

Original Article

Prevalence and Risk Factors of Self-Reported Smell and Taste Alterations: Results from the 2011–2012 US National Health and Nutrition Examination Survey (NHANES)

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Abstract

Chemosensory problems challenge health through diminished ability to detect warning odors, consume a healthy diet, and maintain quality of life. We examined the prevalence and associated risk factors of self-reported chemosensory alterations in 3603 community-dwelling adults (aged 40+ years), from the nationally representative, US National Health and Nutrition Examination Survey (NHANES) 2011–2012. In this new NHANES component, technicians surveyed adults in the home about perceived smell and taste problems, distortions, and diminished abilities since age 25 (termed “alterations”), and chemosensory-related health risks and behaviors. The prevalence of self-reported smell alteration was 23%, including phantosmia at 6%; taste was 19%, including dysgeusia at 5%. Prevalence rates increased progressively with age, highest in those aged 80+ years (smell, 32%; taste, 27%). In multivariable logistic regression, controlling for sociodemographics, health behaviors, and chemosensory-related conditions, the strongest independent risk factor for smell alteration was sinonasal symptoms (odds ratio [OR] = 2.06; 95% confidence interval [CI]: 1.63–2.61), followed by heavy drinking, loss of consciousness from head injury, family income \leq 110% poverty threshold, and xerostomia. For taste, the strongest risk factor was xerostomia (OR = 2.65; 95% CI: 1.97–3.56), followed by nose/facial injury, lower educational attainment, and fair/poor health. Self-reported chemosensory alterations are prevalent in US adults, supporting increased attention to decreasing their modifiable risks, managing safety/health consequences, and expanding chemosensory screening/testing and treatments.

Key words: dry mouth, dysgeusia, head injury, health status, phantosmia

Introduction

The chemosenses, smell and taste, respond to chemical stimuli, including hazardous chemicals, food flavors, and pleasurable aromas. The Disability Supplement to the 1994 National Health Interview Survey

(NHIS), administered to 42 000 randomly selected households, provided the first national estimates for perceived chemosensory problems in US adults—smell problems in 2.7 million and taste problems in 1.1 million adults, both estimates showing increases with age

(Hoffman et al. 1998). Chemosensory problems are more common in older adults, challenging their ability to detect environmental hazards (Pence et al. 2014) and maintain healthy diet (Duffy et al. 1995; Aschenbrenner et al. 2008), weight (Richardson et al. 2004; Simchen et al. 2006), and quality of life (Smeets et al. 2009). For the first time, National Health and Nutrition Examination Survey (NHANES) 2011–2012 administered a taste and smell protocol to US adults aged ≥ 40 years (CDC 2013b). The purpose was to document the extent and comorbidities of smell or taste problems, losses and distortions, labels that we collectively refer to here as “alterations.”

The label “alterations” applied to olfactory perception can encompass partial (hyposmia) to complete (anosmia) loss, and distorted (parosmia) or phantom (phantosmia) smells. These alterations have been associated with sinonasal diseases, upper respiratory infections, head trauma, neurodegenerative diseases, and advancing age (Mann 2002). From odor identification testing, prevalence of anosmia or hyposmia in recent epidemiological studies range from 13.9% to 32.9% in adults 53 years and older, and show age-related increases (Murphy et al. 2002; Brämerson et al. 2004; Wehling et al. 2011; Schubert et al. 2012). However, some older adults perform as well as young adults in olfactory testing; healthy aging may stave off olfactory impairment associated with age-related neurodegeneration and decline in health, memory, and cognition (Rawson 2006). About 1 in 5 patients with chemosensory problems report parosmia or phantosmia (Philpott and Boak 2014); the prevalence of phantosmia or parosmia in the general population, however, is largely unknown.

In terms of taste alterations, complete (ageusia) or moderate-to-severe (hypogeusia) taste loss is rare (Mann 2002), as 3 cranial nerves relay taste information from oral cavity to the brain. Regional taste loss on the anterior tongue is more common (Bartoshuk et al. 2012). The chorda tympani nerve, which innervates the anterior tongue, traverses the middle ear, and is susceptible to damage from infectious agents, middle-ear surgeries, and head trauma (Bartoshuk et al. 2012). Regional taste loss can alter flavor perception (Bartoshuk et al. 2012) and/or produce dysgeusia (distorted, often persistent taste). Dysgeusia also can result from metabolic abnormalities in chronic systemic diseases or their treatments (Ng et al. 2004; Hovan et al. 2010). In the 1994 NHIS, age-related increases in self-reported taste problems were attributed primarily to dysgeusia rather than to loss in taste perception (Hoffman et al. 1998). Taste disturbances also could be caused by some dental procedures, oral infections, or by factors related to oral health (Bromley 2000; Bergdahl and Bergdahl 2002; Shibata et al. 2015).

Previous clinical and population studies (Nordin et al. 1995; Murphy et al. 2002; Wehling et al. 2011) report good specificity (correct identification of normal) but lower sensitivity (correct identification of dysfunction) for self-reported smell ability. Improved sensitivity can be achieved by asking about current and age-related changes in smell (Ship and Weffenbach 1993; Rawal et al. 2014), as well as probing about specific taste qualities and food flavor to minimize smell–taste confusion. Smell is confused with taste when perceived via the mouth and centrally combined with other sensory inputs into unified flavor experiences (Rolls 2006). Subjective assessments also are the primary means to determine chemosensory distortions (e.g., dysgeusia, phantosmia), perceived changes in functioning, and impact on health and quality of life.

As part of national health improvement objectives, US Healthy People 2020 recently included chemosensory-related objectives to encourage identification, treatment, and risk-management of chemosensory disorders (HHS 2015). Accordingly, rapid smell and taste assessments previously standardized in the NIH Toolbox project

(NIH 2012) were adapted for implementation in the NHANES 2011–2014 taste and smell protocol. The protocol comprised a self-report questionnaire in the home-interview (Chemosensory Questionnaire, CSQ) and brief tests in the mobile exam centers (CDC 2013b). The CSQ asked about perceived smell and taste problems and distortions, chemosensory losses with aging, and related risk factors and treatment of chemosensory alterations among US adults aged ≥ 40 years (CDC 2013c). Using these nationally representative data, we examined the prevalence and associated risk factors of self-reported smell and taste alterations in US adults.

Materials and methods

Study population

NHANES 2011–2012 collected questionnaire data and clinical measures from a nationally representative sample of the civilian, noninstitutionalized US population, identified using multistage, stratified probability sampling. The analytical sample was limited to 3603 adults, ages ≥ 40 years, who answered the CSQ (response rate 99.9%). Approval was obtained from the National Center for Health Statistics Research Ethics Review Board. All participants provided written informed consent. The study complied with the Declaration of Helsinki for medical research involving human subjects.

Self-reported chemosensation

The CSQ (CDC 2013c), developed for NHANES based on previous research (Hoffman et al. 1998; Murphy et al. 2002; Rawal et al. 2014) and standard clinical assessments, included single questions capturing perceived smell and taste problems within the past year, dysgeusia and its quality (e.g., metallic, bitter), phantosmia, and changes since age 25 in ability to smell, taste (sweet, salty, sour, bitter), and perceive food flavors (chocolate, strawberry, vanilla). The complete questionnaire, codebook, and data are publicly available online (CDC 2013c). The CSQ was content-validated by chemosensory experts and tested for response problems and cultural appropriateness. Validity and reliability estimates of some CSQ questions have been reported from 2 studies with community-based samples (Rawal et al. 2014, 2015).

Trained interviewers administered the CSQ in the respondent's home; if smell or taste problems were reported, participants were prompted about their effects on quality of life, and whether their problems were discussed with healthcare providers. Participants answered questions on common conditions (e.g., sinonasal, head/orofacial injury) (Mann 2002) that increase risk of chemosensory alterations.

Prevalence estimates

Responses to 3 questions were used in defining self-reported smell alteration and deriving its prevalence estimate: problem with ability to smell in the past year (yes/no); change in ability to smell since age 25 (better/worse/no change); and smelling an unpleasant/bad/burning odor when nothing is there (yes/no). Participants were categorized as having smell alteration if they reported a recent problem, worse sense of smell since age 25, or phantosmia.

Responses to 7 questions were used in defining self-reported taste alteration and deriving its prevalence estimate: problem tasting sweet, sour, salty, or bitter in foods and drinks in the past year (yes/no); separate responses to change in ability to taste salty, sweet, sour, bitter since age 25 (better/worse/no change); change in ability to taste food flavors such as chocolate, vanilla, or strawberry since age 25 (better/worse/no change); and in the past year, having

a taste or other sensation in mouth that does not go away (yes/no). Participants were categorized as having taste alteration if they reported a recent problem, dysgeusia, or worse ability to perceive flavors or taste salt, sweet, sour, or bitter since age 25.

Sociodemographic, behavioral, and health risk factors

A number of putative risk factors, obtained from self-report questionnaires used in NHANES, were evaluated for their associations with reported smell or taste alterations. These questionnaires and the corresponding data and codebooks are available online for public use (CDC 2013a). Smoking exposure was categorized as none (never smoked 100 cigarettes), <10 pack years (PY, packs of cigarettes smoked per day \times years smoked), and ≥ 10 PY. Sinonasal symptoms were defined as self-report of either persistent cold/flu (≥ 1 month) or frequent allergy-related nasal congestion during the past year. Marital status was dichotomized into married or not (widowed/divorced/separated/never married/living with partner). Educational attainment was dichotomized—*not having completed high school versus high school graduate or above*. Income-to-poverty ratio [IPR, family income divided by federal poverty threshold established by the US Census Bureau (Census 2014)] was used as a measure of socioeconomic status, and was analyzed as quartiles (Sabanayagam and Shankar 2012). Self-rated health was dichotomized (excellent/very good/good versus fair/poor). Participants were defined as physically active if they reported doing at least 10 continuous minutes of vigorous- or moderate-intensity activity ≥ 3 days a week. Interview questions also asked about xerostomia (persistent dry mouth) during the past year, and lifetime histories of the following: tonsillectomy; loss of consciousness from head injury, broken nose or other serious injury to face/skull; heavy drinking ($\geq 4/5$ drinks daily); multiple (≥ 3) ear infections; and insertion of tympanostomy tubes to drain fluid from ear(s).

Data and statistical analysis

Statistical analyses were accomplished using STATA, version 12.0. We employed sample weights to account for unequal probabilities of selection, nonresponse bias, and oversampling of certain subgroups in NHANES 2011–2012. Bivariable relationships between self-reported smell or taste alterations and sociodemographic or health characteristics were assessed with chi square or 2-tailed *t*-tests.

Risk factors for self-reported smell or taste alterations were identified by unconditional logistic regression models. Results are reported as odds ratios (ORs) with 95% confidence intervals (CIs). To identify independent risk factors of self-reported smell or taste alterations, multivariable logistic regression models were developed using a purposeful selection method (Bursac et al. 2008). In the purposeful selection method, only variables with *P*-value < 0.25 in the univariate analyses are evaluated in the initial multivariable model. In the iterative process of variable selection for the final model, covariates are removed from the multivariable model if they are non-significant (*P* > 0.1) and not confounders (i.e., the covariate does not change the remaining parameter estimates by more than 15% when removed from the full model). Further details on the purposeful selection process have been described previously (Bursac et al. 2008).

Potential 2-way interactions were tested, and the models were tested for goodness of fit, multicollinearity and misspecifications (UCLA 2015). Missing data (14.4%) were imputed using the Markov Chain Monte Carlo method, a multiple imputation method based on the Bayesian estimation approach (Donders et al. 2006). Unique risk factors for phantosmia and dysgeusia were investigated in separate analyses (results not shown).

Results

Table 1 provides sociodemographic and health characteristics of the study participants, and the prevalence of reported smell and taste alterations by these characteristics. The prevalence of adults who reported smell or taste alteration increased with age, from lowest among the 40–49 year-olds to highest in the ≥ 80 year-olds; no sex differences were observed.

Prevalence of self-reported smell and taste alteration in US adults ≥ 40 years

Smell alteration

The proportion of adults who reported smell problems within the past year was 10.6% (95% CI: 8.5–12.6%). More adults, 16.7% (95% CI: 14.4–19%), reported smell loss since age 25. Only 6% (95% CI: 4.9–7%) reported experiencing phantom odors, of which almost two-thirds were females.

The prevalence of any self-reported smell alterations was 23.3% (95% CI: 19.9–26%). The Venn diagram in Figure 1 shows the number of individuals who were classified as having smell alterations based on responses to only a single question (no overlap in responses) or multiple questions (overlap in responses). The question on smell problems in the past year showed the least overlap with the other 2 smell-related questions: only 9% with smell alteration indicated smell problems alone without phantosmia or smell loss with age. Of those who reported smell problems (*N* = 374), 76% (*N* = 285) reported smell loss since age 25 and 17% (*N* = 63) reported phantosmia.

Taste alteration

The proportion of adults who reported taste problems within the past year was 5.3% (95% CI: 4.6–6%), much lower than reported smell problems. Similar proportions (3.6–4.7%) were seen for loss across salty, sweet, sour, and bitter qualities. About equal proportions reported that their ability to taste these specific taste qualities was better than when they were age 25 (5–7%). Approximately 10% (95% CI: 8.6–11%) noted a loss in ability to “taste” food flavors with age. Five percent (95% CI: 3.9–6.3%) reported dysgeusia, of which 64% were females. The most frequent taste qualities persisting in the mouth were bitter and metallic.

The prevalence of self-reported taste alteration was 18.7% (95% CI: 17.2–20.2%). The Venn diagram in Figure 1 shows the number of individuals who were classified as having taste alterations based on responses to only a single question (no overlap in responses) or multiple questions (overlap in responses). The question on taste problems showed the least overlap: only 7% with taste alteration indicated taste problems alone in the past year without dysgeusia or taste/flavor loss with age.

Ten percent of the study sample reported both smell and taste alterations. Thirty-three percent reported either smell or taste alterations; of these, only 12.4% sought healthcare provider attention during the past year, 3.5% tried healthcare provider-recommended treatments, and 3% said their problem interfered with their health, work or enjoyment of life.

Factors associated with self-reported smell and taste alterations

Table 2 shows crude and adjusted ORs with 95% CIs for risk factors associated with self-reported smell and taste alterations. Results from the original data set are shown, which were not different from results computed with imputed missing data. In multivariable

Table 1. Prevalence of reported smell and taste alterations by sociodemographic and health characteristics in the 2011–2012 NHANES participants 40+ years (*N* = 3603)

Characteristic	All participants	Smell alteration (self-report)		Taste alteration (self-report)	
	<i>N</i>	%	<i>P</i> -value ^a	%	<i>P</i> -value ^a
All participants	3603	23.3		18.7	
Age, years ^b			<0.001		<0.001
Mean (SD/SEM)	59.64 (12.22 SD)	61.21 (0.42)		61.20 (0.44)	
Age strata			<0.001		<0.001
40–49 years	899	18.9		16.1	
50–59 years	913	22.6		21.0	
60–69 years	908	26.2		23.7	
70–79 years	520	21.1		20.2	
80+ years	363	31.7		27.3	
Sex			0.98		0.74
Male	1749	23.3		20.8	
Female	1854	23.3		21.2	
Race/ethnicity			<0.001		<0.005
Mexican-American	309	23.6		23.3	
Other Hispanic	400	24.2		23.2	
Non-Hispanic black	995	21.9		22.3	
Non-Hispanic white	1360	26.4		21.2	
Other, includes multiracial	539	17.1		15.0	
Marital status			<0.001		<0.002
Married	1946	21.0		19.0	
Not Married	1651	25.9		23.2	
Education			0.08		<0.001
Less than high school	1013	25.3		28.0	
High school or above	2585	22.6		18.3	
IPR			<0.001		<0.001
IPR ≤ 1.1	816	29.5		28.2	
1.1 >IPR ≤ 2.0	813	23.0		23.9	
2.0 >IPR ≤ 4.2	810	20.2		17.7	
IPR > 4.2	807	20.6		15.6	
Self-rated health			<0.001		<0.001
Fair or poor	839	31.3		32.3	
Excellent, very good, or good	2250	20.9		17.4	
Physical activity			0.49		<0.001
Yes	1648	22.7		17.5	
No	1955	23.7		23.9	
Smoking exposure			<0.001		<0.009
None	1917	20.2		19.4	
<10 PY	647	21.9		19.9	
≥10 PY	934	30.4		24.3	
“Yes,” have ever had...					
Loss of consciousness due to head injury	422	33.4	<0.001	28.0	<0.001
Broken nose or serious injury to face or skull	499	31.7	<0.001	30.9	<0.001
Tonsils removed	839	27.1	<0.001	22.4	0.13
Ear infections, 3+ times	689	32.7	<0.001	26.3	<0.001
Tube placed in ear to drain fluid	116	35.3	<0.001	25.0	0.26
4/5 or more drinks every day	450	30.9	<0.001	26.0	<0.007
“Yes,” in last 12 months...					
Cold/flu for >1 month	223	38.6	<0.001	26.0	<0.05
Persistent dry mouth	513	38.2	<0.001	43.1	<0.001
Frequent nasal congestion	924	36.3	<0.001	26.2	<0.001

SD, standard deviation; SEM, standard error of mean.

^aTwo-sided *P*-values for χ^2 or *t*-test.^bValue expressed as mean (SD) or mean (SEM).

models, age and sex were not independent predictors of either self-reported smell or taste alteration. Although the final model estimates showed minimal changes with or without the inclusion of age and sex, both were retained in the final model.

Controlling for all variables in the final multivariable model shown in Table 2, independent risk factors for smell alteration were presence of sinonasal symptoms, heavy drinking, xerostomia, history of loss of consciousness from head injury, and low

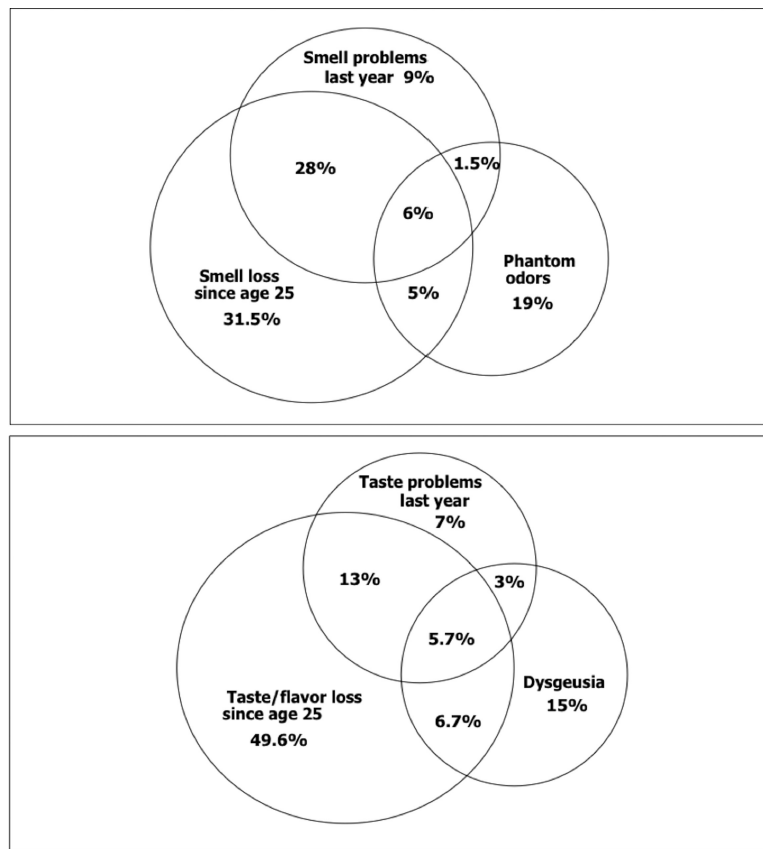


Figure 1. Venn diagrams displaying the proportion of NHANES 2011–2012 participants ≥ 40 years with self-reported smell ($n = 839$) or taste ($n = 756$) alterations based on responses to a single (no overlap) or multiple (overlap) questions, the percentages adding to 100%; Respective counts are $n \times$ proportion (e.g., individuals reporting smell problems alone without phantosmia or smell loss with age = $0.09 \times 839 = 75$).

IPR. Based on the nonsignificant F -statistic, the multivariable model showed good fit [$F(9, 9) = 1.82$; $P = 0.19$]. Those with sinonasal symptoms were twice as likely to report smell alteration compared with those without these problems (OR = 2.06; 95% CI: 1.63–2.61). Lower education, fair/poor health, multiple ear infections, ≥ 10 PY of smoking, and nose/facial injury also were significantly associated with increased odds of smell alteration in univariate analyses, but not in the fully adjusted, multivariable model. Unique to phantosmia, female sex and fair/poor health were significant, independent predictors, in addition to sinonasal symptoms, xerostomia, and low IPR (results not shown).

Controlling for all variables in the final multivariable model shown in Table 2, significant independent predictors of self-reported taste alterations were lower education, xerostomia, fair/poor health, and nose/facial injury. Based on the nonsignificant F -statistic, the multivariable model showed good fit [$F(9, 9) = 0.84$; $P = 0.60$]. Those with xerostomia were over 2 times as likely to report taste alterations than those without (OR = 2.65; 95% CI: 1.97–3.56). Those reporting nose/facial injury had almost twice the odds of reporting taste alterations (OR = 1.90; 95% CI: 1.30–2.76). Although the self-report of taste alteration was significantly associated with race/ethnicity, IPR, and heavy drinking in unadjusted models, these variables were nonsignificant in the fully adjusted, multivariable model. Unique to dysgeusia, history of multiple ear infections was a significant independent predictor in addition to xerostomia and nose/facial injury (results not shown).

Discussion

Since the 1994 NHIS, this study provides new estimates of the prevalence and associated risk factors of self-reported smell and taste alterations in a nationally representative sample of US adults aged ≥ 40 years. The prevalence of smell or taste alterations showed age-related increases and were highest in those aged ≥ 80 years. Self-reported smell problems during the past year (10.6%) were twice as prevalent as taste problems (5.2%). Our findings are comparable to recent epidemiological studies with estimates ranging from 6% to 12% for self-reported olfactory problems (Murphy et al. 2002; Wehling et al. 2011; Lee et al. 2013) and from 5.7% to 13.3% for self-reported taste problems (Michikawa et al. 2011; Welge-Lüssen et al. 2011) in participants of similar age. These current NHANES prevalence estimates are higher than 1994 NHIS estimates—the latter queried only about “chronic” taste or smell problems (lasting ≥ 3 months) during the preceding year. In NHANES, asking about smell loss with age produced a higher prevalence (17%) than asking about a problem within the past year, mirroring earlier findings in a community-based study with reportedly healthy older females (Rawal et al. 2014). Interestingly, almost equal proportions of adults reported better or worse taste perception with aging. It is uncertain if individuals who report heightened taste sensations actually perceive more intensity or instead are more aware of taste sensations like salt and sweet and like them less as they modify the level of sugar and salt in their diet to manage chronic diseases (IOM 2010). The prevalence of phantom smell or taste problems was lowest when compared with other chemosensory alterations, affecting 1 in 20

Table 2. ORs and 95% CIs for risk factors associated with self-reported smell and taste alterations, 2011–2012 NHANES

Variables	Self-reported smell alteration (N = 3212)				Self-reported taste alteration (N = 3081)			
	Crude		Adjusted ^a		Crude		Adjusted ^b	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Age	1.01	1.00–1.02	1.01	1.00–1.02	1.01	1.00–1.02	1.01	1.00–1.02
Sex (reference “female”)								
Male	1.05	0.89–1.24	0.99	0.80–1.22	1.06	0.84–1.33	1.00	0.75–1.34
Race/ethnicity (reference “non-Hispanic White”)								
Mexican American	0.92	0.65–1.29			1.26	1.00–1.59		
Other Hispanic	0.98	0.73–1.30			1.21	0.92–1.61		
Non-Hispanic Black	0.86	0.63–1.18			1.28	1.12–1.45		
Other race (includes multiracial)	0.90	0.54–1.49			0.99	0.65–1.49		
Marital status (reference “not married”)								
Married	0.88	0.73–1.06			0.84	0.67–1.05		
Education (reference “high school or above”)								
Less than high school	1.37	1.03–1.81			2.00	1.68–2.37	1.76	1.52–2.03
Sinonasal symptoms (reference “no”)								
Yes	2.31	1.84–2.90	2.06	1.63–2.61	1.53	1.14–2.05	1.39	0.95–2.01
Xerostomia (reference “no”)								
Yes	1.97	1.65–2.36	1.44	1.17–1.77	3.55	2.93–4.31	2.65	1.97–3.56
Loss of consciousness from head injury (reference “no”)								
Yes	1.77	1.26–2.49	1.59	1.06–2.40	1.33	0.95–1.86		
Nose/facial injury (reference “no”)								
Yes	1.49	1.08–2.06			1.86	1.34–2.59	1.90	1.30–2.76
Tonsillectomy (reference “no”)								
Yes	1.38	0.99–1.94	1.32	0.98–1.81	0.99	0.72–1.38		
Self-rated health (reference “excellent, very good, or good”)								
Fair or poor	1.64	1.19–2.26			2.23	1.72–2.89	1.59	1.11–2.25
Smoking exposure (reference “none”)								
<10 PY	0.93	0.54–1.63			0.98	0.75–1.30		
≥10 PY	1.63	1.20–2.20			1.23	0.90–1.68		
Heavy drinking (reference “no”)								
Yes	1.98	1.50–2.62	1.79	1.27–2.51	1.43	1.15–1.79		
Multiple ear infections (reference “no”)								
Yes	1.45	1.09–1.92			1.32	0.93–1.88		
Tympanostomy tubes (reference “no”)								
Yes	0.97	0.58–1.60			0.79	0.38–1.65		
Moderate to vigorous physical activity (reference “no”)								
Yes	1.03	0.77–1.37			0.74	0.62–0.87		
IPR (reference IPR > 4.21)								
IPR ≤ 1.1	1.58	1.16–2.16	1.51	1.09–2.10	1.99	1.56–2.54		
1.1 > IPR ≤ 2.0	1.11	0.73–1.70	1.01	0.65–1.57	2.04	1.50–2.77		
2.0 > IPR ≤ 4.2	0.97	0.70–1.19	0.90	0.67–1.90	1.19	0.69–1.71		

^aAdjusted ORs from a parsimonious multivariate regression model consisting of age, sex, sinonasal symptoms, xerostomia, losing consciousness from head injury, tonsillectomy, heavy drinking, and IPR.

^bAdjusted ORs from a parsimonious multivariate regression model consisting of age, sex, education, sinonasal symptoms, xerostomia, nose or facial injury, and self-rated health.

adults, which is similar to rates reported previously in large samples of dental (Bergdahl and Bergdahl 2002) and otolaryngology (Landis et al. 2004) patients. Self-reported treatment rates for chemosensory alterations were very low at 3.5%. It is unknown if this low level of treatment rate is because adults with self-reported alterations don't view them as enough of a problem to seek help, are unaware of treatment options, or consider them to be untreatable.

Risk factors for smell and taste alterations in this nationally representative study corroborate findings of prior clinical and population-based studies—sinonasal symptoms (Murphy et al. 2002; Lee et al. 2013), heavy drinking (Schubert et al. 2011), and head injury (Henkin et al. 2013) for risk of smell alterations; xerostomia (Bergdahl and Bergdahl 2002) and facial injury (van Damme

and Freihofer 1992) for risk of taste alterations. Sociodemographic characteristics such as education and IPR were important predictors of chemosensory alterations as observed previously (Boesveldt et al. 2011; Schubert et al. 2012; Lee et al. 2013). We did not observe independent influences of sex and age in self-reported smell or taste alteration, although their effects on measured function are well documented (Rawson 2006; Schubert et al. 2012). Age and sex may exert indirect influences on smell or taste such as increasing the frequency of and probability of exposures that cause smell and taste alterations. In addition, changes in function since age 25 were included in the definition of smell or taste alterations. Similar to our findings, a recent study (Soter et al. 2008) observed no gender differences in self-reported ability to taste specific taste qualities except

sucrose. Consistent with previous reports (Bergdahl and Bergdahl 2002; Harris et al. 2006), more women reported phantosmia and dysgeusia in this nationally representative study.

Two limitations of this study are the cross-sectional design, limiting inference on temporality of observed associations, and reliance on self-report data. Self-reported smell function, in particular, may not be a sensitive indicator of measured alteration especially in mild cases (Murphy et al. 2002; Rawal et al. 2014). In population-based studies (Nordin et al. 1995; Murphy et al. 2002; Shu et al. 2009; Wehling et al. 2011), the prevalence of self-reported smell impairment is consistently lower than the measured prevalence. For example, in 1 US-based population study (Murphy et al. 2002), only 9.5% reported smell impairment compared with measured prevalence of 24.5%; only 20% correctly identified themselves as having smell impairment, with sensitivity estimates that was lower in women than men, and decreased from younger to older age cohorts. Previously reported low sensitivities of self-reported smell alterations however, might have resulted from use of a single question, which simply asked participants to rate their current smell ability (Nordin et al. 1995; Murphy et al. 2002; Wehling et al. 2011). As previously demonstrated, self-reported measures that also ask smell loss with age show better correspondence with measured moderate-to-severe dysfunction (Rawal et al. 2014). The present findings also support using multiple questions to assess perceived chemosensory alteration; for example, only 23% of individuals experiencing phantom odors reported smell problems, and only 28% of those who experienced dysgeusia reported taste problems. Furthermore, subjective assessments are necessary to capture chemosensory distortions (dysgeusia, phantosmia), intermittent losses that may be missed by single measured testing, and to assess perceived health impact of chemosensory alterations.

Findings from this nationally representative survey suggest that self-reported chemosensory alterations are more prevalent in US adults than previously estimated, reinforcing the need to measure and track Healthy People 2020 chemosensory goals aimed at improving diagnosis and treatment rates of chemosensory disorders and reducing their health burden. Taste or smell evaluation is uncommon in gerontological assessments despite the high prevalence of chemosensory alterations in older adults. In clinical settings, an instrument similar to the NHANES CSQ could be used for rapid identification of individuals with chemosensory alterations, facilitating appropriate follow-up for related safety and health needs (e.g., installing natural gas detectors, dietary management). This could be followed-up with additional assessments (Pusswald et al. 2012) to evaluate the effects of chemosensory alterations on health, nutritional status, and/or quality of life and to refer patients to an otolaryngologist, neurologist, or other suitable specialists. Future release of NHANES chemosensory exam data will provide prevalence and associated risk factors of measured chemosensory alterations. Together, findings from the new NHANES taste and smell protocol will have important implications for informing programs and policies to improve prevention, diagnosis, and treatment of chemosensory alterations in the United States.

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