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Odor Detection Thresholds in a Population of Older Adults

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Abstract

OBJECTIVE—To measure odor detection thresholds and associated nasal and behavioral factors in an older adult population.

STUDY DESIGN—Cross-sectional cohort study

METHODS—Odor detection thresholds were obtained using an automated olfactometer on 832 participants, aged 68–99 (mean age 77) years in the 21-year (2013–2016) follow-up visit of the Epidemiology of Hearing Loss Study.

RESULTS—The mean odor detection threshold (ODT) score was 8.2 (range: 1–13; standard deviation = 2.54), corresponding to a n-butanol concentration of slightly less than 0.03%. Older participants were significantly more likely to have lower (worse) ODT scores than younger participants ($p<0.001$). There were no significant differences in mean ODT scores between men and women. Older age was significantly associated with worse performance in multivariable regression models and exercising at least once a week was associated with a reduced odds of having a low (≤5) ODT score. Cognitive impairment was also associated with poor performance while a history of allergies or a deviated septum were associated with better performance.

CONCLUSION—Odor detection threshold scores were worse in older age groups but similar between men and women in this large population of older adults. Regular exercise was associated with better odor detection thresholds adding to the evidence that decline in olfactory function with age may be partly preventable.

Keywords

Odor threshold; Olfaction; Aging; Epidemiology; Population

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Level of Evidence: 3b

INTRODUCTION

Without the most basic component of olfaction, the ability to sense an odor is present, the ability to detect smoke, gas, toxins or spoiled food or enjoy food or pleasant odors may be severely impacted and pose risks to health, safety, nutrition and quality of life. (1–3) However, determining odor detection thresholds, the weakest concentration a person can reliably detect, can be a time-consuming and complicated process and has not been part of large epidemiologic studies. Odor identification tests, which take less time and are easier to administer, have been included in several large population studies. (4–9) From these studies we have learned that dysfunction of odor identification is common among older adults and identified several risk factors, some modifiable, associated with this dysfunction. These types of data are lacking for odor thresholds.

Although odor detection and identification functions are inherently related, findings from identification studies may not uniformly apply to odor detection thresholds. Previous studies have reported odor detection thresholds impacted earlier (10), or to a greater degree (11), with age than odor identification, suggesting age may differentially impact these olfactory functions. Additionally, odor detection thresholds are likely more sensitive to the functionality of the olfactory epithelium than odor identification tests, which utilize suprathreshold levels of odorants. Therefore, odor detection thresholds may be influenced more than odor identification by factors that potentially affect the olfactory epithelium such as infections, inflammation or environmental factors.

Previous studies of odor detection thresholds have been mostly limited to smaller studies using convenience samples or selected populations or studies conducted to test methods or provide normative data. (12–16) These studies have reported worse odor detection among older age groups (12–16) but, in contrast to odor identification studies, no difference in ability between men and women. (13, 16) Other studies of odor detection thresholds and specific conditions have reported nasal sinus disease (17), alcohol dependence (18) smoking (19–20) and neurodegenerative diseases (21–22) associated with poorer odor thresholds. However, results from many of these studies may not be applicable to the general population. Identifying potential factors associated with odor detection thresholds is important as studies of highly-selected healthy older adults suggest some ‘age-related’ decline in olfactory function may be preventable.(23, 24)

Epidemiological studies are necessary to determine the distribution of odor detection thresholds at a population level and identify potential risk factors associated with odor detection dysfunction. The availability of commercial odor detection threshold kits and automated olfactometers has made the administration of odor detection threshold testing process easier to accurately administer and therefore more amenable to inclusion in large epidemiological studies. The objective of this study is to determine the distribution of odor detection thresholds in an older adult population and associated nasal health and behavioral factors.

METHODS

Data for the current study were collected as part of the 21-year follow-up examinations (2013–2015) of participants in the Epidemiology of Hearing Loss Study (EHLS). This population-based study of sensory health and aging in Beaver Dam, WI began in 1993 with examinations approximately every 5 years and participation over 80% at each phase.(25–28) Informed consent was obtained from all participants prior to examination and approval for this research was obtained from the Health Sciences Institutional Review Board of the University of Wisconsin. Examination and interview data were obtained by trained and certified examiners using standardized protocols.

Odor detection thresholds were determined using the automated OLFACT-RL™ (Osmic Enterprises Inc, Cincinnati, OH) olfactometer. The stimuli consisted of a series of 12 binary dilutions of a 4% vol/vol butanol solution (n-butyl alcohol in light mineral oil). Level 1 was the strongest (4% vol/vol) and level 13 the weakest concentration (0.001% vol/vol). Osmic enterprises, Inc. prepared the solution, verified the concentrations by photoionization detection and refilled them in the OLFACT-RL™ as needed during the examination period.

The OLFACT-RL™ was designed to be self-administered however, due to the older age of the EHLS population, a trained examiner assisted all participants with computer entry and ensured participants were positioned correctly during testing. Prior to the test, all participants viewed standard video instructions and completed a practice trial provided by the OLFACT-RL™ program.

The OLFACT-RL™ employs a single staircase, two-alternative forced choice threshold test procedure. The test began at level 8 (0.03%) and was responsive to how well a participant performed. Participants were presented with two puffs of air, one a blank and the other containing butanol. If the participant correctly selected the puff containing butanol two trials in a row, then a one-step weaker concentration was presented in the subsequent trial. If the puff with the butanol was not identified correctly in the first trial, the concentrations increased by two steps in each subsequent trial (level 6, 4, 2, etc), until a correct response was made and the procedure reversed or there were four presentations at the highest concentration (level 1) and the test was stopped. After the first reversal an error resulted in a one-step stronger concentration being presented in the next trial. The test continued until there were 3 reversals, or 4 consecutive presentations at level 1. The odor detection threshold (ODT) score, the weakest concentration of n-butanol a participant could detect, was defined as the mean of the levels (1–13) of the last 2 reversals. Therefore, a higher ODT score reflects greater sensitivity and a lower ODT score reflects less sensitivity.

Covariates

Odor identification ability was assessed with the eight item San Diego Odor Identification Test (SDOIT). (4, 29, 30) Odors were presented in random order with a 45 second delay between odors to minimize adaptation. A 20 item picture array was used to aid identification and allow for nonverbal responses. The SDOIT score is the number of odorants correctly identified (0–8) after two trials. (4, 29)

Height and weight were measured and Body Mass Index (BMI) was calculated as kg/m^2. Participants were classified as cognitively impaired if they scored <24 on the Mini-Mental State Exam (MMSE) (31) or there was a self- or surrogate-report of Alzheimer's disease or dementia. Self-reported medical and behavioral health histories were obtained by interview. Nasal health information included a history of allergies, sinus infections, head injury (concussion, broken nose, skull fracture), nasal polyps, deviated septum and current use of oral or nasal steroids. Recent nasal congestion was defined as a sinus infection or cold or sinus problems in the past week or nasal congestion on the day of examination. Behavioral information included exercise (at least once a week long enough to work up a sweat) (32), smoking history (current, past, never), environmental tobacco smoke exposure (none/little, moderate/high or current smoker) (33) and history of heavy alcohol use (4 or more drinks per day).

Statistical Analyses

All analyses were performed using SAS, version 9.4 (SAS Institute, Inc., Cary, NC). Participants who elected to complete the full examination at the study site were eligible to do the odor threshold test. Mean ODT scores stratified by age and sex were estimated using the least squares mean method. Correlation between the ODT and SDOIT scores were estimated using the Pearson correlation coefficient. To evaluate associations between nasal health and behavioral factors and ODT scores, the score was modeled as both a continuous and dichotomous outcome using linear and logistic regression, respectively. Covariates were first assessed in individual age- and sex adjusted models and then in multivariable models. All multivariable models were adjusted for cognitive impairment because of the known strong association between cognitive impairment and olfactory impairment in this population (34) and the potential for cognitive impairment to impede test performance ability. Two sensitivity analyses, one adjusting for solution batch and one excluding participants with cognitive impairment, were conducted on the final multivariable models.

As the ODT scores were based on a series of 1:2 dilutions of butanol; with the first dilution being one-half the original and the second being one-quarter the original and similarly for all 12 dilutions, the Log base 2 transformed concentration of butanol corresponding to the ODT score was used as the outcome measure. We used linear regression to model covariate relations with the geometric mean concentration, a commonly used measure of central tendency. By exponentiation of the estimated regression coefficients, final linear regression results are presented as percent change in the geometric mean of butanol concentration necessary for detection.

For the logistic regression models, we modelled the odds of having a low ODT score (higher concentration required for detection) for the covariates of interest. A low ODT score was defined as ≤ 5 which represented the lowest 10% of the population. Odd Ratios (ORs) and 95% confidence intervals (CIs) were computed using the parameter estimates and their standard errors.

RESULTS

Of the 864 participants who attempted the odor threshold test, 832 (96%) had complete test results and 32 had incomplete results either due to the participant electing not to complete the test or technical issues with the OLFACT-RL™. The 832 participants with complete data are included in these analyses. Participants were a mean age of 77 years (68–99 year) and 42% were men (Table 1).

Distribution of Odor Detection Threshold Scores

The distribution of ODT scores is shown in Figure 1. The overall mean ODT score was 8.2 (range: 1–13; standard deviation = 2.54), corresponding to a n-butanol concentration of slightly less than 0.03%. Mean ODT scores by age and sex are shown in Table 2. Older participants were significantly more likely to have lower ODT scores (worse detection threshold) than younger participants($p<0.001$) with those aged 68–74 years having a mean score of 8.7 as compared to 6.9 among participants aged 85 years and older. There was no difference in overall mean ODT scores between men and women ($p=0.53$).

The ODT score and SDOIT score were correlated with an age- and sex-adjusted Pearson correlation coefficient of 0.43 ($p<0.001$). Participants who scored poorly on the odor identification test (0–2) had a mean ODT score of 4.6 compared to 6.8 and 8.7 for those who had SDOIT scores of 3–5 or 6–8, respectively.

Butanol Concentration

In linear regression analyses including age and sex, for every 5-year increase in age a 44% higher ($p<0.0001$) mean concentration of butanol was necessary for detection but there was no sex difference ($p=0.22$). In individual age- and sex-adjusted models, a history of allergies was associated with a 24% ($p=0.03$) lower, and cognitive impairment was associated with a 341% ($p<0.001$) higher, mean concentration necessary for detection. There were no significant associations with a history of nasal polyps, deviated septum, head injury, heavy drinking, smoking, ETS exposure, exercise, recent nasal congestion, BMI or use of nasal or oral steroids in age- and sex-adjusted models. In the multivariable model, older age and cognitive impairment continued to be significantly associated with a 43% ($p<0.0001$) and 156% ($p=0.02$) higher, respectively, and allergies with a 22% ($p=0.048$) lower, mean concentration of butanol necessary for detection. (Table 3)

Low ODT Score

In a logistic regression model including age and sex, older participants were significantly more likely to have ODT scores ≤5 (Odds Ratio (OR) =1.41, 95% Confidence Interval (CI) = 1.19, 1.67, for every 5 years age) but there was no association with sex (OR=1.39, 95% CI= 0.90, 2.16, men vs women). In individual age- and sex-adjusted models, participants who exercised at least once a week (OR=0.45, 95% CI=0.27, 0.76) and those who reported a history of a deviated septum (OR=0.20, 95% CI= 0.05, 0.84) were less likely to have a low ODT score whereas those with cognitive impairment (OR=5.07, 95% CI= 2.15, 11.98) were significantly more likely to have a low ODT score. Smoking, ETS exposure, oral or nasal steroid use, BMI, a history of a head injury, heavy alcohol use, nasal polyps, or allergies or recent nasal congestion were not significantly associated with having a low ODT score in age- and sex-adjusted models. In the multivariable model older participants (OR=1.34, 95% CI= 1.11, 1.61, for every 5 years of age) remained significantly more likely to have a low ODT score. Participants who exercised (OR=0.48, 95% CI= 0.28, 0.81) or had a history of a deviated septum (OR=0.23, 95% CI=0.06, 0.99) remained less likely to have a low ODT score. (Table 4) Although the estimate for cognitive impairment remained elevated (OR= 2.50, 95% CI=0.81, 7.72), it was attenuated and not significant in the multivariable model. The estimates for exercise were similar in a multivariable model excluding participants with cognitive impairment.

The final multivariable linear and logistic regression models were re-run including an indicator variable for batches of solution used to refill the olfactometer and results were similar (not shown).

DISCUSSION

In this study, we present what we believe to be the first general population data on odor detection thresholds in older adults obtained with an automated olfactometer. Older age was significantly associated with worse detection function in both linear and logistic regression analyses. There were no significant differences in mean ODT scores between men and women. The range of threshold scores indicated that even in the oldest age group some participants retained good function.

These results are consistent with previous studies that were smaller or, as in the normative studies, had fewer older participants. (12–16, 35) The National Social Life, Health and Aging project (NSHAP) recently administered a modified butanol detection test with 6 concentrations of n-butanol (0.13%–8.0%) presented in an ascending manner to over 2,000 participants aged 62–90 years and also reported worse function at older ages and no differences in ability between men and women. (36) The olfactometer used in the current study utilized 13 concentrations of n-butanol ranging from 0.001% to 4.0% and our results demonstrate there is wide variability in olfactory detection function among older adults.

On a population level few studies have evaluated factors associated with odor detection thresholds. We evaluated associations between detection thresholds and factors previously associated with odor identification (e.g., nasal health history and behavioral factors such as smoking, history of heavy alcohol use, head injury, BMI and exercise). (4, 29, 32,) In the current study, we found exercising at least once a week was associated with reduced odds of having a low ODT score (worse threshold), though it was not associated with butanol concentration in the linear regression models. Exercise, while associated with impaired olfactory function, may not have a direct linear relationship with odor detection thresholds across the full spectrum of olfactory function. The results from this study are similar to previous findings in this population with odor identification. (29, 32)

A history of a deviated septum was associated with decreased odds of a low ODT score and a history of allergies was associated with a lower butanol concentration necessary for detection. These may be chance findings as the results were not consistent across the linear and logistic regression models, were borderline significant and are discordant with previous findings with odor identification in this population. (29,32) Alternatively, participants with a positive history of these conditions may have benefitted from previous treatment for these conditions. We did not collect information about surgical intervention for deviated septum or immunotherapy for allergies. As well, participants with diagnosed conditions may be more likely to be care seekers and therefore have better health overall resulting in slightly better olfactory function as compared to their peers.

Recent nasal congestion, a history of nasal polyps, head injury, smoking and ETS exposure, heavy alcohol use and current use of nasal or oral steroids and BMI were not significantly associated with odor threshold in this study. Smoking was previously associated with the prevalence of olfactory impairment in this population, but not the 5- or 10 – year incidence. (4, 29, 32) Other studies of smoking and olfaction also had mixed results. (5, 13, 19, 20)

Cognitive impairment was significantly associated with lower ODT scores in this study. Although the primary focus of this study was to assess nasal health and modifiable behavioral risk factors and odor thresholds, cognitive impairment was included in these analyses because of the age of the population and known association between olfaction and cognitive impairment and neurodegenerative diseases. (34, 21, 37–38) Although odor threshold tests are thought to require less cognitive load than identification tests, they still require the participant to attend to the task for a period of time, have the ability to identify and remember which puff of air contained the stimuli and communicate this information. Therefore, pathological changes to areas of central olfactory processing due to age or neurodegenerative disease (39, 40) might affect threshold results and these tests should be used and interpreted carefully in people with impaired cognitive function. (41)

There are several limitations in this study that should be noted. No data were available on history of chronic rhinosinusitis or frequent upper-respiratory infections, nasal health conditions that may affect olfactory function. Participants in the EHLS are largely non-Hispanic white and therefore these results may not be generalizable to other populations. Finally, the results may slightly underestimate dysfunction in the population as some participants with poor health did not complete the full 2.5 hour study examination.

Strengths of this study include the large well-defined population-based cohort with high retention over 21 years. (25–28) Participants ranged from early to late old age with good representation even among those over 85 years of age and there was variability of thresholds allowing for analyses of both the threshold (concentration) and extremely low scores. Odor detection thresholds were measured using a standardized protocol and validated instrument and extensive covariate data were available for analyses.

Conclusion

This large study of older adults found odor detection thresholds were worse (less sensitive) in older age groups in a general population. These changes were similar between men and women. Regular exercise was associated with better odor detection thresholds adding to the evidence that decline in olfactory function with age may be partly preventable. Further research is needed to confirm these results in other populations.

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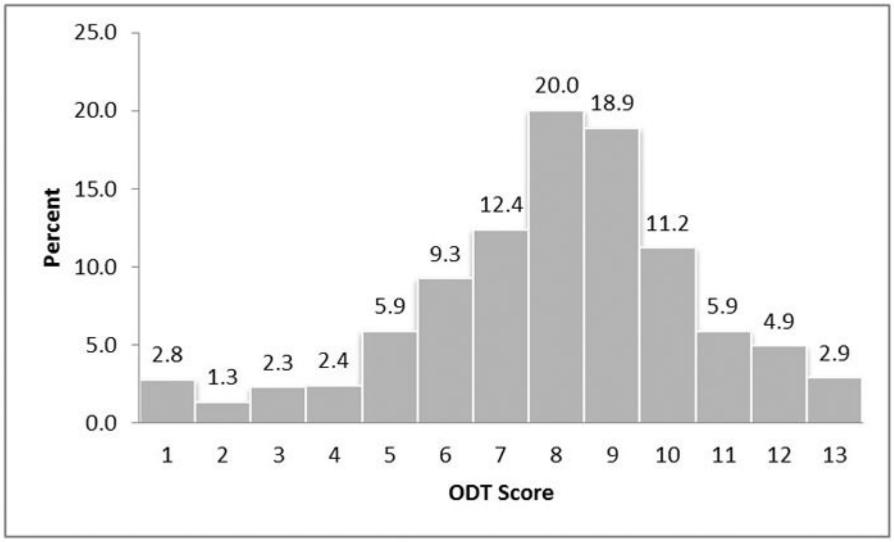

Figure 1.
Distribution of Odor Detection Threshold (ODT) Scores

Table 1

Participant Characteristics (n=832)

	N (%)
Men	346 (41.6)
Women	486 (58.4)
Age group, years	
68–74	359 (43.2)
75–79	225 (27.0)
80–84	136 (16.4)
85+	112 (13.5)
Nasal polyps	23 (2.8)
Deviated Septum	70 (8.6)
Allergies	374 (45.4)
Recent nasal congestion	330 (40.1)
Oral steroid use	19 (2.3)
Nasal Steroid use	45 (5.5)
History Head Injury	344 (41.5)
Smoking history	
Never	368 (45.1)
Past	403 (49.4)
Current	45 (5.5)
Environmental Tobacco Exposure	
None/little	731 (90.6)
Moderate/High	31 (3.9)
Current smoker	45 (5.6)
History of heavy alcohol use	196 (24.3)
Exercise at least once a week	
No	440 (54.7)
Yes	365 (45.3)
BMI	
<25	145 (17.8)
25–29.9	276 (33.9)
>=30	393 (48.3)
Cognitive Impairment	24 (2.9)

BMI: Body Mass Index

Table 2

Mean Odor Detection Threshold (ODT) Scores by Age and sex

	Men		Women		All (n=832)		
Age	**n**	**Mean ODT Score (se)**	**n**	**Mean ODT Score (se)**	**n**	**Mean ODT Score (se)**	**Range**
68–74	160	8.6 (0.20)	199	8.8 (0.17)	359	8.7 (0.13)	1–13
75–79	95	8.0 (0.26)	130	8.2 (0.21)	225	8.1 (0.16)	1–13
80–84	53	7.6 (0.35)	83	7.9 (0.27)	136	7.8 (0.21)	1–13
85+	38	6.9 (0.41)	74	6.9 (0.28)	112	6.9 (0.23)	1–12
All	346	8.1 (0.14)	486	8.2 (0.11)	832	8.2 (0.09)	1–13

se=standard error

Table 3

Multivariable Linear Regression Model for Butanol Concentration

	Effect*	p-value
Age, every 5 years	42.9	<0.0001
Sex, men	6.4	0.65
Nasal Polyps	−16.0	0.65
Nasal Steroids	−11.4	0.67
Allergies	−21.9	0.048
Smoking history, (versus never)		
Past	10.6	0.46
Current	38.9	0.24
History of heavy alcohol use	5.1	0.76
Exercise at least once/week (vs none)	−13.6	0.25
Cognitive impairment	155.7	0.02

*% change in the geometric mean concentration of butanol necessary for detection

Table 4

Multivariable Logistic Regression Model for Low ODT Score (<=5)

	OR	95% CI
Age, every 5 years	1.34	1.11, 1.61
Sex, men	1.43	0.85, 2.41
Deviated Septum	0.23	0.06, 0.99
Recent nasal congestion	0.95	0.59, 1.53
Smoking history (versus never)		
Past smoker	0.99	0.59, 1.66
Current smoker	1.33	0.50, 3.53
History of heavy alcohol use	1.37	0.77, 2.45
Exercise at least once/week (versus none)	0.48	0.28, 0.81
Cognitive impairment	2.50	0.81, 7.72

OR=Odds Ratio; CI=Confidence Interval