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REVIEW

Prevalence, adverse health, and risk factors in association with sensory impairments: data from a prospective cohort study of older Japanese

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Abstract Sensory impairments, mainly of vision and hearing, are prevalent among the older adults, and are the leading causes of disability in people aged 60 years and above around the world. However, epidemiological data on sensory impairments (prevalence, association with adverse health outcomes, risk and preventive factors, etc.) in community-dwelling older people are sparse in Japan. Using data from the Kurabuchi Study, a community-based prospective cohort study of adults aged 65 years or older, the author and colleagues estimated the prevalence of sensory impairments in this population. Vision and hearing impairments were associated with adverse health outcomes, such as depressive symptoms, dependence in activities of daily living, and early death. In addition, antioxidants, sunlight exposure, hyperglycaemia, and nutritional status were identified as possible risk or preventive factors for vision and/or hearing impairments. Further research is needed into whether the maintenance or improvement of sensory functions contributes to the extension of disability-free life expectancy.

Keywords Vision impairment · Hearing impairment · Prevalence · Activities of daily living · Risk factor

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Introduction

In Japan, life expectancy at birth is increasing yearly, and in 2014 it stood at 80.5 years for men and 86.8 years for women [1]. However, although disability-free life expectancy is also increasing, the difference between expected years with activity limitation and those without has not decreased [2]. Given that the proportion of older people has increased steadily, therefore, extension of disability-free life expectancy is an important issue in public health.

The World Health Organization reported in 2004 that sensory impairments, mainly vision and hearing impairments, were the world's leading causes of disability in people aged 60 years and over [3], so it is reasonable to assume that maintaining or improving sensory functions will increase disability-free life expectancy. However, limited epidemiological data (prevalence, association with adverse health outcomes, risk and preventive factors, etc.) are available on sensory impairments in aged community-dwelling Japanese.

The aims of the present series of studies were to use data from the Kurabuchi Study, a community-based study of older Japanese adults, to (1) estimate the prevalence of sensory impairments, (2) examine the association between sensory impairments and adverse health outcomes, and (3) explore the risk and preventive factors for sensory impairments.

Outline of the Kurabuchi study

The Kurabuchi study is an ongoing community-based prospective cohort study being carried out in Kurabuchi Town, Takasaki City, Gunma Prefecture, Japan, which is located approximately 100 km north of Tokyo. Between

2005 and 2006, public health nurses and local welfare commissioners carried out a home-visit health survey using a structured questionnaire, from which we identified a total of 1294 non-institutionalised and functionally independent residents aged 65 years or older as the eligible population. Of these, 834 (348 men and 486 women, participation proportion = 64.5 %) participated in baseline health examinations at eight separate community centres, and were subjected to multidimensional assessments, such as sensory and physical function. These 834 participants made up the main cohort of the Kurabuchi study. There were no clear differences in age, sex, or self-reported vision and hearing loss between the eligible population and the participating main cohort: the proportions of those aged 80 years or older, men, and those with self-reported vision or hearing loss were, respectively, 28.2, 45.3, 9.1, and 13.5 %, in the eligible population, and 26.4, 41.7, 9.0, and 12.4 % in the main cohort.

In the health examinations, corrected visual acuity at 5 m was assessed with a Landolt broken ring chart using an automatic visual analyser (NS-1100, TOMEY Inc., Nagoya, Japan). Stereoscopic 45° fundus photographs centred on the disc and macula were taken with a non-mydriatic fundus camera (CR-DG10, Canon Inc., Tokyo, Japan). Pure-tone air-conduction audiometry, using an audiometer (AA-56, RION Inc., Tokyo, Japan) with circumaural earphones, and the finger friction test were performed in a separate quiet room. In accordance with Japan's Industrial Safety and Health Law's stipulations on health examinations for workers, we tested a signal with an intensity of 30-dB hearing level (HL) at a frequency of 1 kHz and a signal with an intensity of 40-dB HL at a frequency of 4 kHz. We also measured participants' height, weight, demi-span (the distance from the finger root to the sternal notch), midarm circumference, and calf circumference. Body mass index (BMI) was calculated as weight (kg) divided by the square of height (m) predicted by measurement of the demi-span (predicted height in cm for men = (1.39 × demi-span in cm) + 55.56; that for women = (1.44 × demi-span in cm) + 48.23 [4]), because underestimation of height in older adults with kyphosis results in an overestimation of BMI. A beauty imaging system (a laboratory equipment of Procter & Gamble Japan, Kobe, Japan) was used to measure facial wrinkling as a surrogate marker of lifetime sunlight exposure [5]. In addition, non-fasting blood samples were used to measure albumin levels (by nephelometry) and haemoglobin A_{1c} levels (HbA_{1c}, by high-performance liquid chromatography according to the method of the Japan Diabetes Society; levels were then converted according to the National Glycohaemoglobin Standardisation Program [6]) at a single commercial laboratory (SRL Inc., Tokyo, Japan). Blood levels of the antioxidants, including alpha- and gamma-tocopherols, retinol, beta-cryptoxanthin, alpha- and beta-carotenes, lycopene, and lutein and zeaxanthin, were determined by high-performance liquid chromatography. Our structured questionnaire included socioeconomic and lifestyle-related factors, past/current history of illness, and some well-validated scales, such as the Geriatric Depression Scale (GDS) 5-item version [7] and the Hearing Handicap Inventory for the Elderly-Screening version (HHIE-S) [8].

Among 834 participants of the main cohort, we followed 824 (98.8 %) as of 2010 (10 moved out of Kurabuchi). Follow-up data on the participants included information on (1) death, nursing home admission, and long-term care eligibility (provided by the local government); (2) basic activities of daily living (ADL) according to the Katz index [9], higher-order competence of independence according to the Tokyo Metropolitan Institute of Gerontology Index of Competence (TMIG-IC) [10], and depressive symptoms (GDS 15-item version) [11] obtained from annual home-visit health surveys; and (3) functional evaluation (from repeat health examinations).

The protocol of the Kurabuchi Study was approved by the Ethics Committees of School of Medicine, Keio University (Tokyo, Japan) and School of Medicine, Toho University (Tokyo, Japan).

Findings from the Kurabuchi study

Prevalence of sensory impairments

The prevalence of age-related macular degeneration (AMD), including neovascular AMD and geographic atrophy, is approximately 0.6 % in Asian and Western populations aged 40–79 years [12]. Prevalence increases with age, with Japanese population-based studies indicating a prevalence of 1.1 % in subjects aged 60 years and over (the Hisayama study) [13], and 1.0 % in subjects aged 65 years and over (the Funagata study) [14]. In the Kurabuchi study, an ophthalmologist assessed all fundus photographs according to the definition of AMD in the International Age-related Maculopathy Epidemiologic Study Group's grading protocol [15] and found an AMD prevalence of 1.1 % (95 % confidence interval [CI] 0.5–2.2) [16], which corresponds well with the findings of the two studies mentioned above.

We also estimated the prevalence of age-related hearing loss (ARHL) in the Kurabuchi population. We decided to define participants with ARHL as people who met one or more of the following conditions: (1) failure to hear a 30-dB HL signal at 1 kHz and a 40-dB HL signal at 4 kHz in the better ear; (2) failure of both ears in the finger friction test; (3) selection of "a little difficulty" or "a lot of difficulty" in response to the question, "Do you have difficulty hearing and understanding what a person says to you in a quiet room if they speak normally to you, even when wearing your hearing aid?"; (4) possession of a hearing aid; and (5) a score of 8 or more on the HHIE-S. Of the participants, 26.0 % were, thus, classified as having ARHL [17]. Through hearing assessments by otolaryngologists, we estimated that 11.4 % of the participants needed hearing aids, and that 36.0 % of those in need of hearing aids (4.1 % of the total) had never had one.

Association between sensory impairments and adverse health outcomes

Few data on any association between sensory impairments and adverse health outcomes in Japanese older populations were available. A cross-sectional study of the baseline data from the Kurabuchi study showed that vision impairment (a corrected visual acuity of worse than 0.5 in the better eye) was associated with depressive symptoms (GDS5 score $\geq$2) in women, and that there was an association in men between hearing impairment (a failure to hear a 30-dB HL signal at 1 kHz [the speech frequency of the Japanese language] in the better ear) and depressive symptoms [18]. As of the 3-year follow-up, incidence of dependence in ADL, defined as nursing home admission, long-term care eligibility, and/or impaired basic ADL, or died was 10.8 % [19]. In both sexes, vision impairment was associated with dependence in ADL and death. After adjustment for age, sex, education, marital status, smoking, alcohol consumption, diabetes, and history of major illness, the relative risk (RR) of dependence in ADL and death for vision impairment was 1.60 (95 % CI 1.05–2.44) (Fig. 1). For hearing impairment, an increased risk was observed only in men (adjusted RR = 3.10, 95 % CI 1.43–6.72). These findings suggest that vision and hearing impairments evaluated by objective means are independent factors related to adverse health outcomes in community-dwelling older Japanese, and that the associations between sensory impairments and adverse health outcomes might differ according to sex.

We also studied the participants' subjective evaluations of sensory impairments in the longitudinal analyses. A hearing handicap as assessed by HHIE-S was associated with an elevated risk of depressive symptoms (GDS15 score $\geq$6); the adjusted odds ratio (OR) of depressive symptoms was 2.45 (95 % CI 1.26–4.77) [20]. We found that tinnitus, which is a subjective symptom defined as the perception of sound without external auditory stimulus [21], might be causally associated with depressive symptoms in aged men [22]. Self-reported hearing loss as assessed by a single question was associated with dependence in ADL [23] and a decline in Instrumental ADL (a subscale of the TMIG-IC) [24] over the 3-year follow-up period. We considered, therefore, that subjective measures of hearing impairment are also likely to be useful in predicting future declines in the health of older adults.

Risk or preventive factors for sensory impairments

Because our results indicated that sensory impairments lead to adverse health outcomes in older people, we tried to identify modifiable factors that cause such impairments.

Although the pathogenesis of AMD remains undetermined, oxidative stress is widely considered to be a contributing factor [25]. We investigated the effects of serum antioxidants in preventing AMD, and found that in combination, rather than single, they were inversely associated with AMD prevalence [16]. After adjustment for age, sex, smoking, alcohol consumption, education, hypertension, BMI, total cholesterol, HbA_{1c}, cataract surgery, and outdoor activities, the ORs of a one-category increase in antioxidant tertiles were 0.21 (95 % CI 0.05–0.95) for the

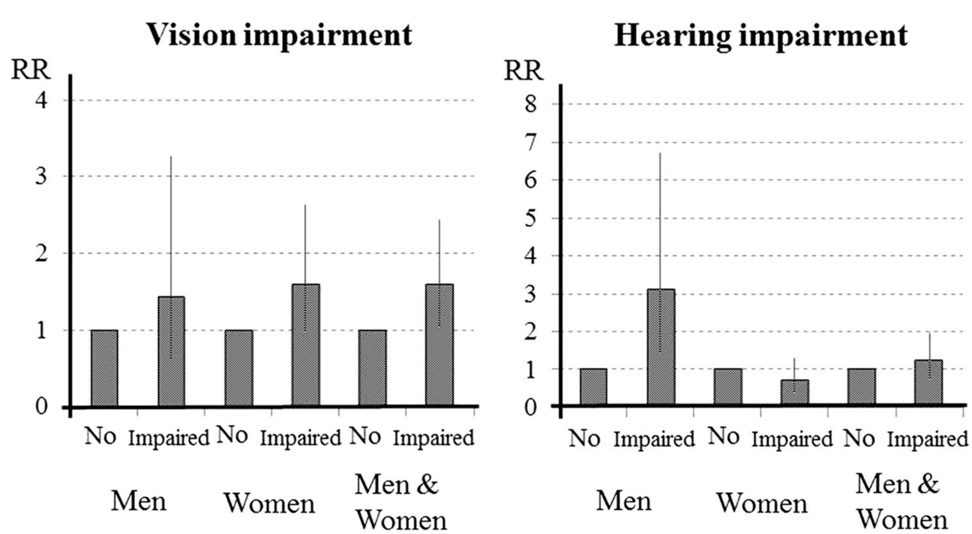

Fig. 1 Association of vision and hearing impairments with adverse health outcomes, including dependence in activities of daily living and death, according to sex [19]. Risk ratios (RRs) of adverse health outcomes were adjusted for age, education, marital status, smoking, alcohol consumption, diabetes, and history of major illness. Vision and hearing impairments were mutually adjusted. Sex was adjusted in the combined-sex analysis. *Error bars* indicate 95 % confidence intervals

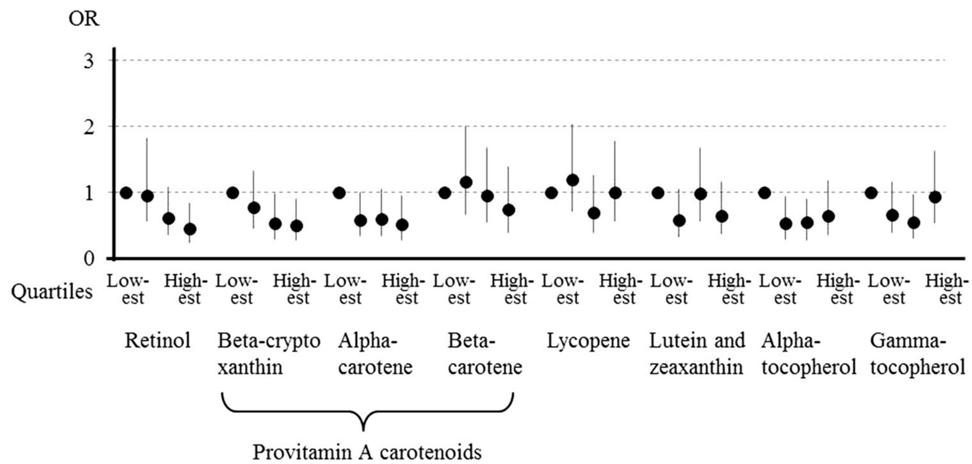

Fig. 2 Cross-sectional association of serum concentrations of retinol, provitamin A carotenoids, and other antioxidants, with hearing impairment [28]. Odds ratios (ORs) of hearing impairment were adjusted for age, sex, smoking, alcohol consumption, hypertension, and total cholesterol. *Error bars* indicate 95 % confidence intervals

carotene family (including alpha- and beta-carotenes and lycopene), and 0.19 (0.04–0.86) for the carotenoid family (including beta-cryptoxanthin, alpha- and beta-carotenes, lycopene, and lutein and zeaxanthin).

With respect to hearing impairment, we thought that vitamin A (retinol), sunlight exposure, hyperglycaemia, and nutritional status might be risk or preventive factors. First, we focused on retinol, because the inner ear has high concentrations of retinol [26], and because retinoic acid (an active metabolite of retinol) has been shown to induce regeneration of rat hair cells [27]. As we expected, increased concentrations of retinol were associated with a decreased prevalence of hearing impairment (defined as a failure to hear a 30-dB HL signal at 1 kHz and a 40-dB HL signal at 4 kHz in the better ear) (Fig. 2) [28]; the adjusted OR for the highest versus lowest quartile category was 0.45 (95 % CI 0.24–0.84). A similar preventive effect was also observed for provitamin A carotenoids (beta-cryptoxanthin and alpha-carotene).

Second, we hypothesized that sunlight exposure leads to hearing impairment through systemic oxidative stress, so we examined the cross-sectional association between facial wrinkling, a surrogate marker of long-term exposure to sunlight, and hearing impairment [29]. As compared with the men in the lowest tertile for wrinkling, the adjusted OR of hearing impairment in the highest tertile was 2.16 (95 % CI 1.00–4.66) (Fig. 3). This positive association was particularly clear in the participants with low concentrations of serum antioxidants. Among the women, wrinkling was not associated with hearing impairment. One possible explanation for this is that we did not adjust sufficiently for sunscreen or cosmetic use in the women, because we did not collect detailed information about sunscreen or cosmetic use.

Third, we investigated the role of hyperglycaemia in hearing impairment. Although hyperglycaemia in diabetes is thought to lead to microangiopathy of the cochlea,

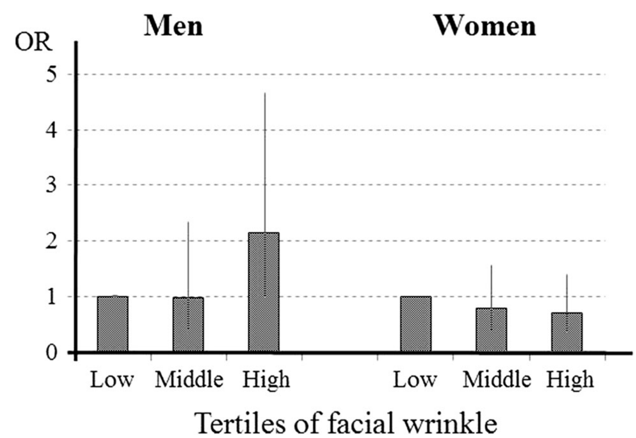

Fig. 3 Odds ratios (ORs) and 95 % confidence intervals for the association between facial wrinkle and hearing impairment in men and women [29]. ORs of hearing impairment were adjusted for age, smoking, sunscreen or foundation use, depressive symptoms, provitamin A carotenoids, and total cholesterol. *Error bars* indicate 95 % confidence intervals

resulting in hearing impairment, the temporal association between diabetes and ARHL remains unclear [30]. When we used HbA_{1c} levels as an index of glycaemic exposure, we found that they were positively associated with the prevalence of hearing impairment (Table 1) [31]. Using data from repeat health examinations after 4 years, we also observed the positive association between HbA_{1c} levels and the incidence of hearing impairment. This association persisted, even after the participants with a self-reported history of diagnosed diabetes were excluded. These findings support the theory of a causal association between diabetes and hearing impairment.

In light of recent evidence of an association between diet quality and hearing impairment [32, 33], we investigated four markers of overall nutritional status, including a serum biomarker (albumin) and three anthropometric indices (BMI, midarm circumference, and calf circumference), in association with the 4-year incidence of hearing

Table 1 Cross-sectional and longitudinal association between haemoglobin A_{1c} (HbA_{1c}) and hearing impairment [31]

HbA_{1c}	Cross-sectional analysis (n = 831)				Longitudinal analysis (n = 338)			
	n	Prevalence (%)	Model 1[a] OR (95 % CI)	Model 2[b] OR (95 % CI)	n	4-year incidence (%)	Model 1[a] OR (95 % CI)	Model 2[b] OR (95 % CI)
<5.6 % (<38 mmol/mol)	412	18.0	Reference	Reference	168	14.3	Reference	Reference
5.6–5.9 % (38–41 mmol/mol)	246	15.0	1.10 (0.68–1.79)	1.10 (0.67–1.80)	108	16.7	1.53 (0.75–3.10)	1.50 (0.73–3.08)
6.0–6.4 % (42–47 mmol/mol)	92	23.9	1.65 (0.88–3.07)	1.67 (0.87–3.18)	30	16.7	1.16 (0.37–3.61)	1.20 (0.38–3.80)
≥6.5 % (≥48 mmol/mol)	81	19.8	1.72 (0.80–3.70)	1.92 (0.83–4.46)	32	25.0	2.62 (0.84–8.15)	2.66 (0.80–8.91)
1.0 % increase			1.30 (1.00–1.68)	1.35 (0.99–1.86)			1.52 (1.03–2.23)	1.51 (1.00–2.28)

CI confidence interval, *OR* odds ratio

[a] Adjusted for age, sex, self-reported history of diagnosed diabetes, education, smoking, occupational noise exposure, provitamin A carotenoids, total cholesterol, and facial wrinkle

[b] Excluded the participants with a self-reported history of diagnosed diabetes

Table 2 Odds ratios (ORs) and 95 % confidence intervals (CIs) for the association between markers of nutritional status and 4-year incidence of hearing impairment [34]

	Incident cases of hearing impairment/ number of participants	OR (95 % CI)[a]
Albumin (g/dl)		
>4.0	38/274	Reference
≤4.0	17/64	2.18 (1.05–4.57)
Body mass index (kg/m^2)		
≥23.0	27/165	Reference
21.0–22.9	7/72	0.58 (0.23–1.44)
19.0–20.9	10/63	0.81 (0.33–1.97)
<19.0	11/38	2.72 (1.10–6.71)
Midarm circumference (cm)		
≥22.0	50/315	Reference
21.0–21.9	2/14	0.79 (0.15–4.08)
<21.0	3/9	4.08 (0.89–18.63)
Calf circumference (cm)		
≥31.0	39/262	Reference
<31.0	16/76	1.90 (0.92–3.95)

[a] Adjusted for age, sex, education, smoking, occupational noise exposure, haemoglobin A_{1c}, provitamin A carotenoids, total cholesterol, and facial wrinkle

impairment [34]. As compared with the reference group (albumin levels > 4.0 g/dl, BMI ≥ 23.0 kg/m^2), the multivariable-adjusted ORs of hearing impairment were 2.18 (95 % CI 1.05–4.57) in the albumin ≤4.0 g/dl group, and 2.72 (1.10–6.71) in the BMI < 19.0 kg/m^2 group (Table 2). For midarm circumference and calf circumference, these marker values tended to be inversely associated with hearing impairment.

Future directions

Since vision and hearing impairments were independent factors in association with adverse health outcomes, these impairments could be targets of the intervention for the extension of disability-free life expectancy. Further research is needed to examine whether maintaining or improving sensory functions can contribute to the extension of disability-free life expectancy.

Also, we should pay attention to olfactory and taste impairments that were not assessed in the Kurabuchi study. A self-administered questionnaire survey of 2791 residents aged 40 years or older (85 % of all eligible residents) of Koumi Town, Nagano Prefecture, Japan in 2010 revealed that olfactory and taste impairments were unexpectedly common, and their prevalence increased with age [35]. Olfactory and taste impairments are known to be associated with quality of life [36]. Epidemiologic evidence also exists of an association between olfactory or taste impairments and adverse health conditions, such as dependence in ADL [37], cognitive impairment [38], and hypertension [39]. We will continue to investigate the health effects of individual and combined sensory impairments, including olfactory and taste impairments, and attempt to clarify the risk and preventive factors.

Conclusion

The author and collaborators estimated the prevalence of AMD and ARHL in a Japanese older population. Our findings suggested that vision and hearing impairments should be considered as independent factors related to adverse health outcomes, and that there were several modifiable risk and preventive factors for sensory impairments.

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Compliance with ethical standards

Conflict of interest The author declares no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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