)	85,435 (27)
Townsend deprivation index quartile		
Q1 (least deprived)	112,182 (26)	82,171 (26)
Q2	110,060 (25)	80,658 (26)
Q3	109,650 (25)	79,911 (25)
Q4 (most deprived)	105,812 (24)	73,474 (23)
BMI, kg/m^2		
<18.5	2,209 (1)	1,619 (1)
>=18.5 to <25.0	143,832 (33)	105,757 (33)
>= 25.0 to <30.0	186,713 (43)	135,802 (43)
>= 30.0	104,950 (23)	73,036 (23)
Smoking status		
Never	239,864 (55)	174,151 (55)
Past	152,767 (35)	111,966 (35)
Current	45,073 (10)	30,097 (10)
Alcohol intake		
Daily or almost daily	91,308 (21)	67,765 (21)
3-4 times a week	103,199 (23)	77,135 (24)
1-2 times a week	113,241 (26)	81,696 (26)
Occasionally	96,732 (22)	67,696 (21)
Never	33,224 (8)	21,922 (7)
Diabetes	23,170 (5)	14,967 (5)
Hypertension	121,709 (28)	87,445 (28)
Cardiovascular disease (CVD)	25,262 (6)	16,446 (5)
APOE e4		
0	332,189 (76)	231,719 (73)
1	96,738 (22)	76,721 (24)
2	8,777 (2)	7,774 (2)

S3: Comparison of case numbers between groups for different sources of dementia diagnoses. We attempted replication using three different approaches of dementia ascertainment. In *manual search*, we used the codes as described by Jiang et al. and searched the inpatient and death records for matches. *FOs* refer to first outcomes, UK Biobank variables derived by taking the earliest diagnosis when using data from primary care, inpatient hospital records, death records, and self-reported medical conditions (category ID 1712). *ADOs* refer to algorithmically-defined outcomes, i.e., UK Biobank variables derived by using data from self-reported medical information, inpatient hospital records, and death records. It was developed by the UK Biobank Outcome Adjudication group for some health outcomes to maximise the positive predictive values.

Source of diagnosis	**Jiang et al.** n (%)		**Mur et al.** n (%)					
Outcome ascertainment			**Manual search**		**FOs**		**ADOs**	
Dementia	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**
Without HL	322,867 (75)	3,015 (52)	233,756 (74)	2,520 (63)	233,828 (75)	2,420 (64)	233,683 (75)	2,556 (64)
HL, without HA	96,085 (22)	2,645 (45)	69,899 (22)	1,098 (28)	69,921 (22)	1,052 (28)	69,864 (22)	1,111 (28)
HL with HA	12,922 (3)	170 (3)	8,694 (3)	314 (8)	8,697 (3)	304 (8)	8,687 (3)	313 (8)

S4: variables with insufficient information.

Hearing aids: it is unclear what the authors did with the participants without hearing loss who indicated to be using hearing aids (n=214). We removed those participants as indicated in **S1**.

Income: it is unclear how the authors dealt with responses that do not fall within the income categorisation schema as presented in the paper. The UK Biobank data showcase for field ID 738 during the baseline assessment visit indicates that 21,299 and 49,825 individuals responded with "do not know" or "prefer not to answer" to the question for this variable, respectively (https://biobank.ndph.ox.ac.uk/showcase/field.cgi?id=738). While the numbers of participants for the lowest two income categories as reported in Jiang et al. correspond roughly to the numbers reported by UK Biobank, the numbers of participants for the highest two income categories are higher in the paper by Jiang et al. than is reported by UK Biobank. For the highest income category (>£52,000)[6], UK Biobank reports a total of 109,166 observations, while Jiang et al. reported 120,249 observations. For the second highest income category (£31,000-£52,000), UK Biobank reports 86,243 observations, while Jiang et al. reported 113,589 observations. It is unclear whether the 21,999 and 49,825 participants noted above were somehow recoded, and if so, how.

Ethnicity: is it unclear how the authors re-classified the variable at field ID 21000. We included classes 1, 1001, 1002, 1003 under "white"; classes 3, 3001, 3002, 3003, 3004, 5 under "Asian"; classes 4, 4003, 4001, 4002 under "black"; classes 2, 6, 2001, 2002, 2003, 2004, 6 under "other".

Education: Jiang et al. used field IDs 6138 ("qualifications") and 845 ("age completed full time education"), but it is unclear how these were used to derive "years of education" used in their analyses. We used only field ID 6138 and classified it as did Stevenson et al. (2021) [2].

Physical activity: it is unclear how Jiang et al. categorised those participants without information on IPAQ groups (field ID 22032). The authors write that they used the number of moderate activity days/week (field 884 ID), but no further details are given. We used https://biobank.ndph.ox.ac.uk/showcase/refer.cgi?id=540 to inform our choice; we set MET to 0, 1, and 2 for those reporting 0-2, 3-6, and 7 moderate activity days/week, respectively.

Dementia diagnosis: the UK Biobank Outcome Adjudication Group released codes that Jiang et al. reported to use. However, the authors did not seem to use all of the codes provided by UK Biobank (https://biobank.ndph.ox.ac.uk/showcase/refer.cgi?id=460), e.g., ICD9 code 331. Moreover, they seemingly used these codes to search the inpatient record and it is unclear whether they also used death records. Variables for dementias that use both sources are also available from UK Biobank (https://biobank.ndph.ox.ac.uk/showcase/label.cgi?id=47; field ID 42018 for all-cause dementia, 42021 for Alzheimer's disease, and 42022 for vascular dementia).

Follow-up: follow-up was calculated as the time difference between the date of baseline assessment and the date of either death, diagnosis of dementia, or right-censoring due to data ascertainment, whichever came first. However, this raises a few questions:

- As the authors noted, right-censoring differs between the three nations (England, Scotland, Wales) and each participant may have (inpatient and primary care) records in multiple nations at different points in time. We used the data provider of the latest inpatient diagnosis for our analysis (which left 54,411 participants without a date of right-censoring) and supplemented it with the data provider of the latest GP diagnosis (which left 30,233 participants without a date of right-censoring).

[6] Jiang et al. combined the two highest income categories ("£52,000-£100,000" and ">£100,000").

- The above approach excludes individuals without any inpatient or primary care records, and it is unclear how Jiang et al. determined the dates of right-censoring for those individuals. We set the date of right-censoring for those individuals at the date of the earliest of the three data providers (Patient Episode Database for Wales; 28.02.2018). This left us with 91 and 835 participants that were diagnosed with dementia[7] or that died after their dates of right-censoring, respectively. For those participants, we shifted their censoring dates to their dates of dementia or – if they died – death. That way, we prevented those individuals from being right-censored before their diagnoses of dementia and/or death.

[7] When using algorithmically-defined outcomes for ascertainment of dementia as per the default analysis as presented in **S5**.

S5: Description of the default analysis and the sensitivity analyses. The bullet points for the default analysis describes our choice for dealing with that variable in the default analysis. The bullet points for the sensitivity analyses describe the variation of that variable that was used for each sensitivity analysis. For example, if a sensitivity analysis (results presented in **S6-7**) is labelled 2-3a, it means that prior to analysis, participants with no censoring date were removed (2) and that those with dementia or death dates after right-censoring were removed (3a); all other steps in this example would be done as per default.

Default analysis:

- Dementia diagnosis: use algorithmically-defined outcomes (ADOs).
- Hearing aids: recode missing observations as no hearing loss.
- Covariates: remove observations with missing data for any covariate prior to adjusted and unadjusted analyses.
- Follow-up:
    - Define source nation (England/Scotland/Wales) based on source of most recent medical record.
    - Prioritise inpatient records (category ID 2000); for those without inpatient records use GP records (field ID 42040).
    - For those missing both inpatient and GP records, set follow-up date to the earliest date of right-censoring (Wales, 28.02.2018).
- Dementia and/or death dates:
    - For those that were diagnosed with dementia after their date of right-censoring, shift the date of right-censoring to the date of dementia diagnosis.
    - For those that died after their date of right-censoring (but who were not diagnosed with dementia), shift the date of right-censoring to the date of death.

Sensitivity analyses:

1. Follow-up calculation:
   Use only inpatient records to determine right-censoring.
2. Missing censoring date
    a. Remove.
    b. Use the most common date (England, 31.10.2022).
3. Dementia and/or death dates
    a. Remove those with dementia/death after right-censoring.
    b. Set to control those with dementia/death after right-censoring.
4. Dementia ascertainment:
    a. Use the ICD codes used by Jiang et al. and search the inpatient records.
    b. Use first occurrences.
5. Covariates:
   Only remove missing observations of covariates that are used in the present model.

S6: Results for analyses predicting dementia as the outcome, with hearing loss as the exposure, expressed as hazards ratios (HR), using Cox proportional hazards models. The tables contain the results for two groups: those participants who wore hearing aids at baseline and those who did not, in each analysis compared to those without hearing loss. Each analysis was done both unadjusted and fully adjusted using confounders as per Jiang et al. The rows for the fully adjusted analyses for sensitivity analyses 5 are greyed out because partial removal of observations by selection of covariates made no sense in the context of full adjustment (see **S5**). Due to the similarity of effect sizes across sensitivity analyses for all-cause dementia (**A**), fewer sensitivity analyses were run for Alzheimer's disease (**B**) and vascular dementia (**C**) than for all-cause dementia.

A		**Simple adjustment**		**Full adjustment**	
Analysis	**N**	**Hearing aid (95% CI)**	**No hearing aid (95% CI)**	**Hearing aid (95% CI)**	**No hearing aid (95% CI)**
Default	316,214	1.49 (1.32-1.67)	1.12 (1.04-1.20)	1.30 (1.15-1.46)	1.07 (0.99-1.15)
1	316,214	1.47 (1.31-1.66)	1.11 (1.03-1.19)	1.29 (1.15-1.46)	1.06 (0.99-1.14)
2a	295,779	1.49 (1.32-1.68)	1.12 (1.04-1.20)	1.30 (1.15-1.47)	1.07 (0.99-1.15)
2b	316,214	1.51 (1.34-1.70)	1.13 (1.05-1.21)	1.31 (1.16-1.48)	1.08 (1.00-1.16)
3a	316,162	1.50 (1.33-1.68)	1.12 (1.04-1.20)	1.31 (1.16-1.48)	1.07 (1.00-1.15)
3b	316,214	1.50 (1.33-1.68)	1.12 (1.04-1.20)	1.31 (1.16-1.48)	1.07 (1.00-1.15)
4a	316,281	1.50 (1.33-1.69)	1.11 (1.04-1.20)	1.31 (1.17-1.47)	1.07 (0.99-1.15)
4b	316,222	1.49 (1.33-1.69)	1.11 (1.03-1.19)	1.31 (1.16-1.47)	1.06 (0.99-1.14)
1-2a	279,362	1.48 (1.31-1.66)	1.11 (1.03-1.19)	1.30 (1.15-1.46)	1.06 (0.99-1.14)
1-2a-3a	279,315	1.49 (1.32-1.67)	1.12 (1.04-1.20)	1.30 (1.16-1.47)	1.07 (0.99-1.15)
1-2a-3a-4a	279,381	1.50 (1.33-1.69)	1.12 (1.04-1.20)	1.32 (1.17-1.49)	1.07 (1.00-1.15)
5	476,966	1.44 (1.31-1.57)	1.13 (1.08-1.20)		
1-5	476,966	1.43 (1.30-1.56)	1.13 (1.07-1.19)		
2a-5	448,222	1.44 (1.32-1.57)	1.14 (1.08-1.20)		
2b-5	476,966	1.46 (1.34-1.60)	1.15 (1.09-1.21)		
3a-5	476,879	1.44 (1.32-1.57)	1.14 (1.08-1.19)		
3b-5	479,966	1.44 (1.32-1.57)	1.14 (1.08-1.20)		
4a-5	477,079	1.44 (1.32-1.57)	1.14 (1.08-1.20)		
4b-5	476,980	1.44 (1.31-1.57)	1.14 (1.08-1.20)		

B		**Simple adjustment**		**Full adjustment**	
Analysis	**N**	**Hearing aid (95% CI)**	**No hearing aid (95% CI)**	**Hearing aid (95% CI)**	**No hearing aid (95% CI)**
Default	316,214	1.16 (0.95-1.42)	1.10 (0.98-1.22)	1.07 (0.87-1.31)	1.09 (0.98-1.22)
1	316,214	1.15 (0.94-1.40)	1.09 (0.98-1.22)	1.06 (0.87-1.30)	1.09 (0.97-1.21)
1-2a	279,362	1.15 (0.94-1.41)	1.09 (0.98-1.22)	1.07 (0.87-1.31)	1.09 (0.97-1.22)
1-2a-3a	279,343	1.17 (0.95-1.43)	1.09 (0.98-1.22)	1.08 (0.88-1.33)	1.09 (0.97-1.22)
1-2a-3a-4a	279,410	1.18 (0.96-1.43)	1.09 (0.98-1.22)	1.10 (0.90-1.34)	1.09 (0.98-1.22)
5	476,966	1.21 (1.05-1.40)	1.10 (1.01-1.19)		

C		**Simple adjustment**		**Full adjustment**	
Analysis	**N**	**Hearing aid (95% CI)**	**No hearing aid (95% CI)**	**Hearing aid (95% CI)**	**No hearing aid (95% CI)**
Default	316,214	1.73 (1.37-2.18)	1.18 (1.01-1.37)	1.35 (1.07-1.71)	1.06 (0.91-1.23)
1	316,214	1.71 (1.36-2.16)	1.17 (1.01-1.36)	1.35 (1.06-1.70)	1.05 (0.91-1.23)
1-2a	299,362	1.71 (1.36-2.16)	1.16 (1.00-1.35)	1.35 (1.06-1.70)	1.04 (0.90-1.22)
1-2a-3a	279,351	1.71 (1.36-2.17)	1.16 (1.00-1.35)	1.35 (1.06-1.71)	1.05 (0.90-1.22)
1-2a-3a-4a	279,420	1.73 (1.37-2.19)	1.16 (0.99-1.35)	1.36 (1.07-1.73)	1.04 (0.89-1.22)
5	476,966	1.63 (1.37-1.94)	1.20 (1.08-1.34)		

S7: Results for analyses predicting dementia as the outcome, with hearing loss as the exposure, expressed as the risk ratio (RR), using logistic regression. The information in the individual tables and columns is analogous to results presented as HRs in **S6**.

A		**Simple adjustment**		**Full adjustment**	
Analysis	**N**	**Hearing aid (95% CI)**	**No hearing aid (95% CI)**	**Hearing aid (95% CI)**	**No hearing aid (95% CI)**
Default	316,214	1.51 (1.34-1.70)	1.08 (1.01-1.16)	1.30 (1.16-1.46)	1.02 (0.95-1.09)
1	316,214	1.51 (1.34-1.70)	1.08 (1.01-1.16)	1.30 (1.16-1.46)	1.02 (0.95-1.09)
2a	295,779	1.49 (1.32-1.67)	1.07 (1.00-1.15)	1.29 (1.15-1.45)	1.01 (0.95-1.09)
2b	316,214	1.51 (1.34-1.70)	1.08 (1.01-1.16)	1.30 (1.16-1.46)	1.02 (0.95-1.09)
3a	316,162	1.52 (1.35-1.71)	1.09 (1.01-1.17)	1.31 (1.16-1.47)	1.02 (0.96-1.10)
3b	316,214	1.52 (1.35-1.71)	1.09 (1.01-1.17)	1.31 (1.16-1.47)	1.03 (0.96-1.10)
4a	316,281	1.52 (1.36-1.71)	1.08 (1.01-1.16)	1.32 (1.16-1.48)	1.02 (0.95-1.09)
4b	316,222	1.52 (1.35-1.71)	1.07 (1.01-1.15)	1.31 (1.16-1.48)	1.01 (0.94-1.09)
1-2a	279,362	1.47 (1.31-1.65)	1.07 (1.00-1.15)	1.28 (1.14-1.44)	1.01 (0.94-1.08)
1-2a-3a	279,315	1.48 (1.31-1.66)	1.07 (1.00-1.15)	1.29 (1.15-1.45)	1.01 (0.94-1.09)
1-2a-3a-4a	279,381	1.49 (1.33-1.68)	1.07 (1.00-1.15)	1.31 (1.16-1.47)	1.02 (0.95-1.09)
5	476,966	1.47 (1.35-1.60)	1.09 (1.03-1.15)		
1-5	476,966	1.47 (1.35-1.60)	1.09 (1.03-1.15)		
2a-5	448,222	1.45 (1.33-1.58)	1.08 (1.03-1.14)		
2b-5	476,966	1.47 (1.35-1.60)	1.09 (1.03-1.15)		
3a-5	476,879	1.47 (1.35-1.61)	1.09 (1.04-1.15)		
3b-5	476,966	1.47 (1.35-1.61)	1.09 (1.04-1.15)		
4a-5	477,079	1.47 (1.35-1.61)	1.09 (1.03-1.15)		
4b-5	476,980	1.47 (1.35-1.61)	1.09 (1.04-1.15)		

B		**Simple adjustment**		**Full adjustment**	
Analysis	**N**	**Hearing aid (95% CI)**	**No hearing aid (95% CI)**	**Hearing aid (95% CI)**	**No hearing aid (95% CI)**
Default	316,214	1.17 (0.96-1.43)	1.06 (0.96-1.18)	1.06 (0.87-1.30)	1.04 (0.93-1.16)
1	316,214	1.17 (0.96-1.43)	1.06 (0.95-1.18)	1.06 (0.87-1.30)	1.04 (0.93-1.16)
1-2a	279,362	1.15 (0.94-1.40)	1.04 (0.93-1.16)	1.05 (0.86-1.28)	1.03 (0.92-1.15)
1-2a-3a	279,343	1.16 (0.95-1.42)	1.05 (0.94-1.17)	1.06 (0.87-1.30)	1.03 (0.92-1.15)
1-2a-3a-4a	279,410	1.17 (0.96-1.42)	1.05 (0.94-1.17)	1.08 (0.88-1.31)	1.03 (0.92-1.15)
5	476,966	1.24 (1.08-1.43)	1.05 (0.97-1.14)		

C		**Simple adjustment**		**Full adjustment**	
Analysis	**N**	**Hearing aid (95% CI)**	**No hearing aid (95% CI)**	**Hearing aid (95% CI)**	**No hearing aid (95% CI)**
1	316,214	1.75 (1.39-2.20)	1.14 (0.98-1.32)	1.35 (1.07-1.70)	1.01 (0.87-1.17)
1-2a	279,362	1.70 (1.35-2.14)	1.11 (0.96-1.29)	1.33 (1.05-1.68)	0.99 (0.85-1.15)
1-2a-3a	279,351	1.70 (1.35-2.15)	1.12 (0.96-1.30)	1.33 (1.05-1.68)	0.99 (0.85-1.15)
1-2a-3a-4a	279,420	1.72 (1.36-2.17)	1.11 (0.96-1.29)	1.34 (1.06-1.70)	0.99 (0.85-1.15)
5	476,966	1.67 (1.40-1.98)	1.15 (1.03-1.28)		

Supplementary references

1. Jiang F, Mishra SR, Shrestha N, et al. Association between hearing aid use and all-cause and cause-specific dementia: an analysis of the UK Biobank cohort. *Lancet Public Health* 2023.
2. Stevenson JS, Clifton L, Kuzma E, Littlejohns TJ. Speech-in-noise hearing impairment is associated with an increased risk of incident dementia in 82,039 UK Biobank participants. *Alzheimers Dement* 2022; **18**(3): 445-56.