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Hearing loss, cognitive ability, and dementia in men age 19–78 years

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Abstract

Hearing loss in later life has been associated with risk of dementia. The impact of risk factors for dementia may change during life, and it is unknown whether hearing loss early in midlife represents a risk factor for dementia. We examined whether hearing loss diagnosed in midlife was associated with an increased risk of dementia. A cohort comprising 942,567 Danish men enrolled in the mandatory conscription board examination was followed from conscription (age 19). Cognitive ability was measured at conscription, while hearing loss was ascertained either by physicians diagnosis at conscription or by the Danish National Patient Registry from 1977 to 2016 (ICD-8:388; 389; ICD-10:H90; H91). Differences in cognitive ability in relation to hearing loss at conscription were calculated using *t* test, while the risk of dementia associated with hearing loss was estimated using Cox regression with adjustment for cognitive ability, education, depression, diabetes, hypertension, and cerebrovascular disease. Men with hearing loss at conscription had about 2 points (corresponding to 0.20 SD) lower mean cognitive score than those without hearing loss. During follow-up, 59,834 men had a hearing loss diagnosis, while 9114 were diagnosed with dementia. Midlife hearing loss was associated with an increased rate of dementia diagnosed before age 60 (adjusted Hazard Ratio (HR) = 1.90 [95% CI 1.59–2.76]) or at a later age (adjusted HR = 1.15 [95% CI 1.06–1.25]). Our study supports the evidence that early identification and correction of hearing loss holds promise for prevention of dementia later in life.

Keywords Cognitive ability · Hearing loss · Dementia · Cohort study

Abbreviations

BPP	Børge Prien Prøve
CI	Confidence interval
DCD	Danish Conscription Database
DCR	Danish Conscription Registry
DNPR	Danish National Patient Registry
HR	Hazard ratio
ICD-8	International Classification of Disease, Eighth Edition
ICD-10	International Classification of Disease, Tenth Edition

Introduction

Hearing loss is one of the most common chronic conditions worldwide [1]. Hearing loss later in life has been associated with an increased risk of dementia [2, 3] and a recent meta-analysis based on three cohort studies provided a pooled risk estimate of 1.94 (95% CI 1.38–2.73) [2]. This relation has been attributed to the increased cognitive load on a vulnerable brain and eventually re-organization and

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reduction of cortical processing with duration of hearing loss [4]. However, the role of risk factors for dementia may change during the life course, and it is unknown if hearing loss in early midlife represents a risk factor for later dementia. Moreover, cognitive impairment -a risk factor for dementia- has been observed in both childhood-onset and adult-onset hearing loss [3], and cognitive load has been suggested to be in the pathway linking hearing loss and dementia [4], but no study has explored the role of cognitive ability on this relation. The aim of this study was therefore twofold. First, we explored if cognitive ability in young adult men was cross-sectionally associated with hearing loss. Secondly, we examined whether hearing loss diagnosed in early and later midlife was associated with an increased risk of incident dementia after adjustment for cognitive ability, educational level, depression, diabetes, hypertension, and cerebrovascular disease.

Methods

Study population

The study was based on data from The Danish Conscription Database (DCD), and the Danish Conscription Registry (DCR) which have been described in detail elsewhere [5]. The **DCD** comprises information from Danish conscription board examinations on nearly all men born 1939–1959 examined from 1957 through 1984 (n = 728,158), while the **DCR** includes data for all men born in 1988–1998 registered at conscription from 2006 through 2015 (n = 351,207). A total of 61,546 (8.5%) men in the DCD and 66,440 (18.9%) in the DCR had missing information on key variables mainly due to lack of registry information for those exempted from the draft board examination due to medical conditions such as intellectual disability, epilepsy or type 1 diabetes. These 127,986 men were excluded from the analyses. Thus, the study population included 666,612 men from the DCD and 284,706 men from the DCR (Fig. 1). The study has been approved by the Danish Data Protection Agency. All data were retrieved from administrative registers and informed consent was not required of participants.

Cognitive measures

Cognitive ability was assessed by the conscription board intelligence test called the Børge Prien Prøve (BPP), which consists of logical, verbal, numerical, and spatial subtests recorded as a total-score with a range of 0–78. The total

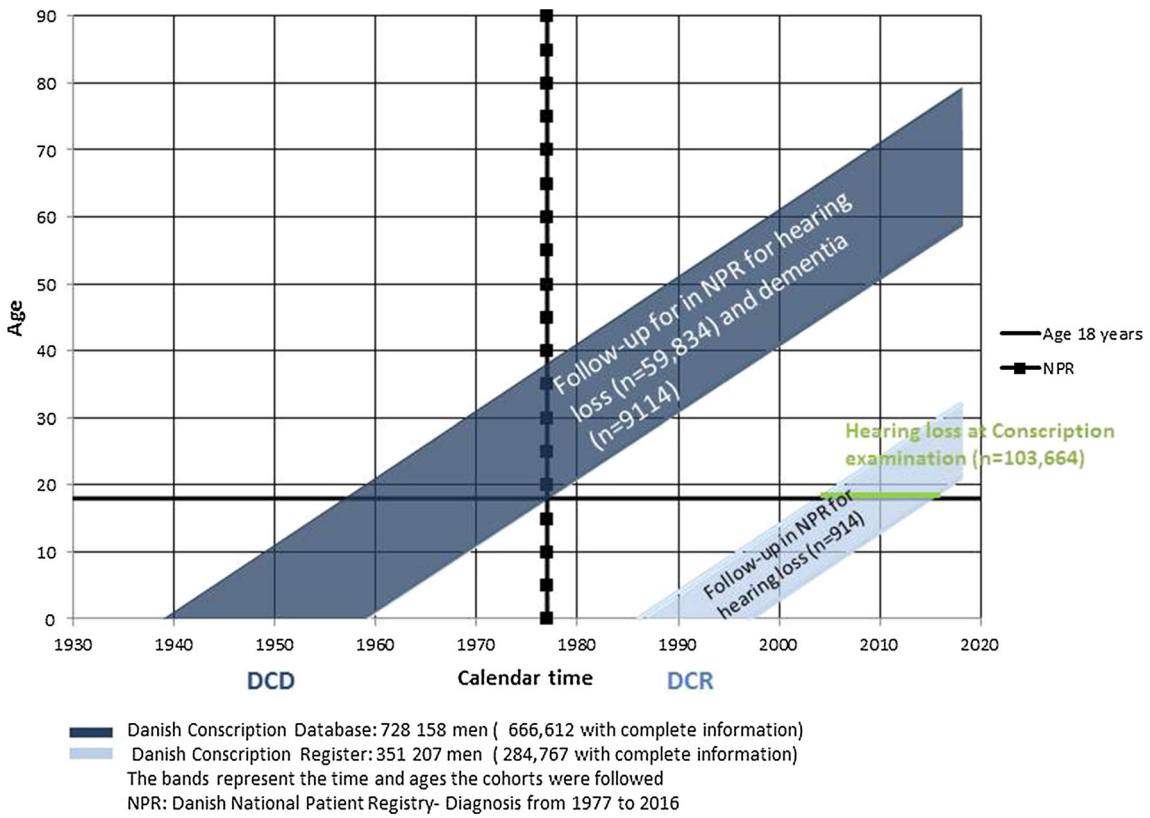

Fig. 1 Overview of conscription examinations and the follow-up for the Danish Conscription Database and the Danish Conscription Registry in the Danish National Patient Registry

BPP score correlates substantially (r = 0.82) with the full-scale Wechsler Adult Intelligence Scale IQ-score (r = 0.82) [6]. The score assesses global intelligence but does not include test of memory.

Hearing loss

Information on hearing loss was obtained from the conscript board examinations and the Danish National Patient Registry (DNPR).

Conscription board examination In the DCD hearing was tested as the ability to hear the medical examiner whisper at a 2 m distance and hearing loss was defined according to a military circular. This information was only available for a subsample of 10,413 men born in 1953. In the DCR hearing loss was diagnosed on the basis of health certificates, subjective reports or an objective health examination including audiometric screening. The recording of the audiogram measurements were undertaken at frequencies 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz. Initial screening were carried out starting at a 20 decibel level. Information on hearing loss was available for all the 284,706 men in the DCR.

DNPR diagnosis of hearing loss Information on any admission to a Danish hospital from 1st of January 1977 until 31st of December 2016 was obtained by record linkage with the DNPR which comprises diagnoses from hospital discharges classified according to the 8th Revision of the International Classification of Disease (ICD8) and the 10th Revision (ICD10) until and from 1995, respectively [7]. Incident cases were defined at the time of the first hospital contact with main or contributory diagnosis of hearing loss (ICD8: 388-389 and ICD10: H90-H91). Thus, the men in the DCD could be followed for hearing loss from between ages 18 (those born in 1959) and 38 (those born in 1939). Whereas the men in the DCR could be followed from birth until time of conscription (Fig. 1).

Dementia (Outcome)

We obtained diagnostic information on all hospital contacts from 1st January 1977 to 30th of April 2016 with ICD-8 code 290 and ICD-10 codes: F00-F03; G30. The validity of dementia diagnoses obtained from the DNPR has been assessed in two studies and they revealed that 70% and 83% of dementia cases diagnosed by an external rater according to ICD-10 conformed to the diagnosis in the register, with the lowest validity in younger patients [7].

Covariates

From the conscription board data we also had information on educational level, which is associated with both early-life cognitive ability as well as hearing loss [5]. Educational level reported at conscription was categorized into low (7–9th grade), medium (vocational training or 10th–11th grade), and high educational level (12th grade or more advanced). Further, information on comorbid depression (ICD8: 296 and ICD10: F31-F34), diabetes (ICD8: 250 and ICD10: E10-E14), hypertension(ICD8: 400-404 and ICD10: I10-I15) and cerebrovascular diseases (ICD8: 430-438 and ICD10: I61-I64) which have been related to hearing loss [8] were retrieved from the DNPR at time of study entry.

Statistical analyses

Cross-sectional association between hearing loss and cognitive ability in young adulthood For the DCR the associations between hearing loss diagnosed at the conscription board examinations or from DNPR and BPP were analyzed using *t* test. For the DCD, the analyses were restricted to the subsample of 10,413 men for whom data on hearing loss was available from the conscription board examination. BPP scores approximated a normal distribution in both samples.

Longitudinal association of midlife hearing loss on first-time hospital contact for dementia The men from the DCR were between 20 and 30 years at the end of follow up and none of them were diagnosed with dementia. Consequently, the analysis was restricted to men from DCD. The association of hearing loss in early and later midlife with subsequent dementia was analyzed using Cox proportional hazard regression models with age as the underlying time scale. Person-years (py) of follow-up were accumulated from age on January 1st 1977 (age 19–39 years) or on the date of the draft board examination, and follow-up was terminated at age of first admission with dementia, death, emigration or end of follow–up (April 1st 2016; age 58–78 years), whichever came first. To account for potential immortal time bias, hearing loss was entered as a time-dependent variable, implicating that individuals diagnosed with hearing loss changed exposure status from non-exposed to exposed at the date of diagnosis. In the adjusted models BPP was entered as a continuous variable and educational level in 3 categories. The initial analysis showed that HRs varied slightly with age at follow-up and consequently data from the DCD was split on follow-up time at age 60 years in order to fulfill the proportional hazard assumption. Men from the DCD who had died (n = 4025) or emigrated (n = 4122) before 1977 were excluded from all analysis. No men were diagnosed with dementia before study entry. All analyses were carried out in STATA version 14.

Table 1 Hazard ratios (HR) and 95% confidence intervals (CI) for the association between hearing loss and incident dementia in 658,465 men from the Danish Conscription Database (DCD)

	Dementia outcomes	
	HR (95% CI)	HR (95% CI)[a]
Age < 60 *years at follow-up* (*number of incident dementia cases* = 3732)		
Hearing loss present	2.32 (1.99–2.71)	1.90 (1.59–2.76)
Per SD increase cognitive ability	0.69 (0.67–0.72)	0.69 (0.66–0.72)
Education		
Middle versus low	0.70 (0.67–0.75)	0.99 (0.91–1.07)
High versus low	0.44 (0.34–0.50)	0.96 (0.84–1.10)
Depression	5.81 (3.44–9.83)	2.58 (1.49–4.46)
Diabetes	8.53 (5.59–13.25)	3.12 (1.91–5.10)
Hypertension	4.67 (3.00–7.25)	1.24 (0.75–2.07)
Cerebrovascular disease	9.22 (5.72–14.86)	3.12 (1.84–5.28)
Age ≥ 60 *years at follow-up* (*number of incident dementia cases* = 5382)		
Hearing loss present	1.39 (1.28–1.50)	1.15 (1.06–1.25)
Per SD decrease cognitive ability	0.81 (0.79–0.84)	0.81 (0.79–0.84)
Education		
Middle versus low	0.88 (0.82–0.93)	1.06 (0.99–1.13)
High versus low	0.70 (0.63–0.76)	1.10 (0.98–1.24)
Depression	4.28 (3.29–5.57)	2.89 (2.19–3.80)
Diabetes	3.23 (2.63–3.96)	2.60 (1.66–2.64)
Hypertension	2.09 (2.63–3.96)	1.13 (0.92–1.39)
Cerebrovascular disease	3.55 (2.87–4.39)	2.31 (1.82–2.91)

[a]Model including hearing loss, cognitive ability, education, depression, diabetes, hypertension and cerebrovascular disease

Results

Cross-sectional relation between hearing loss and cognitive ability in young adulthood

At the conscription board examination (1972–1976), 1194 (11.5%) men from the DCD subsample were diagnosed with hearing loss by the whisper test. These men had a mean BPP of 38.22(SD 12.48), while the 9219 men without hearing loss had 40.23 (SD 11.71) in mean BPP, corresponding to a mean difference of 1.98 (95% CI 1.27–2.69). At conscription board examinations more than 30 years later (2006–2016), 103,664 (36.4%) men from DCR were diagnosed with hearing loss using audiometric screening. These men had a mean BPP of 40.34 (SD 9.72), while the 181,042 men without hearing loss had 41.57 (SD 9.42) in mean BPP, corresponding to a mean difference of 1.22 (95% CI 1.15–1.30). 914 (0.3%) of the men from the DCR had a registration of a hearing loss diagnosis in the DNPR before the conscript board examination. They had been diagnosed at a median age of 8.0 years (IQR 4.8–11.7). These men had a mean BPP of 37.98 (SD 9.64), while the mean BPP for the 283,792 with no hearing loss diagnosis was 41.13 (SD 9.55). Thus, the mean difference was 3.15 (95% CI 2.53–3.77). Mean cognitive scores were similar for men diagnosed with hearing loss before (n = 386; 38.43) or after (n = 528; 37.74) age 7 years.

Hearing loss, and subsequent risk of dementia

Of the 658,465 men from the DCD, 59,834 (9.1%) had been diagnosed with hearing loss between 1977 and 2016 at a median age of 59.9 years (IQR 54.6–65.4). During the follow-up between 1977 and 2016 (median follow-up time of 44.4 years), 9114 (1.4%) of the men were diagnosed with dementia. Hearing loss was associated with increased risk of dementia especially among those diagnosed with dementia onset before age 60 (adjusted HR = 1.90 [95% CI 1.59–2.76]) or at a later age (adjusted HR = 1.15 [95% CI 1.06–1.25]) (Table 1). Adjustment for cognitive ability, education, and comorbidites attenuated the risk estimates with 17%. Eleven % (n = 6607) of the men with hearing loss had been diagnosed before age 50 years. The HRs for dementia were similar for these men compared to those diagnosed at a later age.

Discussion

In this cohort study, men with hearing loss registered at the conscription board examination had around 2 points (corresponding to 0.20 SD) lower mean cognitive score than

those without hearing loss. Hearing loss diagnosed during adult life was associated with an increased rate of dementia. The increase in rate did not differ between those diagnosed with hearing loss in early midlife (before age 50 years) and those diagnosed at a later age.

The inverse association between hearing loss and cognitive ability in young adulthood was seen both in DCD and DCR despite a 30 year span in data collection and use of different hearing loss screening tools. The finding aligns with the results from a number of other cross-sectional studies in populations at different ages [2, 3]. The causal relation between hearing loss and cognitive ability remains unclear, but could either be due to a shared etiology, or the fact that hearing loss causes cognitive reduction through impaired speech perception in younger individuals, while in older people it might be due to the cost of constant effort through increased use of executive function and working memory [4, 9].

The observed association between hearing loss and incident dementia in our study also agrees with previous studies in older populations [2]. The mechanism underlying this relation is also not well understood, but it is likely that the association could be confounded by microvascular pathology, or that hearing loss leads to social disengagement and/or depression [8] which in turn are associated with accelerated brain atrophy [2]. In the present study the risk estimates attenuated with 17% when comorbid depression, diabetes, hypertension and cerebrovascular diseases were adjusted for.

The strength of the present analysis is the large sample size and that information was retrieved from national registers from which we were able to collect data on all hospitalizations for dementia from 1977 with sensitivity measures above 80% [7]. Hearing loss was measured both by audiometric screening and hospital diagnoses. Admittedly, these assessments have not been validated. However, the relatively large difference in the prevalence of hearing impairment related to diagnostic method of 11 and 36% for whisper versus pure tone audiometry, respectively was comparable with previous reports [10]. For the analyses based on hospital diagnoses of hearing loss, we had no information on less severe cases of hearing loss, which might have been diagnosed and treated in primary care. Moreover, we did not have information on whether hearing loss was corrected or not, for example with the help of hearing aids. Such potential misclassification of the exposure might lead to underestimation of risk measures and the interpretation of findings should therefore be done with caution. Dementia is more prevalent in women [2] cand age-dependent gender differences in hearing loss have been reported. Our cohort consisted of men only and the results are not necessarily generalisable to women. However, results from previous cohort studies recently reviewed [2, 3] support that a relationship between hearing loss and risk of dementia also applies to women.

In conclusion, hearing loss was cross-sectionally associated with decreased cognitive ability in young adulthood and hearing loss diagnosed during early and later midlife was associated with higher risk of incident dementia independent of cognitive ability in young adulthood or the age at which hearing loss was diagnosed. This observational study does not provide evidence of effects of hearing treatment on dementia, but the benefits of early screening and management of hearing loss are likely to be significant and without risk.

Authors' contribution Merete Osler (MO) conceptualized and designed the study, acquired the data, carried out the analyses and drafted the initial manuscript. Gunhild Tidemann Christensen (GTC) helped to acquire the data. Maarteen Pieter Rozing was involved in the initial conceptualization of the study. All authors critically reviewed and revised the manuscript and approved the final manuscript as submitted. MO and GTC had complete access to the study data that support the publication.

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Compliance with ethical standards

Conflict of interest None.

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