Hearing Impairment and Fertility: Longitudinal Evidence from the World's Largest Hearing Study

Abstract

Hearing loss (HL) is one of the most common functional limitations - according to WHO it affected 466 million people worldwide in 2018, and this number is projected to almost double by 2050. Having a family may be particularly important for this group; their health is according to earlier work more affected by the presence of a family than the normal hearing. We employ data from the world's largest population level longitudinal survey with objective hearing assessments (HUNT; N=50,462). We find that fertility is considerably lower for both women and men with HL and this difference is greater among more recent cohorts: Among men born 1970, normal hearing individuals have 47% more children than in those with a severe HL, in women the difference is 17%. Childhood hearing loss is more strongly linked to fertility decline than adult HL – and this effect is more pronounced among women.

Motivation

Norway has experienced rapid fertility changes in recent years; the Total Fertility Rate (TFR) has fallen over the last decade (from 1.98 children in 2009 to 1.56 children per woman in 2018), while childlessness has risen (reaching about a quarter of men and one in six women at the age of 40) (Statistics Norway 2019). These changes coincide with a rise in hearing loss (HL), mainly following population ageing since HL prevalence is greater at older ages (Homans et al. 2017). The prevalence of hearing loss in Norway based on the WHO definition has been estimated to about 19% (Borchgrevink, Tambs and Hoffman 2005). Family forms could have particular importance to the hearing impaired; the relative mortality risk from being childless or single is particularly high for those subject to HL compared to the normal hearing population (Engdahl, Idstad and Skirbekk 2019).

The current study aims to analyse how hearing impairment relates to family size for successive male and female birth cohorts based on unique data from the world's largest longitudinal collection of hearing impairment assessments – the Norwegian HUNT (The Nord-Trøndelag Health Study) survey, and key factors that mediate this relationship. The combined changes in objective measures of hearing and fertility change across birth cohorts has, to our knowledge, not yet been analysed using large longitudinal population level data incorporating objective hearing measures.

Prevalence and trends in hearing loss

Hearing (i.e., auditory acuity) is a central sensory dimension which can be measured with high reliability and validity using harmonized assessment tools (Engdahl et al. 2005). Hearing impairment is very common, global estimates suggest the number of individuals was 466 million in 2018 and the number is projected to increase to around 900 million by 2050 - primarily following population ageing (Stevens et al. 2011; World Health Organization 2019).

Family formation, contraception and hearing status

There has been a lack of studies that includes both information on the number of children and reliable longitudinal data on hearing status. Existing studies suggest that fertility outcomes tend to differ between the hearing impaired and those with normal hearing, where the hearing impaired have lower fertility. In Sweden, a study of two counties revealed that cohort fertility was lower among the deaf (1.2 children per woman in Värmland and 1.3 in Närke) than the general population at large in these counties (which was around 1.6 children per woman). This was driven by greater nulliparous shares: among deaf women in Värmland and Närke the share who were childless were 44% and 39%, more

than twice the levels of childlessness observed among hearing women (Carlsson, Danermark and Borg 2004).

Our study

This study investigate whether those with a particular hearing loss prefer fewer children. If so, we will examine if this is mediated by marriage, has changed over time, and depends on whether the hearing loss was present in childhood or not. A major advantage of our study is that we do not rely on self-assessed hearing. Most existing datasets use subjective hearing impairment, which is often a difficult measure with low levels of comparability and harmonization levels. Subjective measures can be linked to how people in terms of their relative hearing compared to peers and social group in a given contexts. Subjective measures of hearing could be poorly related to actual hearing, but rather influenced by peer groups, contextual factors, personality and optimisms as well as socioeconomic standards (Noble 2013).

Data

Study population

Adult hearing cohort. The Nord-Trøndelag Hearing Loss Study (NTHLS) was conducted in Norway from 1996 to 1998 and was part of the Nord-Trøndelag Health Study (HUNT 2), a large, general health-screening study for the entire adult population of Nord- Trøndelag County. In the NTHLS, 17 of the 24 municipalities in the county participated in the hearing examination including pure-tone audiometry. The subjects ranged in age from 20 to 101 years (median = 48.0 years, mean = 50.2, standard deviation = 17.0). The participation rate was 67% in 16 of the 17 municipalities and 41% in one municipality where the population was invited to the hearing examination only after the main HUNT 2 survey was completed. Audiometric data were collected from 50,462 participants, along with detailed health, socioeconomic and demographic information (Engdahl et al. 2005).

Childhood hearing cohort. The school hearing investigation in Nord-Trøndelag, Norway (SHINT) (Aarhus, Homoe and Engdahl 2019). In short, nearly all 7, 10 and 13 years old school children in the entire Nord-Trøndelag County underwent screening with pure-tone audiometry from 1954 to 1986. Children with hearing loss at the screening (thresholds ≥ 20 decibel hearing level (dB HL) at three or more frequencies, or ≥ 30 dB HL at one or more frequencies) were invited to an otorhinolaryngologist (ORL) examination. From 1954 to 1962, average attendance at the ORL examinations for children with positive screening was 97 % (Fabritius 1968), and we have no reason to believe that this high level of attendance changed later. Altogether, 10,269 children took part in the ORL examination, in which 5547 also took part in HUNT and included in this study. Data from NTHLS and SHINT were

linked with data from the National Population Registry and compiled by Statistics Norway using the unique 11-digit personal identification code assigned to all Norwegian residents.

Study variables

Hearing loss

Air conduction hearing threshold levels were obtained by pure-tone audiometry at eight frequencies from 0.25 to 8 kHz in accordance with ISO 8253–1 (1989) as described in an earlier publication in NTHLS (Engdahl et al. 2005) and in SHINT according to the Norwegian standards at the time (Aarhus et al. 2019). Hearing thresholds were defined as pure-tone average (PTA) of four frequencies (0.5, 1, 2, and 4 kHz) in the better ear (adult) and in the worst ear (children) measured in dB HL. Hearing loss was defined as PTA greater than 25 dB HL. SHINT included several follow-ups, and data from the last audiometric test was used including only permanent hearing losses diagnosed with either sensorineural hearing loss, otosclerosis, chronic suppurative otitis media, or hearing loss after recurrent acute otitis media. Subjects with diagnosis yielding temporary hearing loss such as secretory- and acute otitis media was regarded as normal hearing in childhood with hearing threshold equal to zero. We further considered all subjects born between 1941 and 1977 (being in primary school age during SHINT) and not registered with a hearing loss in SHINT as normal hearing in childhood.

Age adjusted adult hearing thresholds in adulthood was calculated separately for each sex by the residuals from regressing PTA on age modelled as a restricted cubic spline with five knots with default knot locations. Hearing loss increases by age in an accelerating non-linear fashion. Restricted cubic splines were preferred over quadratic polynomials for fitting this non-linear relation because their flexibility to fit the data also at the ends.

Findings

Among the 50,462 subjects in the adult hearing cohort, 9008 subjects had an adult hearing loss (Figure 1 and Table 1).

Adult hearing loss decreased the expected number of children ever born by 8% in men and 12% in women (Table 2). In women 39% of the effect was mediated through marriage with a substantial direct effect of hearing loss on the expected number of children. Nearly all the effect (93%) was mediated through marriage in men. Number of children predicted at mean age were 2.17 children for HL vs 2.31 children for normal hearing ever born in men and 2.18 children for HL vs 2.50 children for normal hearing in women. Controlling for confounders diminished the effect in men while the effects seem to remain in women.

Similar results were found for being childless, although the effects in women and men were less different. Adult hearing loss increased the likelihood of being childless by 65% in men and 80% in

women (Table 3). The proportion of the effect mediated through marriage was 68% in men and 46% in women with a substantial direct effect of hearing loss on being childless in both sexes. Proportions of childlessness predicted at mean age were 19% for HI vs 12% in normal hearing in men and 11% for HL vs 6% for normal hearing in women. Again, controlling for confounders significantly reduced the effects in men more than in women.

Among the 50,022 subjects in the childhood hearing loss cohort, 554 subjects had a childhood hearing loss (Figure 1 and Table 4).

Childhood hearing loss decreased the expected number of children ever born by 19% in men and 9% in women (Table 5). Number of children predicted at mean age were 1.71 children for childhood HI vs 2.11 children for normal hearing ever born in men and 2.12 children for HL vs 2.33 children for normal hearing in women. Thirty three percent of the effect was mediated by marriage in men and 38% in women. Controlling for confounders did not alter the effect significantly. Childhood hearing loss increased the likelihood of being childless by 92% in men and 64% in women (Table 6) with proportions mediated through marriage similar to what was found for the number of children. Proportions of childlessness predicted at mean age were 27% for HL vs 14% in normal hearing in men and 11% for HL vs 6% for normal hearing in women. Again, controlling for confounders significantly reduced the effects in men more than in women.

Combining the adult and childhood hearing cohorts resulted in 27,691 participants among which 321 had a hearing loss in childhood and 926 in adulthood (Figure 1). To explore if the effect of adult hearing on the number of children ever born depends on hearing ability in childhood, we estimated the interaction between adult hearing threshold and childhood hearing loss. A significant interaction was found for men ($p=0.010$), but not in women ($p=0.060$) such as the effect of the adult hearing threshold on the expected number of children ever born was higher in men with a hearing loss present in childhood than without. The prediction from the interaction models are graphed in Figure 2.

Finally, to explore if the effects has changed over time, we estimated the interaction between age adjusted hearing thresholds in adulthood and birth year. A significant interaction was found in men ($p<0.0001$), but not in women ($p=0.516$) (Figure 3a and 3b). The figure also indicates the general decrease in the expected number of children in the recent cohorts. Among men born 1970, normal hearing have 47% more children than in those with a severe hearing loss exceeding 80 dB (2.06 vs. 1.40 children ever born). The corresponding number in women born 1970 are 17% (2.37 vs. 2.02). We also estimated interaction between childhood hearing loss and birth year, but there were no significant interactions neither in men ($p=0.798$) nor in women ($p=0.390$).

Discussion

Our results reveal that individuals with hearing impairment have fewer children than their normal hearing peers. Hearing impairment has a stronger negative relation to reproductive outcomes among later born cohorts. Our findings reveal that those who have HL early in life see more negative fertility outcomes than those who experience HL later in life. The negative link between childhood hearing and

Common policy responses to hearing challenges are focused on technical issues (raising the use of hearing aids and implants), or to measures to reduce risks of HL particularly by limiting infectious diseases, noise exposures, medicines and congenital conditions related to hearing loss. Others have focused on promoting social inclusion of people with disabilities, including people with hearing loss and deafness, for example, through workplace or community-based rehabilitation networks and programmes. However, the family aspect has not been sufficiently addressed, even if it can be of crucial importance for the wellbeing and health of the hearing impaired population. Addressing how one can best improve the lives of the hearing impaired given that greater shares will not have partners or children should be a part of the policy agenda. As populations are ageing causing hearing loss to increase, the relationship to family forms, including whether one has children and partners, ma increase in importance in countries all over the world.

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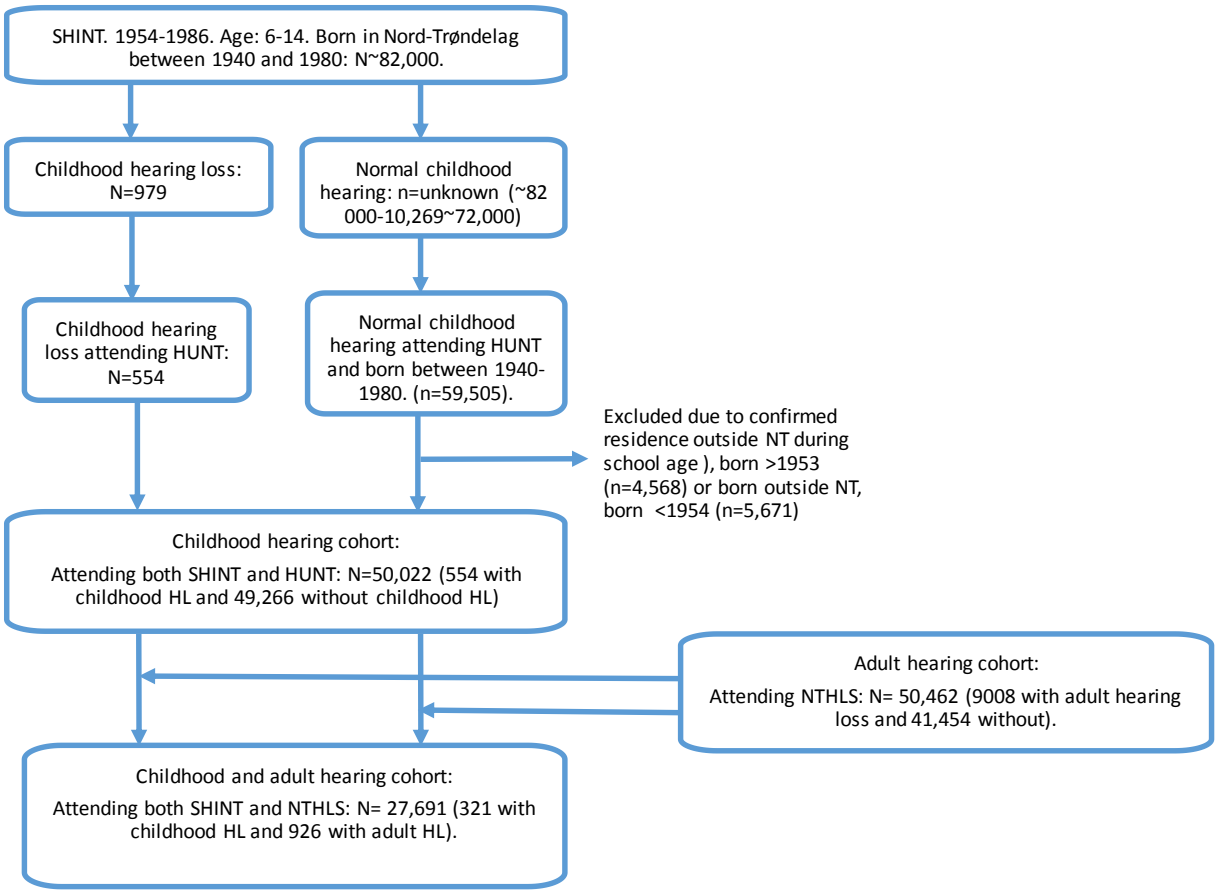
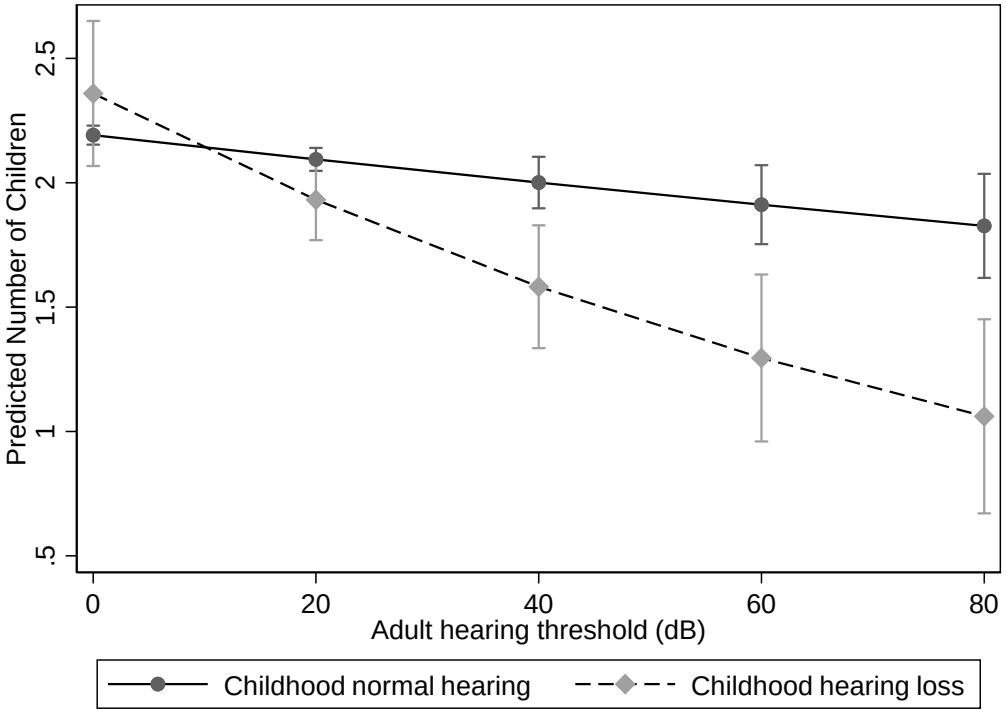
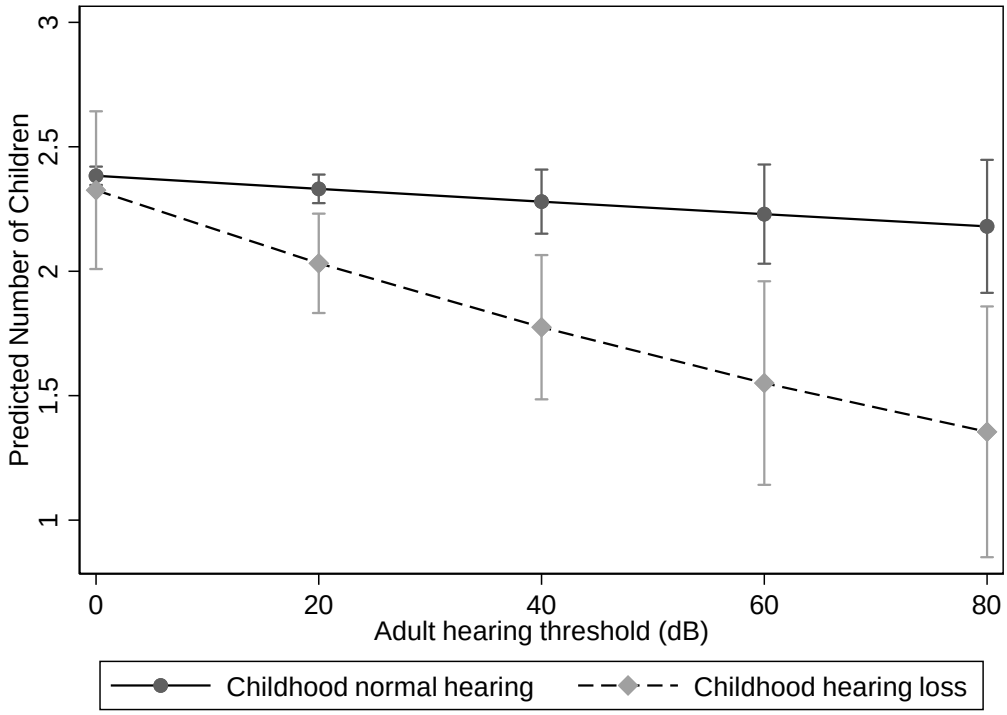


Figure 1. Flow chart of participants of the Nord-Trøndelag Hearing Loss Study (NTHLS) and the School hearing investigation in Nord-Trøndelag (SHINT).

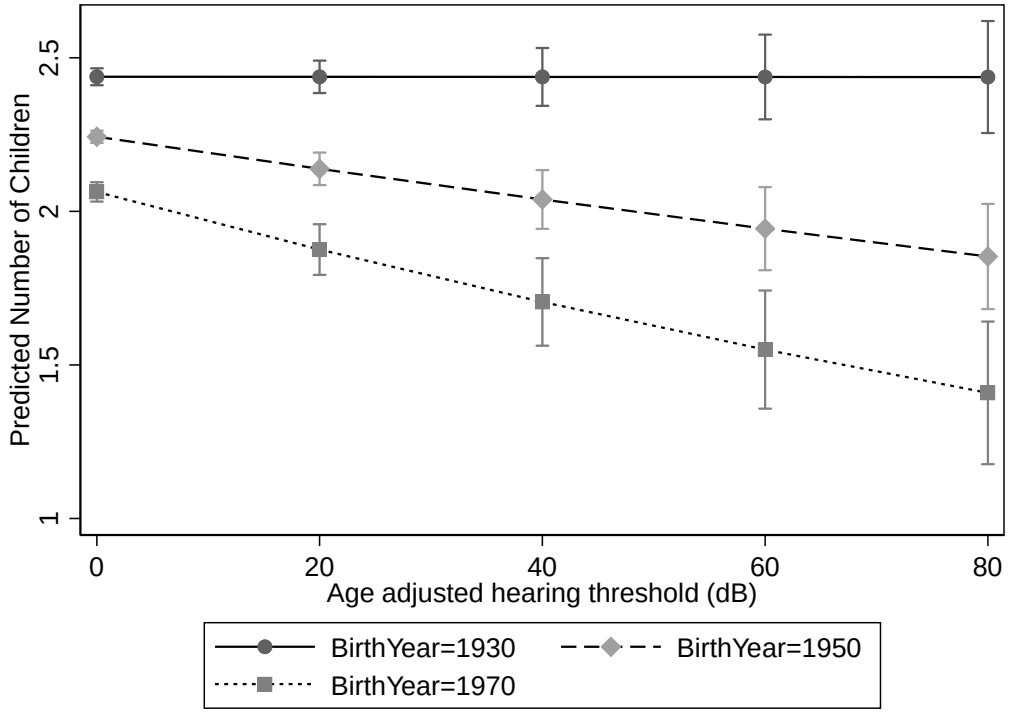


a) Men

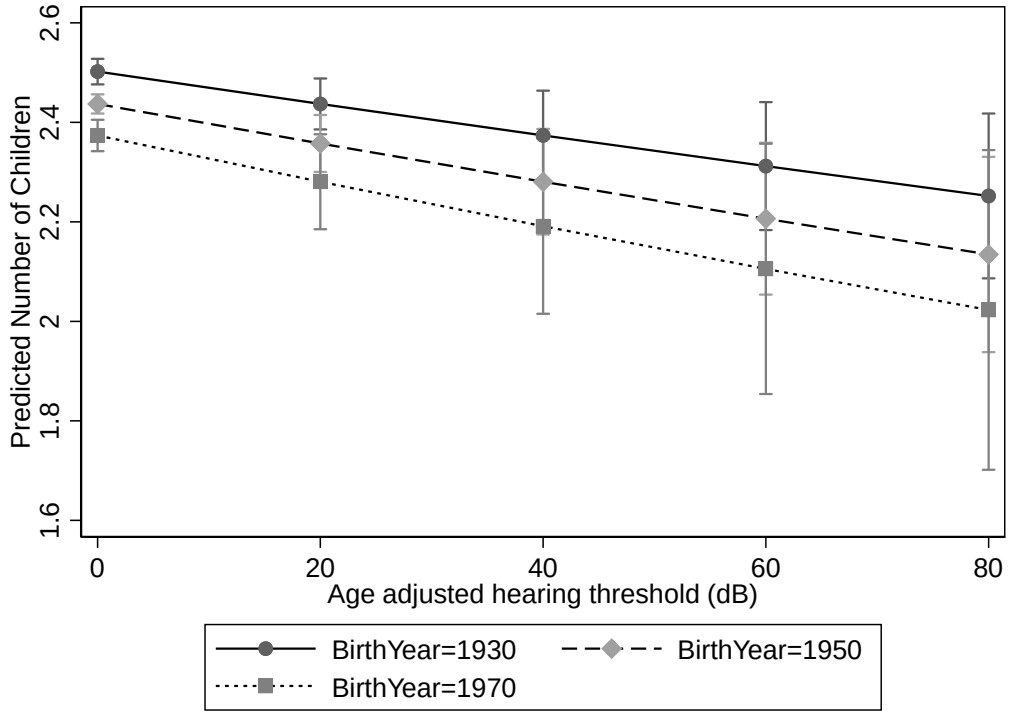


b) Women

Figures 2a and 2b. Number of children ever born for men and b) women by childhood hearing loss and adult hearing threshold (dB).



a) Men



b) Women

Figures 3a and 3b. Number of children ever born for men and women by birth cohort and age adjusted hearing threshold (dB).

Table 1. Descriptive statistics of the adult hearing cohort.

				Adult hearing loss	
			All subjects, n(%)	No, n(%)	Yes, n(%)
	Birth Cohort	Variable	n=50,462	n=41,454	n=9,008
Male	<1940	Age[a], mean (SD)	68.1 (8.0)	64.5 (6.6)	71.6 (7.8)
		Number of children[b] (SD)	2.5 (1.6)	2.6 (1.5)	2.4 (1.7)
		Childless[b]	1,187 (13.8)	471 (11.2)	716 (16.4)
		Married[c]	6,724 (78.3)	3,468 (82.3)	3,256 (74.5)
	1940-1959	Age[a], mean (SD)	46.0 (5.3)	45.8 (5.3)	49.2 (4.7)
		Number of children[b] (SD)	2.2 (1.2)	2.3 (1.2)	2.2 (1.3)
		Childless[b]	982 (10.6)	902 (10.3)	80 (14.8)
		Married[c]	7,565 (81.4)	7,136 (81.5)	429 (79.6)
	>1959	Age[a], mean (SD)	28.7 (4.9)	28.7 (4.9)	30.6 (4.3)
		Number of children[b] (SD)	2.0 (1.2)	2.0 (1.2)	1.6 (1.4)
		Childless[b]	907 (15.8)	885 (15.6)	22 (31.9)
		Married[c]	3,572 (62.2)	3,535 (62.3)	37 (53.6)
Female	<1940	Age[a], mean (SD)	68.9 (8.4)	65.6 (6.9)	74.5 (7.7)
		Number of children[b] (SD)	2.6 (1.6)	2.7 (1.5)	2.3 (1.6)
		Childless[b]	1,110 (11.3)	532 (8.6)	578 (15.8)
		Married[c]	5,841 (59.2)	4,202 (67.7)	1,639 (44.9)
	1940-1959	Age[a], mean (SD)	45.9 (5.4)	45.8 (5.4)	48.5 (5.1)
		Number of children[b] (SD)	2.4 (1.1)	2.4 (1.1)	2.4 (1.3)
		Childless[b]	501 (4.9)	472 (4.7)	29 (9.2)
		Married[c]	8,406 (81.9)	8,169 (82.1)	237 (75.2)
	>1959	Age[a], mean (SD)	28.5 (5.0)	28.5 (5.0)	29.4 (4.9)
		Number of children[b] (SD)	2.3 (1.0)	2.3 (1.0)	2.0 (1.2)
		Childless[b]	443 (6.6)	432 (6.5)	11 (18.0)
		Married[c]	4,546 (67.7)	4,507 (67.7)	39 (63.9)

[a] Age at hearing test in 1996-1998

[b] Fertility observed in 2014

[c] Marital status = 'married' at least once in the period from 1996 to 2014

Table 2. Adult hearing loss and the number of children ever born. Mediation due to marriage.

		IRR	[95% CI]	Proportion mediated
Model 1	Male	0.92	0.90-0.95	0.93

	Female	0.88	0.85-0.90	0.39
Model 2	Male	0.97	0.94-0.99	0.89
	Female	0.86	0.84-0.89	0.30

Model 1 - adjusted for age

Model 2 - adjusted for age, occupational noise exposure, education and income

Table 3. Adult hearing loss and being childless. Mediation due to marriage.

		RR	[95% CI]	Proportion mediated
Model 1	Male	1.65	1.47-1.85	0.68
	Female	1.80	1.59-2.03	0.46
Model 2	Male	1.18	1.05-1.32	0.87
	Female	1.74	1.54-1.96	0.43

Model 1 - adjusted for age

Model 2 - adjusted for age, occupational noise exposure, education and income

Table 4. Descriptive statistics of the childhood hearing cohort.

			Childhood hearing loss	
	Variable	All subjects, n(%) n=50,022	No, n(%) n=49,468	Yes, n(%) n=554
Male	Age[a], mean (SD)	56.7 (10.4)	56.7 (10.4)	56.7 (8.8)
	Number of children[b] (SD)	2.1 (1.3)	2.1 (1.3)	1.7 (1.3)
	Childless[b]	3,686 (14.6)	3,599 (14.4)	87 (27.4)
	Married[c]	17,554 (69.4)	17,360 (69.5)	194 (61.0)
Female	Age[a], mean (SD)	55.8 (10.7)	55.8 (10.7)	57.7 (9.2)
	Number of children[b] (SD)	2.3 (1.1)	2.3 (1.1)	2.1 (1.2)
	Childless[b]	1,720 (7.0)	1,694 (6.9)	26 (11.0)
	Married[c]	17,849 (72.2)	17,695 (72.3)	154 (65.3)

[a] Age in 2014

[b] Fertility observed in 2014

[c] Marital status = 'married' at least once in the period from 1996 to 2014

Table 5. Childhood hearing loss and the number of children ever born. Mediation due to marriage.

		IRR	[95% CI]	Proportion mediated
Model 1	Male	0.81	0.73-0.89	0.34
	Female	0.90	0.82-0.99	0.38
Model 2	Male	0.82	0.75-0.91	0.29
	Female	0.91	0.83-0.99	0.38

Model 1 - adjusted for age

Model 2 - adjusted for age, occupational noise exposure, education and income

Table 6. Childhood hearing loss and being childless. Mediation due to marriage.

		RR	[95% CI]	Proportion mediated
Model 1	Male	1.92	1.51-2.43	0.36
	Female	1.64	1.09-2.47	0.44
Model 2	Male	1.73	1.36-2.20	0.33
	Female	1.62	1.08-2.44	0.43

Model 1 - adjusted for age

Model 2 - adjusted for age, occupational noise exposure, education and income