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Improved hearing in Swedish 70-year olds—a cohort comparison over more than four decades (1971–2014)

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Abstract

Objective: the world population is ageing rapidly. In light of these demographic changes, it is of interest to generate current data regarding the prevalence and characteristics of age-related hearing loss. The purpose of this study was to investigate

hearing acuity and the prevalence of hearing loss in a contemporary age-homogenous cohort of old adults, and to assess secular trends in hearing function during the last half-century (1971–2014).
Methods: we performed a prospective population-based cohort comparison study of unscreened populations. As part of a geriatric population-based study (H70), a new cohort of 70-year olds (n = 1,135) born in 1944 was tested with computerised automated pure-tone audiometry. The hearing thresholds were compared to three earlier born cohorts of 70-year olds, born in 1901–02 (n = 376), 1906–07 (n = 297) and 1922 (n = 226), respectively.
Results: significant improvements in median pure-tone thresholds were seen at several frequencies in both men (range: 5–20 dB, $P < 0.01$) and women (range: 5–10 dB, $P < 0.01$). When investigating the effect of birth cohort on hearing in a linear regression, significant trends were found. Men's hearing improved more than women's. The prevalence of hearing loss declined in the study period (1971–2014) from 53 to 28% for men and 37 to 23% for women ($P < 0.01$).
Conclusions: these results indicate that the hearing acuity in Swedish 70-year olds has improved significantly over more than four decades. The largest improvements were seen at 4–6 kHz in men, possibly reflecting a decrease in occupational noise exposure. Further studies are required to pinpoint the reasons for improved hearing-health among older people.

Keywords: *age-related hearing loss, population-based, cohort comparison, audiometry, older people*

Introduction

Age-related hearing loss (ARHL), or presbyacusis, is of worldwide societal and public health concern. The World Health Organisation (WHO) ranks adult onset hearing loss as one of the principal contributing causes of global burden of disease, particularly in high-income countries [1]. ARHL refers to a symmetrical, slowly progressing decline in auditory function with increased age, predominantly affecting the high frequencies. It hampers communication and social interaction with a negative impact on functioning and reduced quality of life as some of the outcomes [2, 3]. Additionally, there is a growing body of evidence implying that hearing loss—especially untreated—has substantial effects on physical and cognitive health [4–6].

ARHL is highly prevalent among old persons affecting more than 50% of those aged 65 and above [7]. According to a report from the United Nations [8], the number of persons in the world aged ≥60 will more than double from 900 million in 2015 to ~2.1 billion in 2050. As the age structures of global populations shift upwards, up-to-date figures regarding age-related health conditions, like ARHL, are needed. Moreover, in order to gradually assess the hearing rehabilitation needs of older populations, as well as identifying ways of preventing ARHL, it is important to investigate how the prevalence rates change over time. Although, several studies have examined generational trends in prevalence of hearing loss among younger age groups [9, 10], relatively few studies are concerned with old persons [11, 12].

The H70 study is a large-scale gerontological and geriatric population-based investigation [13], which was initiated in the early 1970s aiming to study medical and social aspects of ageing. Participants are recruited from, and representative of inhabitants of Gothenburg, a medium-sized European city, with a population of 5,41,000 in 2014. Since the beginning of the study, several birth cohorts of 70-year olds have been enrolled and followed up longitudinally. The comprehensive study protocol includes physiological and cognitive tests and questionnaires. Efforts have been made to keep the methodology unchanged over the years to enable cohort comparisons. Hearing data have been collected since the beginning of the study [14–17].

The objectives of the present study were to investigate the hearing acuity and prevalence of hearing loss in a contemporary unscreened birth cohort of 70-year olds; and additionally, to assess whether changes in hearing has occurred over the course of the last 4½ decades.

Methods

Participants and procedures

This was a prospective population-based study of an unscreened population of 70-year olds within the H70 framework. A new birth cohort was enrolled in the study in 2014–15. Every 70-year-old in Gothenburg, born during 1944 on pre-specified dates were invited to the examination (n = 1,664). Participants were subjected to a comprehensive test program consisting of physiological and cognitive examinations and interviews. Hearing examination was offered to all participants, and was completed by 1,135 (response rate 68.2%; 535 men and 600 women). Audiometry was not conducted on those requiring home visits, which explains some of the non-response. Other reasons included time constraints or inability to understand the test instructions.

Hearing testing

The hearing protocol consisted of computerised automated pure-tone audiometry, otoscopy and history taking. The tests were conducted by research nurses in a quiet office setting. Support and calibration of the equipment were provided regularly by audiologists. Audiometry was performed with an Entomed audiometer and Sennheiser HDA200 circum-aural headphones. The automated test procedure essentially followed the modified Hughson Westlake method for determining the thresholds, combining descending and ascending series of stimuli [18]. Air-conduction thresholds were obtained at eight test frequencies in the interval of 0.25–8 kHz. The limits of the audiometer were set to 0–90 dB HL.

Cohort comparisons

For the purpose of investigating how hearing acuity and prevalence rates have changed over time, data from the present cohort (H70/44) were compared to three previous H70-cohorts of 70-year olds, born in 1901–02, 1906–07 and 1922, respectively. To get more reliable statistical analyses, the two earliest cohorts were merged into one (H70/01-07). The sampling methods of cohorts H70/01-07 and H70/22 were similar to that of H70/44, with response rates ranging from 69% to 75%. Audiometry was conducted manually on random subsamples (~40%) of the cohorts, with 673 (55% women) of H70/01-07 and 276 (58% women) of H70/22 having completed hearing testing. Audiometry was performed according to standardised methodology (ISO 8253-1) by qualified audiologists using Telephonics TDH-39 headphones in quiet office settings [17].

Statistical analyses

Changes in hearing were studied in the period (1971–2014) by comparing median hearing levels across the test frequencies (left/right, and better/worse ear), using the Mann–Whitney *U*-test. 'Better ear' was defined as the ear with the lowest 8-frequency pure-tone average. Men and women were analysed separately and the significance level was chosen at $P < 0.01$. As hearing thresholds are measured in 5 dB-steps, medians were interpolated according to the method described by Hoffman *et al.* (2010) [9]. Changes in prevalence of hearing loss, defined as a four frequency pure-tone-average (PTA4) >25 dB HL in the better hearing ear [19], were investigated through pairwise comparison with a *Z*-test. The effect of birth cohort on PTAs in the mid-frequencies (0.5, 1 and 2 kHz) and the high frequencies (4 and 8 kHz) was also investigated by testing for linear trends in a regression analysis. Additionally, in order to determine whether there were any gender-based differences, a test of interaction between cohort and gender was added to the analysis. All analyses were carried out using IBM SPSS Statistics 22 [20].

The project was approved by the Regional Ethical Review Board (No. 869-13). All participants gave written informed consent.

Results

Table 1 outlines the median audiometric thresholds of the three cohorts studied, tested in 1971–77, 1922 and 2014, respectively. The same data are displayed graphically in audiogram format in Figure 1. As shown, median thresholds were similar across most frequencies when comparing the two earlier born birth cohorts, with only few exceptions (Table 1). Detailed analyses of these earlier birth cohorts are available elsewhere [17]. In the recent cohort (H70/44), however, an overall decline in median audiometric thresholds—i.e. improved hearing—is apparent at most of the test frequencies, especially in the men. Statistically significant improvements ($P < 0.01$) in the range of 5–20 dB were seen in both ears in the men at 0.25–6 kHz. The most substantial changes affected 4 kHz (left ear: 59.7–45.4 dB, right ear: 59.6–40.2) and 6 kHz (left ear: 64.6–50.2, right ear: 59.8–45.5). No data are available at 6 kHz from one of the previous cohort (H70/01-07) since it was not part of the test protocol. The women of the recent cohort similarly showed improvements in median thresholds, as compared to their earlier born counterparts. The magnitude of the decrease, however, was more modest. Significant changes in the range of 5–10 dB were seen at 0.25, 0.5, 1 and 6 k Hz in the left ear and at 0.25–6 k Hz in the right ear. For the new cohort (H70/44), the 10th, 25th, 75th and 90th percentiles are also given in Table 1. For corresponding values of the earlier born cohorts, see Jonsson *et al.* [17]. Floor effects were observed in the lower frequencies and the highest variability was seen at 8 kHz. Significant linear trends—indicating that the hearing improves as a function of birth cohort—were observed for both $PTA_{0.5;\ 1;\ 2\,kHz}$ and $PTA_{4;\ 8\,kHz}$ in both ears of the men and the women (Table 1).

The prevalence of hearing loss (PTA4 > 25 dB HL in the better hearing ear) also decreased significantly ($P < 0.01$) in the study period, from 53% (95% confidence interval (CI): 0.48–0.59) to 28% (95% CI: 0.24–0.32) for the men, and from 37% (95% CI: 0.32–0.42) to 22% (95% CI: 0.20–0.26) among women (Figure 2). Of those with hearing loss in the recent cohort (H70/44) 21.4, 6.3 and 0.2% of the men had a slight, moderate and severe degree of loss, respectively. The corresponding values for the women were 18.4, 3.2 and 0.2%. None of the subjects had profound hearing loss.

Discussion

Principal findings

This study demonstrates that hearing acuity in 70-year-old Swedes, both in terms of median audiometric thresholds and hearing loss prevalence, has improved significantly over a time period of nearly half a century (1971–2014). To the best of our knowledge, this is the first study to show a clear trend of improved hearing in age-homogenous groups of old persons. The study also provides up-to-date figures regarding age-related hearing function, which may serve as a reference material for health care planning. Employing the hearing loss definition recommended by the WHO (PTA4 > 25 dB HL, better hearing ear), hearing loss prevalence in the most recent cohort (H70/44) was estimated at 27.8% (95% CI: 26.2–30.1) for men and 22.2% (95% CI: 19.9–23.8) for women, which is in line with European estimates of prevalence for this age-group [21].

Comparison with other studies

Medians in both right and left ear were significantly lower (better) at most of the test frequencies in the 1944 cohort

Table 1. Median pure-tone thresholds and pure-tone averages (PTA) in the left/right ear of 70-year olds from three different birth cohorts in the H70 study. Percentiles are shown for the most recent cohort (born in 1944). Medians were compared with the Mann–Whitney *U*-test. Significant improvements ($P < 0.01$) are marked in the table with superscript letters, where *a* means cohort 1901/07 and *b* cohort 1922. Significant linear trends of PTAs are seen for both men and women, suggesting improved hearing

Left ear

		Medians and percentiles													
		0.25 kHz		0.5 kHz		1 kHz		2 kHz		4 kHz		6 kHz		8 kHz	
Cohort	Percentile	M	W	M	W	M	W	M	W	M	W	M	W	M	W
1901–07	50	15.3	19.6	15.1	15.4	15.2	15.1	29.6	24.6	59.7	39.7	–	–	65.4	55.2[b]
1922	50	15.0	15.0[a]	15.1	15.2	15.2	15.4	29.9	24.9	55.2	34.8[a]	64.6	49.6	69.9	60.33
	10	1.4	1.9	1.7	2.4	2.1	3.1	10.9	11.0	28.0	14.9	33.7	20.1	50.8	38.1
	25	1.4	5.6	5.7	5.9	5.9	6.4	16.4	16.9	33.5	18.2	42.6	23.5	55.0	45.4
1944	50	5.4[a,b]	9.6[a,b]	9.8[a,b]	10.0[a,b]	10.0[a,b]	14.5[a,b]	24.8[a,b]	24.9	45.4[a,b]	30.2[a]	50.2[b]	39.8[b]	65.3	55.4
	75	12.3	12.8	13.3	17.2	16.9	21.4	36.1	32.7	56.0	41.1	61.7	51.8	76.1	67.5
	90	13.3	17.8	14.8	22.5	20.3	24.9	55	37.1	66.2	49.6	70.8	53.2	87.0	76.0

		Pure-tone averages (standard deviations)			
		0.5, 1, 2 [kHz]		4, 8 [kHz]	
		M	W	M	W
1901–07		23.6 (15.2)	22.1 (14.4)	59.8 (17.9)	45.9 (17.5)
1922		24.9 (14.3)	21.5 (11.2)	61.5 (15.3)	45.8 (14.9)
1944		18.2 (14.4)	18.4 (12.8)	56.0 (17.6)	43.3 (17.9)
	Linear trend:	−2.9, $P < 0.001$	−1.9, $P < 0.001$	−2.0, $P = 0.001$	−1.3, $P = 0.022$

Right ear

		Medians and percentiles													
		0.25 kHz		0.5 kHz		1 kHz		2 kHz		4 kHz		6 kHz		8 kHz	
Cohort	Percentile	M	W	M	W	M	W	M	W	M	W	M	W	M	W
1901–07	50	19.5	15.5	15.3	15.5	15.5	19.7	25.4	24.9	59.6	35.3	–	–	64.5	54.9
1922	50	14.8[a]	14.9[a]	15.0	15.2	15.2	15.5	25.3	25.2	50.1[a]	34.8	59.8	44.9	65.0	59.8
	10	1.8	3.3	2.0	3.4	1.7	3.2	3.6	9.9	21.8	10.9	27.6	15.1	40.2	34.9
	25	5.5	5.8	5.8	6.2	5.8	6.6	11.3	11.8	31.8	17.7	34.8	23.0	53.5	43.3
1944	50	5.5[a,b]	9.9[a,b]	9.9[a,b]	10.3[a,b]	9.9[a,b]	14.7[a,b]	19.5[a,b]	19.8[a,b]	40.2[a,b]	25.3[a,b]	45.5[b]	35.2[b]	65.0	53.1
	75	12.4	13.5	13.7	17.5	16.3	18.4	26.9	27.6	52.5	36.6	55.9	47.3	76.3	67.4
	90	12.2	19.2	18.7	21.2	26.7	23.9	37.9	35.5	56.5	44.6	57.2	52.7	86.4	73.9

		Pure-tone averages (standard deviations)			
		0.5, 1 and 2 [kHz]		4 and 8 [kHz]	
		M	W	M	W
1901–07		25.3 (17.1)	23.0 (14.2)	58.3 (20.1)	45.5 (17.9)
1922		22.1 (10.9)	23.5 (15.4)	57.0 (15.4)	43.8 (16.2)
1944		16.1 (13.5)	17.2 (11.9)	51.7 (19.1)	41.7 (17.9)
	Linear Trend:	−4.7, $P < 0.001$*	−3.0, $P < 0.001$	−3.4, $P = 0.001$	−1.9, $P = 0.001$

*Men improved more than women, as demonstrated by significant test of interaction ($P = 0.014$)

compared with earlier born cohorts. Interestingly, 8 kHz remained unchanged for both genders. The same pattern was seen in both the better and the worse ear (Figure 1). Results from other similar studies are somewhat conflicting. Rosenhall *et al.* [22] for instance did not find any significant changes in hearing when comparing cohorts of 75-year olds, also from the H70 Study, over a 25-year period, where the participants of the most recent cohort were born in 1930. Trends of improved hearing were, however, reported by Zhang *et al.* [11] who investigated the effect of birth cohort on the prevalence of hearing impairment, by comparing data from the Epidemiology of Hearing Loss Study (EHLS) and the Beaver Dam Offspring Study (BOSS). The latter included the children of the participants in EHLS. The odds of having hearing impairment were 13% lower in men (OR = 0.87, 95% CI: 0.83, 0.92) and 6% lower in women (OR = 0.94, 95% CI: 0.89, 0.98), which according to the authors suggested that older adults may be retaining good hearing longer than previous generations. This is in line with the findings of the present study. Moreover, in the study by Hoffman *et al.* [9] improved hearing was also noted in specific age groups of the American

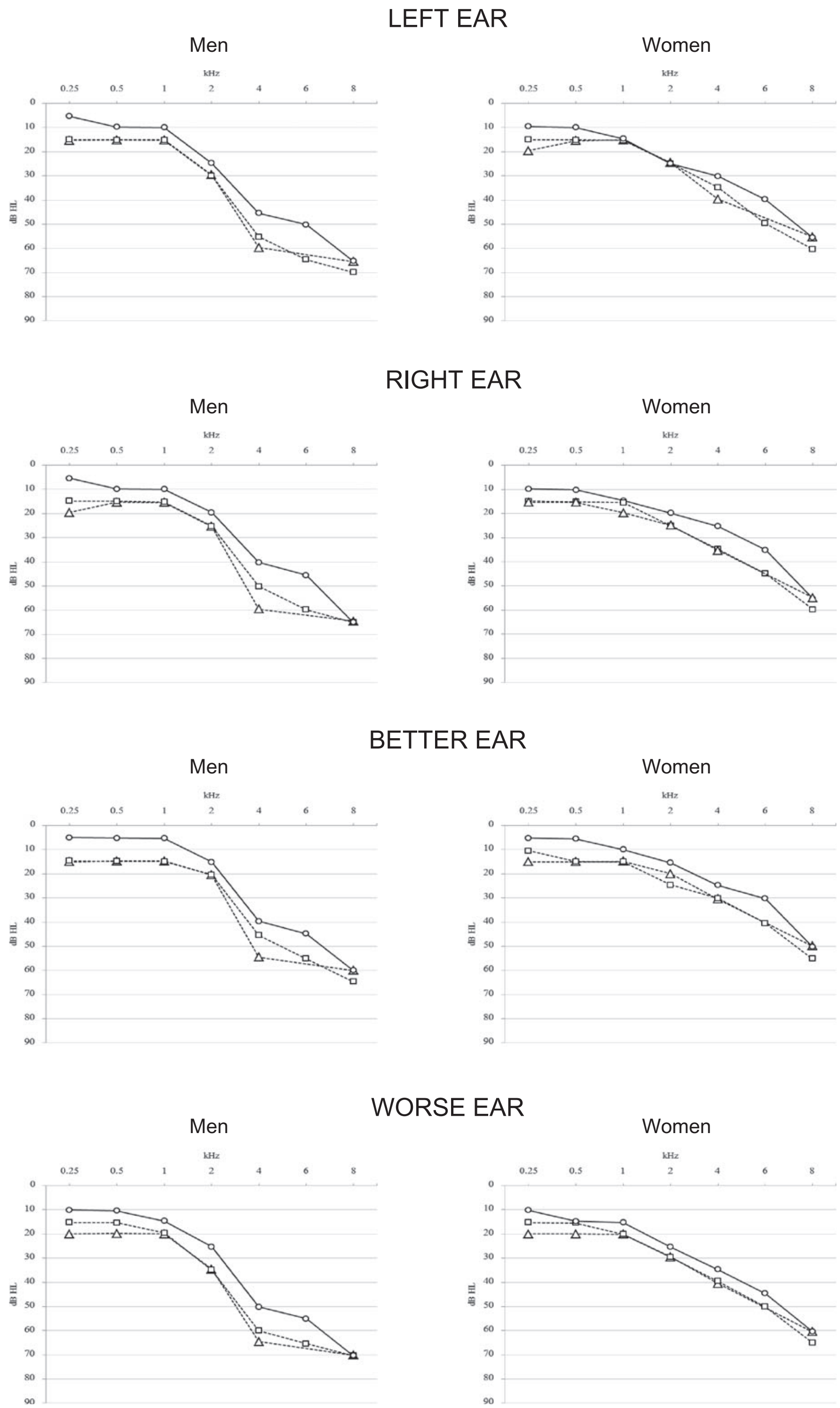
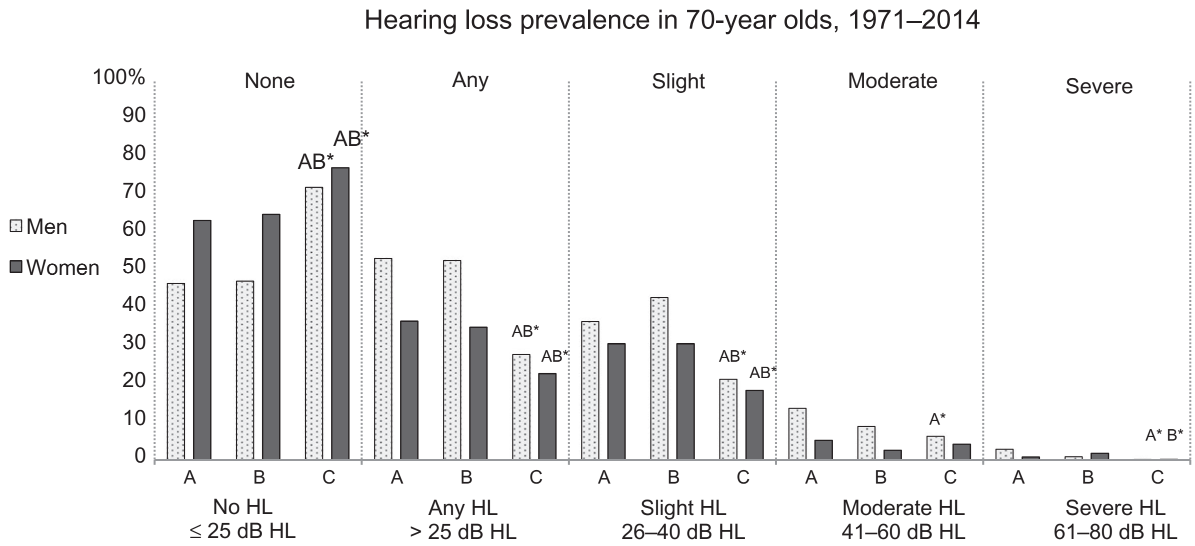


Figure 1. The median pure-tone thresholds by ear and gender in three different cohorts, here displayed graphically in audiogram format. The participants were born in the years 1901–07 (n = 674), 1922 (n = 226) and 1944 (n = 1,135). Significant cohort differences, consistent with improved hearing, were observed at most frequencies. For details refer to Table 1.

population. Additionally, the same authors recently published an updated comparison [23] between the 1999–2004 cycle of NHANES with the most recent 2012–14 cycle, where a decline in hearing loss prevalence was confirmed for the American population (20–69 years of age).

The prevalence of hearing loss also dropped significantly during the study period (range: 15–20 pp., $P < 0.01$), especially for the men. When divided into categories of hearing loss severity (Figure 2), rates of slight and moderate hearing loss were lower in the present cohort. Few participants had



Birth Cohort	M	W	M	W	M	W	M	W	M	W
A. H70/1901-07	46.7	63.3	53.3	36.7	36.6	30.7	13.7	5.2	2.9	.8
(n = 673)	(143)	(233)	(163)	(135)	(112)	(113)	(42)	(19)	(9)	(3)
B. H70/1922	47.3	64.9	52.7	35.1	42.9	30.7	8.9	2.6	.9	1.8
(n = 226)	(53)	(74)	(59)	(40)	(48)	(35)	(10)	(3)	(1)	(2)
C. H70/1944	72.1	77.2	27.9	22.8	21.4	18.4	6.3	4.2	.2	.2
(n = 1126)	(377)	(458)	(146)	(135)	(112)	(109)	(33)	(25)	(1)	(1)

HL = Hearing Loss. M = Men. W = Women

Figure 2. Percentage of participants with and without hearing loss ($PTA_{0.5,\ 1,\ 2,\ 4}$ > 25 dB HL in the better hearing ear) by gender and cohort in the H70 study, covering the time period of 1971–2014. Percentages are also given for hearing loss severities, according to WHOs definition, where slight = 26–40; moderate = 41–60 and severe = 61–80 dB HL. Statistically significant differences between the cohorts are denoted above the bars in the figure, for men and women separately. 'AB' indicates that C is significantly different from both A and B, $^{*}P < 0.01$.

severe hearing loss. Knowledge of the ARHL prevalence is important to be able to estimate hearing rehabilitation needs. Although hearing loss prevalence has declined in 70-year olds, there is still a significant proportion (22–28%) of old persons affected by hearing loss, and as the number of older people continues to expand, the need of rehabilitation will remain high. It is noteworthy that the definition of hearing loss used here (WHO) excludes persons with unilateral hearing loss as well as those with sharply sloping audiogram, groups known to experience disability.

Strengths and limitations

There are both strengths and limitations to this study. A noteworthy strength, which makes this study unique in the context of studies investigating generational trends in ARHL, is that the compared cohorts were age-homogenous, i.e. the participants were of the same age at the time of testing. This is an advantage as age is a strong risk factor for hearing loss and other health conditions. Moreover, participants were recruited and examined in a consistent manner over the years, decreasing the risk for methodological bias. Additionally, response rates in the H70 studies have been generally high, making the findings generalisable. Nevertheless, there were some methodological discrepancies worth considering, which may account for some of the observed difference in hearing function. For instance, in the most recent cohort (H70/44), we conducted automated audiometry as opposed to manual. Previous studies have demonstrated, however, that these methods yield similar results [24]. Furthermore, the audiometry was conducted with sound-dampening circum-aural headphones, in contrast to the less dampening supra-aural headphones that were used in the older cohorts. It is, therefore, not possible to rule out that ambient background noise may have influenced the hearing thresholds in the low frequencies. On the other hand, the testing took place in quiet offices with low ambient noise levels recorded for all of the included cohorts.

Explanatory factors

In this study, the largest improvements of up to 20 dB were seen in men at 4 and 6 kHz (Figure 1), potentially alluding to reductions of noise-induced hearing loss. Noise is one of the main risk factors of hearing loss [25], primarily impairing hearing in this particular frequency region. Historically, more men than women have been exposed to harmful noise, through occupation as well as use of firearms. Half a century ago, the economy of Gothenburg was based on heavy industry to a greater extent than today. Aural health in heavy industry has improved considerably in recent decades because of hearing conservation programmes [26]. Generational improvements in terms of living standards, health care, smoking and nutrition are other important factors to consider. Changes in rates of other medical conditions, like vascular disease, may also be involved. Further analysis of generational changes in the risk factors associated with hearing loss is required to establish the reasons for improved hearing.

The results of the present study may be interpreted in light of the compression of morbidity hypothesis, which posits that the age of onset of chronic illness may be postponed more than the age at death [27]. As a consequence, most of the morbidity in life is compressed into a shorter period with less lifetime disability.

The observation of improved hearing-health in early old age is an important observation on its own merit. However, although not within the scope of this article, future studies should focus on establishing which factors contribute to this development.

Conclusions

Hearing acuity and prevalence of hearing loss in 70-year-old Swedes have improved over the last half-century. The most distinct improvements were seen in men and in the high frequencies. Although the reasons for the improvement were not investigated in this study, the nature of the findings suggests that noise-induced hearing impairment could be an important factor. The findings highlight the importance of modifiable risk factors in the prevention of ARHL. Further research is needed, however, to pinpoint the possible reasons for improved hearing in this age-group. In spite of the decline in prevalence of ARHL demonstrated in this study, the need of hearing rehabilitation remains substantial.

Key points

- Age-related hearing loss is a public health problem which deserves attention as population's age rapidly across the world.
- Hearing among 70-year-old men and women in Gothenburg, Sweden has improved significantly over the last 45 years.
- The amount of people in this age-group in need of hearing rehabilitation remains high, due to the growing number of old persons.

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Conflict of interest

None.

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Development and validation of Visual Impairment as a Risk for Falls Questionnaire

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Abstract

Purpose: visual impairment is associated with an increased risk of falls, yet eye care professionals are infrequently members of falls prevention clinics. The aim of this preliminary study was to validate a newly created Visual Impairment as a Risk for Falls Questionnaire intended to be used by those professionals not involved in eye care.

Methods: about 53 participants with various visual impairments known to be associated with falls and 33 participants with normal sight were contacted within 4 months of a full oculo-visual assessment and were asked the questions from the current questionnaire pertaining to their visual function. A retrospective file review was undertaken and the sensitivity and specificity of participants' responses were calculated compared to the actual vision impairment based on the findings from their visual assessment.