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Assessment of sensory impairment in older adults with dementia

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A R T I C L E I N F O

Keywords:
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Olfactory loss
Color vision

A B S T R A C T

Background: Over 55 million people worldwide are living with dementia. The rate of cognitive decline increases with age, and loss of senses may be a contributing factor.
Objectives: This study aimed to analyze hearing, olfactory function, and color vision in patients with dementia.
Materials and methods: The sample comprised 40 patients with dementia and 37 cognitively normal controls aged 41–85 years. All participants underwent conventional pure-tone audiometry and a screening version of the Hearing Handicap Inventory for Adults, the Odorized Markers Test of olfactory function and the Ishihara color vision test. The effects of comorbidities and lifestyle factors were also assessed.
Results: Patients with dementia had significantly worse hearing at almost all frequencies tested and significantly greater olfactory impairment than cognitively normal controls. Color vision impairment was found in less than 8% of the sample, with no significant difference between the groups. Impairment of two senses (hearing and olfaction) was significantly more common in patients with dementia than in controls.
Conclusion: Individuals with dementia were found to have sensory decline, namely hearing and olfactory impairment. Color vision was rarely impaired in the sample. Participants with dementia tended to have more multisensory impairments than controls.

1. Introduction

As the organism ages, changes in physical function occur, comorbidities affecting health increase, cognitive decline sets in, and the incidence of chronic diseases rises. While a slower ability to process information, difficulty finding appropriate words, or mild and short-term memory loss are part of normal aging and are often seen in older adults around the age of 80, dementia cannot be considered a consequence of the physiological aging process (Jaul and Barron, 2017). Rates of dementia increase with age, and according to the most recent data from 2023, more than 55 million people are living with dementia worldwide (World Health Organization, 2023). Dementia is also the seventh leading cause of death and one of the major causes of disability and dependency globally (World Health Organization, 2023). Although age is the most important factor in the development of dementia, it can also occur in younger people. Up to 9% of cases are early-onset, with symptoms appearing before the age of 65 (World Health Organization, 2017). Dementia is responsible for 11.9% of all years lived with disability due to a non-communicable disease, and its rates are expected to keep rising as global life expectancy continues to increase (World Health Organization, 2017).

Age, genetic factors, and female sex are considered to be non-modifiable risk factors for dementia (Janoutová et al., 2021; World Health Organization, 2017). Modifiable risk factors specific to dementia include cognitive inactivity, social isolation, depression in middle age, and lower education (World Health Organization, 2017). There is also an association with vascular risk factors, such as coronary heart disease, which has been found to be more prevalent among dementia patients

Abbreviations: ARHL, age-related hearing loss; dB, decibel; ENT, ear, nose, and throat; HHIA-S, Hearing Handicap Inventory for Adults – screening version; Hz, hertz; ISO, International Organization for Standardization; kHz, kilohertz; n, number; OMT, Odorized Markers Test; SD, standard deviation; WHO, World Health Organization.

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compared to cognitively normal controls (Janoutová et al., 2021).

The relationship between sensory impairment and the risk of dementia is also being investigated. There is a confirmed association between the presence of cognitive decline or dementia and hearing impairment (Chern and Golub, 2019; Deal et al., 2016; Dupuis et al., 2015), olfactory impairment (Huart et al., 2015; Kovalová et al., 2024; Lu et al., 2019; Roberts et al., 2016; Vasavada et al., 2015), and color vision impairment or other visual problems (Anang et al., 2014; Campos et al., 2019; Pache, 2003; Salamone et al., 2009; Salobrar-García et al., 2019). In addition, it has been reported that the risk of dementia may increase with the number of senses impaired, although the nature of this relationship is still not fully understood (Brenowitz et al., 2019).

The objectives of the study were to evaluate hearing threshold, olfactory performance, and color discrimination in individuals diagnosed with dementia and to verify the usefulness of pure-tone audiometry, the Hearing Handicap Inventory for Adults, the Odorized Markers Test, and the Ishihara color vision test as screening tools in seniors with dementia. Finally, the study aimed to compare the prevalence of multisensory impairment relative to the presence of dementia.

2. Materials and methods

Patients from neurology departments of two healthcare institutions were recruited for the study. Diagnosis of dementia and age over 40 years were the inclusion criteria. The main exclusion criterion was having severe dementia causing an inability to communicate and complete all tests. Patients with asymmetrical hearing loss and those with hearing, color vision, or olfactory impairments diagnosed in early working age were also excluded. Data were collected over a period of more than two years in collaboration with two neurology and ear, nose, and throat (ENT) departments.

2.1. Data collection and processing

Patients' hearing threshold was measured using pure-tone audiometry, and subjective hearing loss was determined with a questionnaire. Olfactory performance was evaluated with the Odorized Markers Test, and color vision with the Ishihara test. Information on participants' health status and comorbidities was obtained from their medical records, and information on their lifestyle was provided by interview. The study was conducted in accordance with the Declaration of Helsinki (World Medical Association, 2022). Prior to the assessments, participants were informed about the procedure and gave written consent for the processing of the acquired data. All subjects had the opportunity to ask questions and/or request to be excluded from the study at any time and without giving reasons.

2.2. Hearing test

All eligible participants underwent pure-tone audiometry with a range of eight conventional frequencies (i.e., 0.250, 0.5, 1, 2, 3, 4, 6 and 8 kHz). The Madsen Astera^2 audiometer was used along with Sennheiser HDA300 headphones. Testing was performed in a soundproof audiology booth, and the ear identified by the participant as the better-hearing one was always tested first. The results were recorded separately for the left and right ears, and the hearing loss was expressed in decibel (dB) hearing levels on an audiogram. The measurements were performed according to ISO 8253-1, 2010 Acoustics – Audiometric test methods (ISO 8253-1, 2010, 2010) and ISO 266, 1997 Acoustics – Preferred frequencies (ISO 266, 1997, 1997). The standards were last reviewed and confirmed in 2021 (ISO 8253-1, 2010, 2010) and 2023 (ISO 266, 1997, 1997), respectively, and can be considered up-to-date.

A quick and simple tool to determine the ability to understand human speech is the standardized Hearing Handicap Inventory for Adults (Kovalová et al., 2022). It allows for a quick assessment of subjective speech understanding and perception in both hearing-impaired and normal-hearing individuals (Kovalová et al., 2022). Developed and published in 1990 by Newman, Weinstein and Jacobson (Newman et al., 1990), it has been translated into many languages and abridged to allow its use for screening purposes (HHIA-S). It has proven useful in both working-age adults and seniors over 65 years of age (Kovalová et al., 2022).

2.3. Olfaction test

Olfactory performance was assessed with the Odorized Markers Test (OMT), invented and implemented by Czech experts (Brothánková et al., 2022; Vodička et al., 2007). It is considered to be a simple, accessible and easy-to-use method. The principle of this test consists in naming the smells of six individual markers by the patient. The markers also differ in color, with the black marker smelling of licorice, the brown one of cinnamon, the red one of strawberry, the blue one of blueberry, the yellow one of lemon, and the green one of apple. In the first part of the test, the subject identifies the odors spontaneously; in the second part, they choose from a list of four options (corresponding in color to the color of the marker), with only one being correct. In the first part, the subject receives one point for each different specific name, and in the second part for choosing the correct option. The maximum number of points obtained in the test is 12, the minimum is 0 (Brothánková et al., 2022). A score of 9–12 points is considered normal, a range of 6–8 suggests hyposmia, and a score of 0–5 indicates anosmia (Brothánková et al., 2022). Participants were instructed not to smoke prior to testing. The test was administered by trained ENT staff in a quiet room with adequate ventilation.

2.4. Color vision test

To examine color vision, one of the most widely used screening methods, the Ishihara test with pseudoisochromatic plates (Birch, 1997; Van Staden et al., 2018), was used. Each plate presents a numeral or shape composed of colored dots on a background of contrasting dots, and the subject is asked to identify that numeral or shape (Van Staden et al., 2018). The plates are designed to be used in an environment with adequate daylight. If electric lighting is used, it must approximate daylight as closely as possible to achieve valid results.

A version with 14 plates with numerals was used for testing. The participant was seated in a quiet room with adequate lighting, at a reasonable distance of $\pm$70 cm from the plate, which was perpendicular to their line of sight. Each image was presented to the participant for a maximum of 4 s. None of them reported wearing glasses with colored filters that could distort the result.

2.5. Statistical analysis

Hearing levels (dB) obtained by pure-tone audiometry were compared between patients with dementia ($n = 40$) and healthy controls ($n = 37$). For the purpose of statistical analysis, hearing loss was classified according to WHO's grades of hearing impairment (Olusanya et al., 2019), defined as the averages of values at 500, 1000, 2000 and 4000 Hz in the better ear. If the difference between the average values for the left and right ears was greater than 15 dB, the participant was excluded from the study. Data were exported to Microsoft Excel 2016, where basic descriptive statistics were calculated. Full statistical evaluation was performed using descriptive statistics, chi-squared test, nonparametric Mann–Whitney test, and Fisher's test in Stata v.13. Data were tested at a 5% significance level.

3. Results

3.1. Characteristics of participants

A total of 77 participants (57.1% men) older than 40 years were recruited for the study. The sample consisted of patients with dementia treated in a neurology department (51.9%) and cognitively normal controls (48.1%). The study group consisted of 13 (32.5%) patients with Alzheimer's dementia, followed by 11 (27.5%) patients with vascular dementia, 5 (12.5%) with mixed dementia, 2 (5.0%) with Lewy bodies dementia, 1 (2.5%) with dementia in Parkinson's disease and 1 (2.5%) with Frontotemporal dementia. The remaining subjects had dementia due to other unspecified causes. Due to the low number of patients in each category, more detailed statistical analyses for each group were not performed.

The mean age of all participants was 71.17 (SD 9.71) years, with a significant difference ($p = 0.016$) between those with dementia and controls. Socioeconomic characteristics and lifestyle factors for each group are shown in Table 1.

Statistical comparison of the study groups with respect to socioeconomic factors (education, type of work, family status) and lifestyle factors (physical activity, leisure activities, smoking) revealed differences in the way they spent their leisure time. Surprisingly, compared to cognitively normal controls, significantly more patients with dementia reported reading ($p = 0.006$) and solving crosswords ($p = 0.043$) in their leisure time (see Discussion). However, cognitively normal controls reported more leisure-time sports ($p = 0.025$), with cycling, swimming and hiking being the most common. In addition, statistically significantly more controls reported engaging in other leisure-time physical activities ($p = 0.032$), most commonly gardening, walking or travelling. From a socioeconomic perspective, there was a non-significantly higher proportion of controls living alone in their household and a non-significantly lower proportion of controls with only physical jobs. Of the 77 participants, 62 (80.5%) suffered from hypertension, 20 (26.0%) from atherosclerosis, 11 (14.3%) from coronary heart disease, and 7 (9.1%) from peripheral artery disease, with no significant difference between patients with dementia and controls. There were 49 (63.6%) participants with a history of stroke; for this comorbidity, a highly significant difference ($p < 0.001$) was observed between patients with dementia and controls, with the latter being more affected. However, this difference may be explained by the fact that both the patients with dementia and the cognitively normal controls were recruited from neurology department patients, with the majority of controls being followed up specifically for a history of stroke.

Table 1
Characteristics of participants.

		Dementia n (%)	Controls n (%)	p-value
Total participants		40 (100)	37 (100)	
Women		19 (47.5)	14 (37.8)	0.392[a]
Mean age ±SD		73.77 ± 7.78	68.35 ± 10.86	**0.016**[b]
Education	elementary school	11 (27.5)	10 (27.0)	0.962[a]
	high school or university	29 (72.5)	27 (73.0)	
Type of work	only physical	21 (52.5)	17 (45.9)	0.565[a]
	both physical and mental	19 (47.5)	20 (54.1)	
Family status	living alone	15 (37.5)	19 (51.4)	0.221[a]
	living with someone	25 (62.5)	18 (48.6)	
Physical activity	sports	23 (57.5)	30 (81.1)	**0.025**[a]
	other physical activity	12 (30.0)	20 (54.1)	**0.032**[a]
Leisure activities	reading	23 (57.5)	10 (27.0)	**0.006**[a]
	solving crosswords	16 (40.0)	7 (18.9)	**0.043**[a]
	attending cultural events	10 (25.0)	4 (10.8)	0.142[c]
Smoking	smokers	6 (15.0)	12 (32.4)	0.070[a]
	non-smokers	21 (52.5)	15 (40.5)	0.293[a]
	ex-smokers	13 (32.5)	10 (27.0)	0.600[a]
Cardiovascular diseases	hypertension	33 (82.5)	29 (78.4)	0.648[a]
	atherosclerosis	10 (25.0)	10 (27.0)	0.839[a]
	history of stroke	16 (40.0)	33 (89.2)	**<0.001**[c]
	coronary heart disease	7 (17.5)	4 (10.8)	0.520[c]
	peripheral arterial disease	1 (2.5)	6 (16.2)	0.050[c]

n = number of participants; SD = standard deviation.
[a] Chi-squared test.
[b] Nonparametric Mann–Whitney test.
[c] Fisher's test; significance level 5%.

3.2. ENT examination

Otoscopy and rhinoscopy revealed six and 20 pathologies, respectively. The most common ear pathology was sequelae of otitis (6.5% of participants), and the most common disorder of the nose was a deviated septum (18.2%). No significant difference in their presence was observed between patients with dementia and controls (Table 2). None of the participants had undergone nasal or ear surgery in their lifetime.

3.3. Hearing test

All 77 participants were able to complete pure-tone audiometry without major difficulty. It revealed the presence of some degree of hearing impairment in almost 65% of them (Table 3). Some hearing impairment was defined as a loss of more than 25 dB in the better hearing ear (Olusanya et al., 2019). Among cognitively normal controls, significantly more individuals had no hearing impairment ($p = 0.016$), and there were nonsignificantly more patients with dementia in each impairment subgroup (Table 2).

Audiometry thresholds of patients with dementia were compared to those of cognitively normal controls separately for each frequency. Both ears were tested (i.e., left and right ear values for each participant). Table 3 shows the numbers of ears tested and the proportion of ears with a response at each frequency. Significantly poorer hearing thresholds were found in patients with dementia at almost all frequencies, except at 0.25 kHz, where the difference was on the borderline of statistical significance (Table 3).

The mean HHIA-S scores were not significantly different between the study groups ($p = 0.509$). Although all participants were able to

Table 2
Results of ENT examination and tests used.

		Dementia n (%)	Controls n (%)	p-value
Total participants		40 (100)	37 (100)	
Ear pathology		5 (12.5)	1 (2.7)	0.202[a]
Nasal pathology		11 (27.5)	9 (24.3)	0.750[b]
HHIA-S mean score ±SD		5.12 ± 9.87	5.35 ± 10.86	0.509[c]
HI (WHO)	no impairment	9 (22.5)	18 (48.6)	**0.016**[b]
	slight impairment	17 (42.5)	13 (35.1)	0.507[b]
	moderate impairment	11 (27.5)	4 (10.8)	0.086[a]
	severe impairment	3 (7.5)	2 (5.4)	1.000[a]
OMT	mean score ±SD	5.42 ± 3.35	9.10 ± 2.37	**<0.001**[c]
	normosmia	9 (22.5)	26 (70.3)	**<0.001**[b]
	hyposmia	13 (32.5)	8 (21.6)	0.284[b]
	anosmia	18 (45.0)	3 (8.1)	**<0.001**[a]
Color vision impairment		3 (7.5)	3 (8.1)	1.000[a]

n = number of participants; SD = standard deviation; HI (WHO)=World Health Organization's grades of hearing impairment (i.e., averages of values at 500, 1000, 2000 and 4000 Hz in the better ear); HHIA-S=Hearing Handicap Inventory for Adults – screening version; OMT=Odorized Markers Test.
[a] Fisher's test.
[b] Chi-squared test.
[c] Nonparametric Mann–Whitney test; significance level 5%.

Table 3
Average hearing thresholds at individual frequencies in patients with dementia and cognitively normal controls.

	Frequency [kHz]	Dementia AHT (min; max)	Responding ears n (%)	Controls AHT (min; max)	Responding ears n (%)	p-value
Pure-tone audiometry	**0.25**	24 (5; 65)	80 (100)	21 (0; 80)	74 (100)	0.050[a]
	0.5	29 (10; 70)	80 (100)	22 (0; 80)	74 (100)	**<0.001**[a]
	1	31 (0; 75)	80 (100)	24 (5; 70)	74 (100)	**0.002**[a]
	2	40 (10; 80)	80 (100)	32 (5; 70)	74 (100)	**0.012**[a]
	3	49 (10; 85)	80 (100)	42 (10; 80)	74 (100)	**0.028**[a]
	4	54 (15; 95)	80 (100)	43 (10; 80)	74 (100)	**0.002**[a]
	6	58 (15; 100)	80 (100)	47 (5; 90)	71 (95.9)	**0.002**[a]
	8	66 (20; 100)	80 (100)	48 (10; 105)	71 (95.9)	**<0.001**[a]

n = number of ears; kHz = kilohertz; AHT = average hearing threshold.
[a] Nonparametric Mann–Whitney test; significance level 5%.

complete the HHIA-S, the results differed from the pure-tone audiometry results. Audiometry revealed some degree of hearing loss in 31 patients with dementia (77.5%), compared to only eight (20.0%) identified with the HHIA-S. Similarly, 19 controls (51.4%) had some degree of hearing loss according to audiometry, but in only seven (18.9%) was detected by the HHIA-S. Some of the participants who scored 0–8 points on the HHIA-S (i.e., no impairment) actually had hearing loss, some of them severe, and that almost all of those scoring 10–24 points on the HHIA-S score of (i.e., slight to moderate impairment) in fact had moderate to severe hearing loss. Thus, pure-tone audiometry was more sensitive in detecting hearing loss.

3.4. *Olfaction test*

The OMT results showed that significantly more patients with dementia suffered from olfactory impairment (Table 2). Cognitively normal controls scored highly significantly better (9.10 ± 2.37 points) than patients with dementia ($p < 0.001$). Based on their OMT scores, participants were classified into three basic categories (i) normosmia, or normal sense of smell (n = 35; 45.5%); (ii) hyposmia, or decreased ability to smell (n = 21; 27.3%); and (iii) anosmia, or significant impairment or even loss of smell (n = 21; 27.3%). Statistically significantly more patients with dementia had anosmia compared to cognitively normal controls ($p < 0.001$); the proportion of individuals with hyposmia did not differ significantly between the two groups. OMT proved to be a sufficiently sensitive method and its usefulness was confirmed both in elderly patients with dementia who were able to complete the test without complications and in cognitively normal controls. The OMT scores and the average hearing loss in the better ear in patients with dementia and controls are shown in Fig. 1.

3.5. *Color vision test*

The number of participants with a 100% pass rate on the Ishihara test was surprisingly high at 47 (61%), meaning that less than 40% made at least one mistake. However, only six individuals (7.8%) showed results suggestive of color vision impairment, evenly distributed between the dementia group (n = 3) and the control group (n = 3). Given the very small number of participants with impaired color vision, no further in-depth analyses were performed.

3.6. *Multisensory impairment*

A comparison of average hearing loss, OMT results, and presence of color vision impairment between patients with dementia and controls is shown in Fig. 2.

Fig. 2 shows that of the 50 individuals with some degree of hearing loss, the majority (n = 35; 70%) also had olfactory impairment, mostly those with dementia (n = 24; 68.6%). Color vision impairment (black mark in Fig. 2) was rare, with four participants having slight hearing impairment, and three having olfactory impairment. A comparison of participants with respect to multisensory impairment is shown in Table 4.

As seen in Table 4, just under a quarter of the sample (24.7%) were completely free of sensory impairment, with a statistically significantly higher proportion of cognitively normal controls ($p = 0.003$). A very significantly higher proportion of individuals with two impaired senses was observed among those with dementia ($p < 0.001$).

4. Discussion

Sensory impairments have been reported to be associated with a higher risk of dementia (Luo et al., 2018), and hearing loss has been specifically mentioned in this context (Loughrey et al., 2018). Although a number of screening tools, such as the whispered voice test (Labanca et al., 2017) or screening questionnaires (Kovalová et al., 2022; Newman et al., 1990), are used to detect hearing impairment in both the working-age population and older adults, pure-tone audiometry is considered the gold standard in the assessment of hearing loss. In the present study, pure-tone audiometry results confirmed that greater hearing loss can be observed in older adults with dementia at almost all conventional frequencies in the 0.25–8 kHz range. Significant decreases in hearing thresholds were observed at higher frequencies (Table 3), where age-related hearing loss (ARHL) is manifested. It is this type of hearing impairment that has been found to be associated with increased rates of cognitive decline (Gurgel et al., 2014; Lin et al., 2013; Loughrey

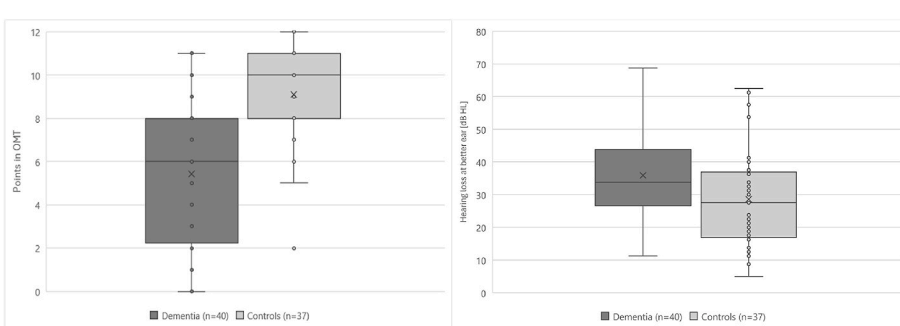

Fig. 1. Comparison of average hearing loss in dB in the better ear (right) and OMT scores (left) in patients with dementia and cognitively normal controls.

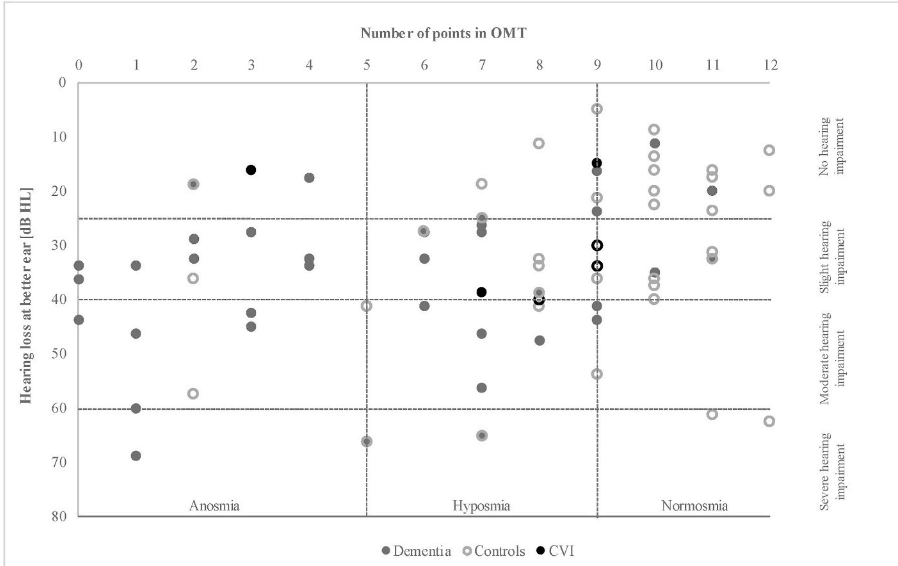

Fig. 2. Representation of hearing, olfactory and color vision impairment (CVI) across participants.

Table 4
Presence of multisensory impairment in patients with dementia and controls.

	Dementia	Controls	Total	p-value
	n (%)	n (%)	n (%)	
Total participants	40 (100)	37 (100)	77 (100)	
No sensory impairment	4 (10.0)	15 (40.5)	19 (24.7)	**0.003**[a]
One sense impaired	8 (20.0)	12 (32.4)	20 (26.0)	0.213[b]
Two senses impaired	27 (67.5)	9 (24.3)	36 (46.8)	**<0.001**[b]
Three senses impaired	1 (2.5)	1 (2.7)	2 (2.6)	1.000[a]

n = number of participants.
[a] Fisher's test.
[b] Chi-squared test; significance level 5%.

et al., 2018). A 2017 meta-analysis based on the results of 40 studies reported that ARHL is a modifiable risk factor for cognitive decline and dementia (Loughrey et al., 2018). Additionally, the risk increases with the severity of hearing loss (Lin et al., 2013). However, the mechanism of this association is not clearly understood. It has been hypothesized that cognitive decline and ARHL are a consequence of neurodegenerative pathology (Fischer et al., 2016). Some experts believe that ARHL could be used as an early marker for the development of dementia (Albers et al., 2015; Gurgel et al., 2014).

Besides hearing loss, olfactory (Pacyna et al., 2023) or color vision (Anang et al., 2014) impairments have also been discussed as such potential early markers. The sense of smell is quite often impaired in Parkinson's patients (Doty, 2012). It is a so-called non-motor symptom that appears ahead of motor symptoms (Doty, 2012). In the case of Alzheimer's disease, olfactory impairment may predict the transition from mild cognitive impairment to Alzheimer's dementia (Quarmley et al., 2016). Unlike pure-tone audiometry for detecting hearing loss, there is no gold standard for olfactory impairment. Numerous olfaction tests, such as the Sniffin' Sticks Test (Lojkowska et al., 2011; Paschen et al., 2015), the University of Pennsylvania Smell Identification Test Dulay et al. (2008); Vasavada et al. (2015), the Cross-Cultural Smell Identification Test (Lee et al., 2014), or the Open Essence test (Makizako et al., 2014), have repeatedly proven useful. The present study showed that the OMT, invented and implemented by Czech experts (Brothánková et al., 2022; Vodička et al., 2007), is a suitable, simple and accessible method to assess the sense of smell in the elderly. This test was able to detect olfactory impairment in 54.5% of the sample, with significantly more olfactory impaired participants suffering from dementia (Table 2). The dementia group had even more individuals with anosmia than with hyposmia (Table 2). Significantly more patients with dementia had simultaneous impairment of two senses ($p < 0.001$) compared to the control group (Table 4). Multisensory impairment has been reported to be strongly associated with an increased risk of developing dementia (Brenowitz et al., 2019).

To detect color vision impairment, the present study used the Ishihara test, one of the most widely applied tools. The test was selected to verify the hypothesis that a greater degree of color vision impairment is seen in people with cognitive decline (Salamone et al., 2009; Pache, 2003). This hypothesis failed to be confirmed as the test showed color vision impairment in only less than 8% of the participants, with the prevalence being the same in both the dementia group and the control group. The question is whether the results obtained would have been different had a different color vision test been used. However, in perspective of the suitability of the Ishihara test for this study group, it should be added that all participants quickly understood the test and readily cooperated. The fact that all of them had previously taken the Ishihara test at least once considerably facilitated their compliance. From this perspective, the Ishihara plates proved to be suitable even for seniors with cognitive decline. Compliance would perhaps be affected by using the different color vision test.

Another interesting finding was the significantly higher prevalence of athletes in the control group. Although there are different views in the literature on the relationship between physical activity and dementia, the results of meta-analyses support this association between physical activity, cognitive decline and dementia (Blondell et al., 2014). Older physically active adults are more likely to maintain their cognitive level than those who do not exercise (Livingston et al., 2017). Results from another meta-analysis showed that physical activity has a protective effect against cognitive decline (Sofi et al., 2011). It should be added that physical activity alone has a positive effect on improving balance, reducing falls and other outcomes in the elderly (Livingston et al., 2017). A surprising result was observed regarding hobbies and leisure activities, as significantly more patients with dementia in the present study reported reading ($p = 0.006$) and solving crosswords ($p = 0.043$) in their leisure time, which is in contrast to previously published results from a larger cohort (Janoutová et al., 2021). The explanation for this difference is questionable, but it may be due to the small number of participants in our study groups.

Sensory impairment and its relationship to cognitive impairment have long been the subject of interest and research. However, more research is needed to establish clear causal mechanisms and clarify this association.

4.1. Limitations

(i) The relatively small number of participants (n = 77) is one of the limitations of this study.
(ii) Another one is the difference in mean age between patients with dementia (73.77 ± 7.78 years) and controls (68.35 ± 10.86 years).
(iii) Finally, it is the risk of selection bias, as participants were recruited from hospital neurology departments. This explains the significantly higher prevalence of stroke among cognitively normal controls, since a high proportion of neurology patients without dementia are those followed up after stroke.
(iv) No analyses regarding color vision impairment were performed because the small number of participants in each group would have reduced the statistical power of such a comparison, rendering it meaningless.

5. Conclusion

The study found that patients with dementia had poorer hearing and smell than cognitively normal controls. However, no difference was observed in the presence of color vision impairment. Patients with dementia tended to have multisensory impairment compared to controls, while there were more individuals without sensory impairment in the control group. Although the association between hearing impairment and cognitive decline is frequently encountered and reported, the exact mechanism is still not understood and therefore requires further attention and research.

Informed consent statement

Informed consent was obtained from all subjects involved in the study.

Institutional review board statement

The study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics Committee of Palacký University Olomouc.

Data availability statement

The study materials and the details of all analyses are available from the corresponding author upon reasonable request.

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