Social Science & Medicine 220 (2019) 219–225

Contents lists available at ScienceDirect

Social Science & Medicine

journal homepage: www.elsevier.com/locate/socscimed

Hearing loss, family status and mortality – Findings from the HUNT study, Norway

Bo Engdahl[a,*], Mariann Idstad[a], Vegard Skirbekk[a,b]

[a] Norwegian Institute of Public Health, Postbox 4404 Nydalen, N-0403, Oslo, Norway
[b] Mailman School of Public Health, Columbia University, USA

ARTICLE INFO

Keywords:
Hearing loss
Marriage
Childbearing
Mortality
Conjugal support
Intergenerational support

ABSTRACT

Hearing loss as well as being single has been associated with an increased risk of all-cause mortality. The purpose of the study is to assess whether being single or childless moderates the elevated risk of mortality in hearing impaired. The Nord-Trøndelag hearing Loss Study examined 50,462 persons above 20 years of age during 1996–1998. The Norwegian Cause of Death Registry was used to identify deaths until 2016. Data on marital status was obtained from the Norwegian Population Registry. Hearing loss was defined as the pure-tone average (0.5–4 kHz) of hearing thresholds greater than 25 dB hearing level (dB HL) in the better ear. Associations between hearing loss and mortality risk were estimated using Cox regression after an average follow-up of 17.6 years. Hearing loss was associated with increased risk of all-cause mortality before 75 years of age (hazard ratio [HR] 1.3, 95% confidence interval [CI] 1.2–1.4) and cardiovascular mortality (HR 1.8, 95% CI 1.5–2.1) but not with cancer mortality (HR 1.1, 95% CI 0.9–1.3) or mortality due to injuries (HR 1.4, 95% CI 0.9–2.3). Adjusting for socio-economic characteristics, cardiovascular risk-factors, diseases, and family status, reduced the associations for all-cause mortality (HR 1.1, 95% CI 1.0–1.2) and cardiovascular mortality (HR 1.4, 95% CI 1.2–1.6). The adjusted mortality risk was found to be significantly related to family status. Being divorced raised the mortality risk associated with hearing loss among those below 75 years of age. There was a similar tendency also for being childless, although this was only significant for females. There was also a trend for a lower mortality related to hearing loss in subjects with a well-hearing partner. More focus should be given to those who lack a family when having functional limitations such as hearing impairment.

1. Introduction

Hearing loss is a growing health challenge. In terms of years of disability adjusted life years (DALYs), a measure that combines years of life lost (YLL) with years lived with disability (YLD), it rose from 430 in 1990 to 550 DALYs per 100 000 in 2015 globally (Murray et al., 2015), being the fourth leading cause of YLDs (Wilson et al., 2017). Hearing loss is strongly age dependent increasing from about 1% among those aged 40–44 up to 50% in women and 62% in men aged 80–84 in Norway (Borchgrevink et al., 2005); therefore ongoing demographic change - with ageing of large cohorts and extensions to longevity - is likely to imply a sharp increase in the number of individuals with hearing loss. At the same time, family constellations in many countries change rapidly - with growing proportions live without a partner, growing shares do not marry or experience union dissolutions and rising shares do not have children (Hagestad, 2018; Hill, 2017; Kalmijn, 2015; Sobotka, 2017). In the current study, we seek to study these phenomena together – will not having children or being partnered represent additional risks for the hearing impaired?

Elevated mortality and health impairments have been identified among those who lack a partner or children (Agerbo et al., 2012; Grundy and Kravdal, 2010; Hansen et al., 2009; Miller et al., 2013; Wood et al., 2007). A separate literature has identified that those who suffer from hearing loss tend to live shorter lives (Contrera et al., 2015; Feeny et al., 2012; Fisher et al., 2014; Karpa et al., 2010; Schubert et al., 2017). A 12 years Canadian follow-up study, consisting of 12,375 women and men aged 18 and older, found that impaired hearing as well as being male and being widowed increased the risk of mortality (Feeny et al., 2012). Another study found that social isolation was more common among women than men (16% versus 12%), but they were less likely to report hearing difficulties (5% versus 7%). Hearing difficulties were more prevalent at older ages: 25% of men and 18% of women at age 75 or older. When sociodemographic factors (age, education, living arrangements, regular driver, workforce participation), incontinence,

* Corresponding author.
E-mail addresses: Bolars.engdahl@fhi.no (B. Engdahl), Mariann.Idstad@fhi.no (M. Idstad), Vegard.Skirbekk@fhi.no (V. Skirbekk).

https://doi.org/10.1016/j.socscimed.2018.11.022
Received 26 June 2018; Received in revised form 8 November 2018; Accepted 11 November 2018
Available online 13 November 2018

fear of falling, and functional limitations were taken into account, the odds of being socially isolated increased with the severity of the hearing impairment among women but not among men (OR: 1.04, 95% CI: 1.00, 1.09) (Ramage-Morin, 2016).

Hearing loss may be more related to mortality than vision impairment. A study of 4926 Icelandic individuals, aged ≥67 years, 43.4% male, who completed vision and hearing examinations between 2002 and 2006 in the Age, Gene/Environment Susceptibility-Reykjavik Study (AGES-RS) and were followed prospectively for mortality through 2009, categorised participants as having 'moderate or greater' degree of impairment for vision only (VI), hearing only (HI), and both vision and hearing (dual sensory impairment, DSI) after a median follow-up of 5.3 years. The prevalence of HI, VI and DSI were 25.4, 9.2 and 7.0%, respectively. People with HI remained at higher risk for CVD mortality [HR: 1.70 (1.27–2.27)], whereas people with DSI remained at higher risk of all-cause mortality [HR: 1.43 (1.11–1.85)] and CVD mortality [HR: 1.78 (1.18–2.69)]. Mortality rates were significantly higher in men with HI and DSI and were elevated, although not significantly, among women with HI. Vision impairment alone was not associated with increased mortality (Fisher et al., 2014).

There are several explanations to the association between hearing loss and mortality. Hearing loss and mortality may share some of the same risk factors such as cardiovascular, occupational and socio-economic risk factors contributing to both hearing loss (Engdahl et al., 2015; Helvik et al., 2009) and mortality. This could be mediated by several factors. There is evidence that hearing impairment has a detrimental effect on physical activity levels (Chen et al., 2015) and social functioning (Danielsson et al., 2015). Hearing loss may worsen mental health (Strawbridge et al., 2000; Tambs, 2004) and cognitive function (Loughrey et al., 2018). Other health risks like traffic accidents and falls are also greater among those with a hearing impairment (Jiam et al., 2016). For example, hearing loss may hinder a person's ability to notice approaching cars that are out of view. Hearing loss has been found to be associated with both poorer balance due to reduced spatial awareness, lower cognitive capacity for balance and vestibular problems (Agmon et al., 2017). Disability in walking, cognitive function and self-rated health have been shown to mediate the association between hearing loss and mortality (Karpa et al., 2010).

Hearing loss can interact with health in very different manners. The communication barrier that accompanies hearing loss may elicit a feeling of handicap and inferiority, which in turn can lead to lowered self-esteem, social isolation, and lower use of health care services (Chang et al., 2009; Fellinger et al., 2012; Kuenburg et al., 2016; Ramage-Morin, 2016).

Marriage and parenthood have been found to be related to improved health and lower mortality risks (Einiö et al., 2016; Frisch and Simonsen, 2013; Rossin, 2011; Tamakoshi et al., 2011; Van den Berg and Gupta, 2015). Although a variety of risk factors mediate these relations, ranging from less cigarette smoking and better diets to greater use of healthcare services and better coping when one has a disease. Important gender mechanisms may be present. Although both sexes have lower mortality when married, men tend to gain more than women from having a family (Grundy and Read, 2015). Moreover, the likelihood that one does not have children may be much greater among men than women - in Norway 23% of men at the age of 45 are childless compared to 13% of women - and more men than women have limited contact with their children (León et al., 2017; Puur et al., 2011; Statistics Norway, 2016).

Children and partners can provide support when it comes to functional decrements. People who have a spouse and/or children tend to have lower disease rates, lower risk of mental health problems, better health, and to live longer than those who are single and/or childless (Agerbo et al., 2012; Hansen et al., 2009; Miller et al., 2013; Wood et al., 2007). Families may be more likely to stay supportive and present even during spells of poor health compared to friends or those with weaker ties, which may reduce some of the mortality risk associated with functional impairments. Having a partner could allow one to be socially active to a greater extent, as the spouse may provide support, take initiative and help one overcome thresholds for socializing with others. A spouse could also encourage the use of technical implementations such as hearing aids, and assist in consulting health services when necessary. Being in a relationship may also serve as a buffer against detrimental economic consequences of hearing loss.

The combined effect of hearing loss and partnership and parent status has, to our knowledge, not yet been investigated, which is what we seek to do in the current study. This study investigates if being single (never married, widowed, divorced and childless) increases the mortality risk associated with hearing loss. Further, we will study whether any effects differ by gender. Functional losses may be lower when there is another present party that helps with everyday tasks. If having a partner is protective, we will study if this is true also when the partner is hearing impaired.

2. Material and methods

2.1. Study population

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 was finished. Audiometric data were collected from 50,462 participants. More detailed information about the study is found elsewhere (Engdahl et al., 2005).

2.2. Study variables

2.2.1. 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). Hearing impairment was defined as the pure-tone average of hearing thresholds greater than 25 dB hearing level (dB HL) for the pure-tone average of four frequencies (0.5, 1, 2, and 4 kHz) in the better ear.

2.2.2. Marital status, cohabiting status, single status and number of children

Data on marital status (married, cohabiting, single) and number of children was obtained for the year 1996 from the National Population Registry and compiled by Statistics Norway. Data were linked using the unique 11-digit personal identification code assigned to all Norwegian residents. Cohabiting were all couples that were living together but not married. Singles were all subjects not cohabiting further divided into never married, divorced/separated and widowed. In cases where two individuals who were in a partnership participated in HUNT 2, we assessed the hearing ability for both.

2.2.3. Covariates

We collected information on covariates from national registers and from HUNT 2 questionnaires and measurements. From national registers and considered complete, we had information on level of highest education (primary and secondary school, vocational school, high school, undergraduate and graduate school) and pensionable income in 1996 (in NOK). The following cardiovascular risk-factors previously shown to be related to hearing loss (Engdahl et al., 2015) were collected from questionnaire data and measurements in HUNT 2 (1995-97):

smoking, alcohol consumption, diabetes, physical inactivity, resting heart rate and waist circumference. In addition we included having or having had myocardial infarction, angina pectoris, stroke/brain haemorrhage or cancer.

Smoking was categorised as daily smokers or not. Alcohol use was categorised into teetotal, not drinking in the last month but not teetotal, drinking not more than 8 times in the last month, and drinking more than eight times in the last month. Physical activity was classified into four groups; inactive (no activity); low (< 3 h light activity and/or < 1 h heavy activity per week); medium (≥ 3 h light activity and/or < 1 h heavy activity per week) and high (any light activity and ≥ 1 h heavy activity per week) (Stensvold et al., 2011). Resting heart rate and waist circumference were treated as continuous variables in the analyses.

Data on covariates were missing mainly for physical activity (31% missing), alcohol use (9%), smoking (5%) and cancer (4%).

2.2.4. Mortality

Information on death and causes of death was obtained from the National Cause of Death Registry. The data on death are considered to be complete. The primary end point was death from any cause until the end of follow-up on October 1, 2016 (all-cause mortality). In addition, we assessed deaths from cardiovascular causes (International Classification of Diseases, Tenth Revision [ICD-10]: I00-99), deaths from cancer (ICD-10: C00-97), and deaths from injuries (ICD-10:S00-S99, T00-T98).

Each subject's follow-up started in 1996–1998 (the beginning of the study period). All subjects were followed until death or until October 1, 2016, whichever occurred first allowing for a follow-up time of about 20 years.

2.2.5. Statistical analysis

All descriptive analyses and survival analyses were conducted using Stata version 15.0.

Simple statistics included student t tests for comparing means and chi-square tests for comparing proportions. Cox proportional hazards regression models were used to estimate hazard ratios (HRs) and 95% confidence intervals (95% CIs). We tested for multiplicative interactions between hearing loss and marriage, cohabiting and single status and between hearing loss and having children including all main effects in the model. Because hearing loss and mortality both increase with advancing age, the participant's age at the date of exiting the study was used as time-scale for the analyses. Analyses were adjusted for or stratified on sex. We also adjusted for the covariates smoking, alcohol use, physical activity, diabetes, resting heart rate, waist circumference, myocardial infarction, angina pectoris, stroke/brain haemorrhage, cancer, income, education, marriage, cohabiting, single and children status. Because participants with complete data might have a different health status compared with those with missing data, we performed multiple imputation of missing values to lower the risk of potential biases in complete case analysis and to not lose power. We used the *mi procedure* in Stata using chained equations to obtain 10 imputed data sets, and used Rubin's rules to combine effect estimates and estimate standard errors to allow for the uncertainty caused by missing data.

Testing the assumption of proportional hazards was performed by the *stphtest* in Stata. Analyses were stratified on covariates for which the effect did not meet the proportional hazards assumption using the *strata* option in Stata. This is equivalent to fitting separate Cox proportional hazards models under the constraint that the coefficients are equal but the baseline hazard functions are not. Because the proportional hazards assumption did not hold for the exposure variable of interest, hearing loss, we estimated separate effects for two different age periods of follow-up: up to and equal to 75 years of age and above 75 years. This by using the command *stssplit* in Stata.

All statistical tests were two-tailed and calculated at a 95% confidence interval ($p < 0.05$).

Table 1
Characteristics of the study cohort.

	All subjects, n (%) n = 50,462	Hearing loss	
		No, n (%)	Yes, n (%)
		n = 41,454	n = 9008
Male	23,622 (46.8)	18,642 (45.0)	4980 (55.3)
Age[a], mean (SD)	50.5 (16.9)	46.1 (14.6)	70.6 (11.4)
Single	13,925 (27.6)	10,609 (25.6)	3316 (36.8)
Divorced/separated	2375 (4.7)	2036 (4.9)	339 (3.8)
Widowed	4024 (8.0)	1890 (4.6)	2134 (23.7)
Never married	7526 (14.9)	6683 (16.1)	843 (9.4)
Cohabiting	5589 (11.1)	5431 (13.1)	158 (1.8)
Married	30,948 (61.3)	25,414 (61.3)	5534 (61.4)
Children	45,332 (89.8)	37,760 (91.1)	7572 (84.1)
Deaths	12,718 (25.2)	6385 (15.4)	6333 (70.3)

[a] Age at entry participating in HUNT 2.

3. Results

Hearing impaired participants are substantially older, more likely to be male and slightly less likely to have children. There are no difference in marriage status between subjects with and without hearing loss, but subjects with hearing loss are more likely to be single and less likely to cohabit. While age at entry averaged 51 years (19–99), age at exit was 68 years on average (22–102). During follow-up (median follow-up time, 17.6 years), 12,717 (25%) participants died and 3146 died before the age of 75 years (Table 1).

Table 2 shows crude as well as multivariable adjusted all-cause mortality rates, stratified by sex and for two follow-up times, up to 75 years and above 75 years of age, expressed as HRs with 95%. Hearing loss was crudely associated with an increased risk of all-cause mortality in females and males, with a higher risk before 75 years of age. After multivariable adjustments for covariates the strength of these associations were generally weakened with significant associations before 75 years of age only (HR = 1.10, 95% CI 1.00, 1.21, p = 0.045).

Table 3 shows the association between hearing loss and all-cause mortality stratified on marriage, cohabiting and single status. The multiplicative interactions between hearing loss and different living status was jointly significant both before and above 75 years of age in the unadjusted models. The mortality risk was highest in divorced/separated and never married subjects. While the effects were similar in women and men, the interactions were only jointly significant in males when stratified on sex. Multivariable adjustments for covariates resulted in a lower mortality risk in all groups, but the interactions were still jointly significant in men and in the total sample. There was also a tendency for an increased mortality risk due to hearing loss among

Table 2
Association between hearing loss and all-cause mortality estimated up to 75 years and above 75 years of age. Cox regression with attained age as time scale.

	Deaths		Model 1	Model 2[b]
			HR (95% CI)	HR (95% CI)
All[a]	< =75 years	3146	1.29 (1.17–1.41)	1.10 (1.00–1.21)
	> 75 years	9071	1.12 (1.07–1.17)	1.01 (0.97–1.06)
Female	< =75 years	1274	1.33 (1.12–1.58)	1.14 (0.96–1.35)
	> 75 years	4935	1.06 (1.00–1.13)	0.99 (0.93–1.05)
Male	< =75 years	1872	1.27 (1.14–1.42)	1.04 (0.93–1.17)
	> 75 years	4636	1.19 (1.11–1.26)	1.04 (0.98–1.12)

[a] Adjusted for sex by stratification.
[b] Adjusted for smoking, alcohol use, physical activity, diabetes, resting heart rate, waist circumference, myocardial infarction, angina pectoris, stroke/brain haemorrhage, cancer, income, education, marriage, cohabiting, single and children status.

Table 3
Association between hearing loss and all-cause mortality stratified on marriage, cohabiting and single status. Cox regression with attained age as time scale.

		Single			Cohabiting HR (95% CI)	Married HR (95% CI)	Interaction[c] p-value
		Divorced/separated HR (95% CI)	Widowed HR (95% CI)	Never married HR (95% CI)			
Model 1							
All[a]	< =75 years	1.74 (1.31–2.31)	1.27 (0.91–1.77)	1.30 (1.00–1.69)	0.64 (0.32–1.29)	1.19 (1.06–1.34)	0.001
	> 75 years	1.21 (0.95–1.54)	1.02 (0.94–1.11)	1.16 (0.99–1.35)	0.88 (0.54–1.41)	1.14 (1.08–1.20)	0.000
Female	< =75 years	1.73 (1.01–2.97)	1.14 (0.75–1.73)	1.78 (1.01–3.13)	1.61 (0.49–5.30)	1.20 (0.96–1.50)	0.115
	> 75 years	1.11 (0.78–1.59)	1.01 (0.93–1.11)	1.11 (0.87–1.41)	0.81 (0.32–2.06)	1.08 (0.99–1.18)	0.088
Male	< =75 years	1.74 (1.24–2.43)	1.57 (0.89–2.76)	1.20 (0.89–1.61)	0.48 (0.21–1.12)	1.19 (1.04–1.36)	0.004
	> 75 years	1.30 (0.93–1.81)	1.06 (0.86–1.30)	1.19 (0.97–1.47)	0.90 (0.52–1.57)	1.18 (1.10–1.27)	0.002
Model 2[b]							
All[a]	< =75 years	1.40 (1.05–1.87)	1.25 (0.90–1.74)	1.08 (0.83–1.40)	0.57 (0.29–1.16)	1.04 (0.93–1.17)	0.003
	> 75 years	1.12 (0.87–1.43)	0.97 (0.89–1.05)	1.11 (0.94–1.30)	0.72 (0.44–1.16)	1.03 (0.98–1.09)	0.013
Female	< =75 years	1.39 (0.79–2.43)	1.08 (0.71–1.65)	1.37 (0.77–2.44)	1.38 (0.40–4.75)	1.05 (0.84–1.31)	0.220
	> 75 years	1.11 (0.76–1.63)	0.96 (0.87–1.05)	1.04 (0.81–1.33)	0.57 (0.21–1.56)	1.03 (0.95–1.13)	0.065
Male	< =75 years	1.33 (0.94–1.89)	1.41 (0.79–2.53)	1.01 (0.75–1.36)	0.42 (0.18–0.99)	1.01 (0.88–1.16)	0.004
	> 75 years	1.18 (0.84–1.67)	1.01 (0.82–1.25)	1.14 (0.92–1.42)	0.78 (0.43–1.42)	1.04 (0.97–1.12)	0.188

[a] Adjusted for sex by stratification.
[b] Adjusted for smoking, alcohol use, physical activity, diabetes, resting heart rate, waist circumference, myocardial infarction, angina pectoris, stroke/brain haemorrhage, cancer, income, education, and children status.
[c] Test if all coefficients on the interaction terms are jointly equal to zero.

Table 4
Association between hearing loss and all-cause mortality stratified on children status. Cox regression with attained age as time scale.

		Childless	Parents	Interaction p-value
		HR (95% CI)	HR (95% CI)	
Model 1				
All[a]	< =75 years	1.35 (1.07–1.71)	1.25 (1.12–1.38)	0.539
	> 75 years	1.15 (1.03–1.28)	1.11 (1.06–1.16)	0.571
Female	< =75 years	2.12 (1.32–3.41)	1.24 (1.03–1.49)	0.038
	> 75 years	1.11 (0.95–1.30)	1.05 (0.99–1.12)	0.530
Male	< =75 years	1.19 (0.91–1.56)	1.25 (1.10–1.41)	0.754
	> 75 years	1.19 (1.01–1.39)	1.18 (1.10–1.26)	0.919
Model 2[b]				
All[a]	< =75 years	1.15 (0.91–1.45)	1.08 (0.97–1.19)	0.214
	> 75 years	1.09 (0.97–1.22)	1.00 (0.95–1.05)	0.093
Female	< =75 years	1.74 (1.07–2.82)	1.06 (0.88–1.28)	0.006
	> 75 years	1.06 (0.90–1.25)	0.98 (0.92–1.04)	0.513
Male	< =75 years	1.01 (0.78–1.33)	1.04 (0.92–1.18)	0.889
	> 75 years	1.15 (0.98–1.35)	1.03 (0.96–1.10)	0.113

[a] Adjusted for sex by stratification.
[b] Adjusted for smoking, alcohol use, physical activity, diabetes, resting heart rate, waist circumference, myocardial infarction, angina pectoris, stroke/brain haemorrhage, cancer, income, education, married, cohabitation and single status.

childless, although this tendency was only seen in women with a significant multiplicative interaction in women up to 75 years of age only (Table 4). Again, adjust for the broad set of covariates led to lower mortality risks, but the interaction in women up to 75 years of age was still significant with HR = 1.74 (95% CI 1.07, 2.82) among childless women, and HR = 1.06 (95% CI 0.88, 1.28) among parents.

The group of married was further divided based on the hearing status of their partner. In total 27,510 cases (13,755 pairs) participated in HUNT 2 with hearing ability assessed for both partners. The unadjusted all-cause mortality of married participants with a well-hearing partner (n = 22,530) was HR = 1.14 (95% CI 1.00, 1.30), while with a poor-hearing spouse (n = 4980) it was HR = 1.32 (95% CI 1.02, 1.71). This tendency of a protective effect was however not significant (p = 0.241). The correlation in hearing loss between spouses was small with a partial correlation of 0.006 controlling for age.

Table 5 shows the association between hearing loss and cause of mortality. While there were generally significant unadjusted associations between hearing loss and cardiovascular related mortality, there were significant associations with cancer or injury related mortality for in men ≥ 75 years only. Multivariable adjustments for covariates lowered the association with cardiovascular mortality, especially for men, although the association remained significant in the total sample and for women.

Analysis of cause-specific mortality was also stratified on family status, but due to small samples, restricted to single, married and children status up to 75 of age (Tables 6 and 7). Being married seems to protect against injury related mortality in hearing impaired men and women in both unadjusted and adjusted analyses (Table 6). Also, having children seems to protect against cardiovascular mortality in hearing impaired women and against injury related mortality in hearing impaired men and women in both unadjusted and adjusted analyses (Table 7). However only the interactions with having children were significant.

4. Discussion

Hearing loss was associated with increased risk of all-cause mortality and cardiovascular mortality, particularly before 75 years of age, yet the association was weaker when adjusting for socio-economic characteristics, cardiovascular risk-factors, diseases, marital status and

Table 5
Association between hearing loss and cause of mortality. Cox regression with attained age as time scale.

			Deaths	Model 1	Model 2[b]
				HR (95% CI)	HR (95% CI)
All[a]	Cardiovascular	< =75 years	2545	1.76 (1.51–2.06)	1.40 (1.20–1.64)
		> 75 years	3881	1.30 (1.21–1.39)	1.09 (1.01–1.16)
	Cancer	< =75 years	2606	1.09 (0.93–1.26)	0.96 (0.82–1.12)
		> 75 years	2007	1.07 (0.98–1.17)	1.04 (0.94–1.14)
	Injuries	< =75 years	326	1.39 (0.85–2.27)	1.24 (0.76–2.02)
		> 75 years	295	1.06 (0.83–1.35)	0.96 (0.75–1.23)
Female	Cardiovascular	< =75 years	1010	2.21 (1.64–2.99)	1.66 (1.22–2.25)
		> 75 years	2017	1.26 (1.15–1.39)	1.10 (1.00–1.21)
	Cancer	< =75 years	1145	1.00 (0.76–1.32)	0.92 (0.70–1.22)
		> 75 years	855	0.99 (0.86–1.14)	0.94 (0.82–1.09)
	Injuries	< =75 years	138	1.19 (0.41–3.39)	1.07 (0.37–3.08)
		> 75 years	170	0.83 (0.61–1.14)	0.83 (0.60–1.14)
Male	Cardiovascular	< =75 years	1535	1.63 (1.36–1.95)	1.16 (0.97–1.40)
		> 75 years	1864	1.34 (1.21–1.48)	1.10 (0.99–1.22)
	Cancer	< =75 years	1461	1.13 (0.94–1.35)	1.02 (0.85–1.23)
		> 75 years	1152	1.14 (1.01–1.28)	1.06 (0.94–1.20)
	Injuries	< =75 years	188	1.46 (0.84–2.54)	1.20 (0.68–2.11)
		> 75 years	125	1.54 (1.02–2.31)	1.45 (0.96–2.19)

[a] Adjusted for sex by stratification.
[b] Adjusted for smoking, alcohol use, physical activity, diabetes, resting heart rate, waist circumference, myocardial infarction, angina pectoris, stroke/brain haemorrhage, cancer, income, education, marriage, cohabiting, single and children status.

whether one has children. The associations are moderated by marital/partnership status. For instance, excess mortality among those with hearing loss is particularly high among men and women aged below 75 and those who are divorced or separated. The modification was weakened by adjusting for socio-economic characteristics, cardiovascular risk-factors and diseases, yet remained significant for men. There was also a trend for a lower mortality related to hearing loss in subjects with a well-hearing partner. Analyses of cause-specific mortality revealed significant modifications by marital status and having children on the effect of hearing loss on injury specific mortality in men and women and on cardiovascular mortality in women only. No clear sex differences were found except for that childless women (but not childless men) showed an increased mortality risk due to hearing loss.

The results confirm earlier reports of a weak association between hearing loss measured by audiometry and increased risk of all-cause mortality (Anstey et al., 2001; Contrera et al., 2015; Fisher et al., 2014; Karpa et al., 2010; Schubert et al., 2017) and cardiovascular mortality (Fisher et al., 2014; Karpa et al., 2010). The reduction in the associations when adjusting for cardiovascular risk-factors do not support a direct association between hearing loss and mortality and is in line with other studies (Genther et al., 2015; Karpa et al., 2010; Schubert et al., 2017). To our knowledge, there are no previous studies that have investigated if being married or having children modifies this relationship. Family formation has since long been shown to be protective for mortality, and this could be linked to social and economic support, lifestyles and coping strategies when faced with disease. Health risk behaviours that may be altered when one enters a marriage or has children, such as smoking cessation. Smoking leads to adverse health outcome, higher risk of cardiovascular disease and greater mortality (Chiu et al., 2018; Hilz, 2018; Newton et al., 2014).

The major advantages of our study are the large sample representative of the general population of the Nord-Trøndelag county with register based data on mortality, causes of mortality, marital status and number of children, audiometrically measured hearing loss and a long follow-up averaging over 17 years. In many respects, Nord-Trøndelag is representative of Norway regarding geography, economy, industry and sources of income, age distribution, morbidity and mortality. However, the county has no large cities, and the mean levels of education are slightly lower than the national averages. The large sample size made it possible to do sub-group analyses and estimate interactions although the precision and power to statistically test for interactions are limited.

Table 6
Association between hearing loss and cause-specific mortality stratified on single status. < =75 years. Cox regression with attained age as time scale.

		Model 1			Model 2[b]		
		Single HR (95% CI)	Married HR (95% CI)	Interaction[c] p-value	Single HR (95% CI)	Married HR (95% CI)	Interaction[c] p-value
All[a]	Cardiovascular	1.68 (1.28–2.20)	1.71 (1.41–2.08)	0.913	1.43 (1.09–1.87)	1.39 (1.14–1.69)	0.081
	Cancer	1.30 (0.97–1.75)	1.02 (0.85–1.22)	0.139	1.17 (0.87–1.57)	0.91 (0.76–1.09)	0.110
	Injuries	2.11 (1.03–4.34)	0.88 (0.43–1.81)	0.065	1.78 (0.86–3.67)	0.89 (0.43–1.83)	0.132
Female	Cardiovascular	1.71 (1.04–2.81)	2.39 (1.63–3.52)	0.298	1.34 (0.81–2.20)	1.84 (1.25–2.72)	0.970
	Cancer	1.32 (0.84–2.07)	0.82 (0.57–1.18)	0.056	1.28 (0.81–2.03)	0.76 (0.53–1.10)	0.081
	Injuries	1.31 (0.28–6.11)	0.47 (0.06–3.55)	0.250	1.18 (0.25–5.58)	0.42 (0.06–3.13)	0.266
Male	Cardiovascular	1.66 (1.21–2.29)	1.55 (1.24–1.93)	0.712	1.25 (0.90–1.73)	1.12 (0.89–1.41)	0.035
	Cancer	1.29 (0.87–1.91)	1.11 (0.90–1.37)	0.572	1.18 (0.79–1.77)	1.01 (0.82–1.25)	0.499
	Injuries	2.49 (1.09–5.67)	1.00 (0.46–2.19)	0.370	2.08 (0.90–4.78)	0.89 (0.40–1.98)	0.434

[a] Adjusted for sex by stratification.
[b] Adjusted for smoking, alcohol use, physical activity, diabetes, resting heart rate, waist circumference, myocardial infarction, angina pectoris, stroke/brain haemorrhage, cancer, income, education, and children status.
[c] Test if all coefficients on the interaction terms are jointly equal to zero.

Table 7
Association between hearing loss and cause-specific mortality stratified on children status. < =75 years. Cox regression with attained age as time scale.

		Model 1			Model 2[b]		
		Childless HR (95% CI)	Parents HR (95% CI)	Interaction[c] p-value	Childless HR (95% CI)	Parents HR (95% CI)	Interaction[c] p-value
All[a]	Cardiovascular	1.60 (1.08–2.35)	1.75 (1.47–2.07)	0.675	1.34 (0.91–1.98)	1.39 (1.17–1.65)	0.751
	Cancer	1.10 (0.71–1.70)	1.08 (0.92–1.27)	0.970	1.06 (0.69–1.64)	0.95 (0.81–1.12)	0.937
	Injuries	3.80 (1.64–8.82)	0.90 (0.48–1.68)	0.029	3.37 (1.41–8.05)	0.85 (0.45–1.58)	0.039
Female	Cardiovascular	5.93 (1.97–17.81)	2.06 (1.50–2.83)	0.070	4.43 (1.46–13.43)	1.53 (1.11–2.11)	0.526
	Cancer	1.27 (0.52–3.08)	0.97 (0.72–1.30)	0.595	1.23 (0.50–3.04)	0.89 (0.67–1.20)	0.601
	Injuries	4.40 (0.73–26.40)	0.67 (0.16–2.84)	0.017	3.05 (0.48–19.27)	0.60 (0.14–2.58)	0.014
Male	Cardiovascular	1.35 (0.89–2.05)	1.64 (1.34–2.01)	0.405	1.02 (0.67–1.56)	1.18 (0.96–1.45)	0.834
	Cancer	1.05 (0.64–1.73)	1.14 (0.93–1.39)	0.649	1.02 (0.62–1.70)	1.03 (0.84–1.26)	0.651
	Injuries	3.65 (1.41–9.49)	0.97 (0.49–1.95)	0.404	3.69 (1.38–9.84)	0.78 (0.39–1.58)	0.441

[a] Adjusted for sex by stratification.
[b] Adjusted for smoking, alcohol use, physical activity, diabetes, resting heart rate, waist circumference, myocardial infarction, angina pectoris, stroke/brain haemorrhage, cancer, income, education, and cohabiting status.
[c] Test if all coefficients on the interaction terms are jointly equal to zero.

A key limitation is selection in terms of who gets partnered and has children, where hearing could play an important role as well. Another limitation is unobserved factors that both influence family outcomes and hearing as well as mortality, and we therefore do not know whether our study represent causal relations. Caution needs to be given as to whether the results can be generalized to other periods, and different contexts and populations. Since mortality and marital status were complete for all participants, and the participation rate in the population survey was relatively high (67% for the vast majority of the county), a substantial selection bias is unlikely. There is however still a possibility of bias regarding survey inclusion concerning hearing loss, family status and health (although great effort was taken to avoid health- and social selection related to family status). The hearing examination was only a small part of the health examination program and it is not clear whether some individuals would opt out in order to avoid the hearing examination.

We have treated cohabiting and married participants as independent observations. Potentially, individuals with hearing loss may be more likely to partner with each other. If this being a problem, this would likely have underestimated the standard error of the estimates, and possible resulted in a bias towards higher associations in couples. However, the correlation in hearing loss between spouses was negligible after controlling for age. Moreover, most people find a partner relatively early in adult life, while most of those with a hearing problem become evident only later in adult life, suggesting that most would not be aware of a potential person's hearing condition at the time of entering a partnership. Moreover, when stratifying on sex there is no dependence between spouses because there are very few couples with the same sex. Actually, the main analyses was also stratified on sex using the strata option as the effect of sex did not meet the proportional-hazard assumption. So, the effect estimates for the main analyses is based on a combination of two likelihoods across the sex strata, each with negligible dependence among spouses.

5. Conclusions

Hearing impairment and a lack of a partner or offspring independently relates to greater mortality. Our study identifies that excess mortality may be particularly high among individuals with certain family constellations, such as men who are divorced or women who do not have children. In light of our findings, more focus should be given to those being single or childless when having functional limitations such as hearing impairment. When governments develop plans to lower the incidence of hearing impairment, they may want to consider the family dimension when designing intervention and social and health support systems and to make efforts to help individuals with hearing loss more suited for their family context. The finding that hearing impaired childless are much more likely to die due from CVD causes (women) and from injuries is important suggest that more attention should be given to risk factors leading to these outcomes in these groups.

It might be useful to design policies that would help one identify and provide special support for those who are hearing disabled and do not have a family. This can include training for using and adapting hearing aids and other technical facilities that could improve the quality of life, counselling, providing instructions and training sessions. Also structural changes like regulations and recommendations including acoustic characteristics for the construction of homes, office buildings, restaurants and public spaces should be considered for improving the lives of hearing impaired who may lack family support.

One may also target policies to better identify those at risk, including a general screening of hearing disabilities among single and childless adults. One possibility is to assess hearing during general primary doctor visits, to allow for better data – and to link this information to child parity and partner status. Moreover, better education and retraining among health care personnel to be able to provide better health care services for those with hearing loss (Solheim et al., 2016). In the light of the poor health outcomes of the divorced hearing impaired, one may consider more family therapy opportunities that provided services for those with hearing loss. Interventions could also include generally better availability of support for those who have hearing disabilities (including more availability of interpreters for the hearing impaired, options to write, draw and through gesticulation explain ones health symptoms and disease histories).

It is well known that rapid population level ageing is likely to result in a greater prevalence of hearing impairment, and that a loss of hearing can raise mortality risks. However, it has not yet been much focus on how these effects relate to ongoing changes in family constellations, including a greater frequency of divorce and rising childlessness. Our findings verify that the effect of hearing loss on mortality is greater among the divorced and childless hearing impaired, accounting for other observable health and socioeconomic characteristics. In sum, a more comprehensive assessments of the situation of the hearing impaired that accounts for their family situation can help us to better foresee their health challenges and to design more effective policy interventions for this group.

Acknowledgement

The Nord-Trøndelag Health Study (the HUNT Study) is a collaboration between the HUNT Research Center (Faculty of Medicine and Health Sciences, Norwegian University of Science and Technology

(NTNU)), Nord-Trøndelag County Council, Central Norway Regional Health Authority, and the Norwegian Institute of Public Health.

References

Agerbo, E., Mortensen, P.B., Munk-Olsen, T., 2012. Childlessness, parental mortality and psychiatric illness: a natural experiment based on in vitro fertility treatment and adoption. J. Epidemiol. Community Health 67, 374–376 jech-2012-201387.

Agmon, M., Lavie, L., Doumas, M., 2017. The association between hearing loss, postural control, and mobility in older adults: a systematic review. J. Am. Acad. Audiol. 28, 575–588.

Anstey, K.J., Luszcz, M.A., Giles, L.C., Andrews, G.R., 2001. Demographic, health, cognitive, and sensory variables as predictors of mortality in very old adults. Psychol. Aging 16, 3–11.

Borchgrevink, H.M., Tambs, K., Hoffman, H.J., 2005. The Nord-Trondelag Norway Audiometric Survey 1996-98: unscreened thresholds and prevalence of hearing impairment for adults > 20 years. Noise Health 7, 1–15.

Chang, H.P., Ho, C.Y., Chou, P., 2009. The factors associated with a self-perceived hearing handicap in elderly people with hearing impairment–results from a community-based study. Ear Hear. 30, 576–583.

Chen, D.S., Betz, J., Yaffe, K., Ayonayon, H.N., Kritchevsky, S., Martin, K.R., et al., 2015. Association of hearing impairment with declines in physical functioning and the risk of disability in older adults. J. Gerontol. A Biol. Sci. Med. Sci. 70, 654–661.

Chiu, M., Rahman, F., Vigod, S., Lau, C., Cairney, J., Kurdyak, P., 2018. Mortality in single fathers compared with single mothers and partnered parents: a population-based cohort study. Lancet Public Health 3, e115–e123.

Contrera, K.J., Betz, J., Genther, D.J., Lin, F.R., 2015. Association of hearing impairment and mortality in the national health and nutrition examination survey. JAMA Otolaryngol. Head Neck Surg. 141, 944–946.

Danielsson, H., Pichora-Fuller, K., Dupuis, K., Rönnberg, J., 2015. Modeling the Effect of Early Age-related Hearing Loss on Cognition and Participation in Social Leisure Activities. Ageing and speech Communication, Bloomington, Indiana, pp. 11–14 October, 2015.

Einiö, E., Nisén, J., Martikainen, P., 2016. Number of children and later-life mortality among Finns born 1938–50. Popul. Stud. 70, 217–238.

Engdahl, B., Aarhus, L., Lie, A., Tambs, K., 2015. Cardiovascular risk factors and hearing loss: the HUNT study. Int. J. Audiol. 54, 958–966.

Engdahl, B., Tambs, K., Borchgrevink, H.M., Hoffman, H.J., 2005. Screened and unscreened hearing threshold levels for the adult population: results from the Nord-Trøndelag Hearing Loss Study. Int. J. Audiol. 44, 213–230.

Feeny, D., Huguet, N., McFarland, B.H., Kaplan, M.S., Orpana, H., Eckstrom, E., 2012. Hearing, mobility, and pain predict mortality: a longitudinal population-based study. J. Clin. Epidemiol. 65, 764–777.

Fellinger, J., Holzinger, D., Pollard, R., 2012. Mental health of deaf people. Lancet 379, 1037–1044.

Fisher, D., Li, C.M., Chiu, M.S., Themann, C.L., Petersen, H., Jonasson, F., et al., 2014. Impairments in hearing and vision impact on mortality in older people: the AGES-Reykjavik Study. Age Ageing 43, 69–76.

Frisch, M., Simonsen, J., 2013. Marriage, cohabitation and mortality in Denmark: national cohort study of 6.5 million persons followed for up to three decades (1982–2011). Int. J. Epidemiol. 42, 559–578.

Genther, D.J., Betz, J., Pratt, S., Kritchevsky, S.B., Martin, K.R., Harris, T.B., et al., 2015. Association of hearing impairment and mortality in older adults. J. Gerontol. A Biol. Sci. Med. Sci. 70, 85–90.

Grundy, E., Kravdal, Ø., 2010. Fertility history and cause-specific mortality: a register-based analysis of complete cohorts of Norwegian women and men. Soc. Sci. Med. 70, 1847–1857.

Grundy, E., Read, S., 2015. Pathways from fertility history to later life health: results from analyses of the English study of ageing. Demogr. Res. 1–54.

Hagestad, G.O., 2018. Interdependent Lives and Relationships in Changing Times: a Life-course View of Families and Aging. Lives in Time and Place and Invitation to the Life Course. Routledge, pp. 135–159.

Hansen, T., Slagsvold, B., Moum, T., 2009. Childlessness and psychological well-being in midlife and old age: an examination of parental status effects across a range of outcomes. Soc. Indicat. Res. 94, 343–362.

Helvik, A.S., Krokstad, S., Tambs, K., 2009. Socioeconomic inequalities in hearing loss in a normal population sample from the HUNT Study. Am. J. Public Health 99, 1376–1378.

Hill, R., 2017. Family Development in Three Generations. Routledge.

Hilz, R.W.,M., 2018. Marital status, partnership and health behaviour: findings from the German ageing survey (DEAS). Comp. Popul. Stud.-Zeitschrift für Bevölkerungswissenschaft 43, 32.

Jiam, N.T., Li, C., Agrawal, Y., 2016. Hearing loss and falls: a systematic review and meta-analysis. Laryngoscope 126, 2587–2596.

Kalmijn, M., 2015. Family disruption and intergenerational reproduction: comparing the influences of married parents, divorced parents, and stepparents. Demography 52, 811–833.

Karpa, M.J., Gopinath, B., Beath, K., Rochtchina, E., Cumming, R.G., Wang, J.J., et al., 2010. Associations between hearing impairment and mortality risk in older persons: the Blue Mountains Hearing Study. Ann. Epidemiol. 20, 452–459.

Kuenburg, A., Fellinger, P., Fellinger, J., 2016. Health care access among deaf people. J. Deaf Stud. Deaf Educ. 21, 1–10.

León, E., Jiménez-Morago, J.M., Muñoz-Silva, A., 2017. Contact between birth parents and children in kinship care in a sample from Spain. Child Fam. Soc. Work 22, 1075–1083.

Loughrey, D.G., Kelly, M.E., Kelley, G.A., Brennan, S., Lawlor, B.A., 2018. Association of age-related hearing loss with cognitive function, cognitive impairment, and dementia: a systematic review and meta-analysis. JAMA Otolaryngol. Head Neck Surg. 144, 115–126.

Miller, R.B., Hollist, C.S., Olsen, J., Law, D., 2013. Marital quality and health over 20 years: a growth curve analysis. J. Marriage Fam. 75, 667–680.

Murray, C.J., Barber, R.M., Foreman, K.J., Ozgoren, A.A., Abd-Allah, F., Abera, S.F., et al., 2015. Global, regional, and national disability-adjusted life years (DALYs) for 306 diseases and injuries and healthy life expectancy (HALE) for 188 countries, 1990–2013: quantifying the epidemiological transition. Lancet 386, 2145–2191.

Newton, N.J., Ryan, L.H., King, R.T., Smith, J., 2014. Cohort differences in the marriage–health relationship for midlife women. Soc. Sci. Med. 116, 64–72.

Puur, A., Sakkeus, L., Põldma, A., Herm, A., 2011. Intergenerational family constellations in contemporary Europe: evidence from the generations and gender survey. Demogr. Res. 25, 135.

Ramage-Morin, P.L., 2016. Hearing difficulties and feelings of social isolation among Canadians aged 45 or older. Health Rep. 27, 3.

Rossin, M., 2011. The effects of maternity leave on children's birth and infant health outcomes in the United States. J. Health Econ. 30, 221–239.

Schubert, C.R., Fischer, M.E., Pinto, A.A., Klein, B.E.K., Klein, R., Tweed, T.S., et al., 2017. Sensory impairments and risk of mortality in older adults. J. Gerontol. A Biol. Sci. Med. Sci. 72, 710–715.

Sobotka, T., 2017. Childlessness in Europe: Reconstructing Long-term Trends Among Women Born in 1900–1972. Childlessness in Europe: Contexts, Causes, and Consequences. Springer, pp. 17–53.

Solheim, J., Shiryaeva, O., Kvaerner, K.J., 2016. Lack of ear care knowledge in nursing homes. J. Multidiscip. Healthc. 9, 481.

Statistics Norway, 2016. Population Statistics. Oslo, Norway: Statistics Norway.

Stensvold, D., Nauman, J., Nilsen, T.I., Wisloff, U., Slordahl, S.A., Vatten, L., 2011. Even low level of physical activity is associated with reduced mortality among people with metabolic syndrome, a population based study (the HUNT 2 study, Norway). BMC Med. 9, 109.

Strawbridge, W.J., Wallhagen, M.I., Shema, S.J., Kaplan, G.A., 2000. Negative consequences of hearing impairment in old age: a longitudinal analysis. Gerontol. 40, 320–326.

Tamakoshi, A., Tamakoshi, K., Lin, Y., Mikami, H., Inaba, Y., Yagyu, K., et al., 2011. Number of children and all-cause mortality risk: results from the Japan Collaborative Cohort Study. Eur. J. Publ. Health 21, 732–737.

Tambs, K., 2004. Moderate effects of hearing loss on mental health and subjective well-being: results from the Nord-Trøndelag hearing loss study. Psychosom. Med. 66, 776–782.

Van den Berg, G.J., Gupta, S., 2015. The role of marriage in the causal pathway from economic conditions early in life to mortality. J. Health Econ. 40, 141–158.

Wilson, B.S., Tucci, D.L., Merson, M.H., O'Donoghue, G.M., 2017. Global hearing health care: new findings and perspectives. Lancet 390, 2503–2515.

Wood, R.G., Goesling, B., Avellar, S., 2007. The Effects of Marriage on Health: a Synthesis of Recent Research Evidence. Mathematica Policy Research, Washington DC.