HHS Public Access

Author manuscript

Chemosens Percept. Author manuscript; available in PMC 2015 April 10.

Published in final edited form as:

Chemosens Percept. 2014 December 1; 7(3-4): 108–116. doi:10.1007/s12078-014-9170-7.

Sensitivity and Specificity of Self-Reported Olfactory Function in a Home-Based Study of Independent-Living, Healthy Older Women

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Abstract

Introduction—The 2011–14 US National Health and Nutrition Examination Survey chemosensory protocol asks adults to self-rate their orthonasal (via nostrils) and retronasal (via mouth) smell abilities for subsequent odor identification testing. From data collected with a similar protocol, we aimed to identify a self-reported olfactory index that showed the best

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Compliance with Ethics Requirements

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008 (5). Informed consent was obtained from all patients for being included in the study.

Conflict of Interest

Shristi Rawal declares that she has no conflict of interest.

Howard J. Hoffman declares he has no conflict of interest.

Audrey K. Chapo declares that she has no conflict of interest.

Valerie B. Duffy declares that she has no conflict of interest.

sensitivity (correctly identifying dysfunction) and specificity (correctly indentifying normosmia) with measured olfaction.

Methods—In home-based testing, 121 independent-living older women (age 73±7 years) reported their olfactory function by interviewer-administered survey. Olfactory function was measured orthonasally via composite (odor threshold, identification task) or identification task alone.

Results—Only 16 % of women self-rated “below average” smell function. More women perceived loss of smell (38 %) or flavor (30 %) with aging. The rate of measured dysfunction was 30 % by composite (threshold and identification) and 21.5 % by identification task, the latter misclassifying some mild dysfunction as normosmia. An index of self-rated smell function and perceived loss yielded the most favorable sensitivity (65 %) and specificity (77 %) to measured function. Self-rated olfaction showed better agreement with severe measured dysfunction; mild dysfunction was less noticed.

Conclusions—Self-reported indices that query about current and perceived changes in smell and flavor with aging showed better sensitivity estimates than those previously reported. Specificity was somewhat lower—some older adults may correctly perceive loss unidentified in a single assessment, or have a retronasal impairment that was undetected by an orthonasal measure.

Implications—Our findings should inform self-rated measures that screen for severe olfactory dysfunction in clinical/community settings where testing is not routine.

Keywords

Health status; Smell; Odor threshold; Odor identification; Aging; Females

Introduction

Olfactory dysfunction impairs the ability to detect warning odors (Santos et al. 2004) through the nostrils (orthonasal olfaction) and flavors of foods through the oral cavity (retronasal olfaction) and can diminish quality of life (Smeets et al. 2009; Keller and Malaspina 2013). The risk of olfactory dysfunction increases with age related to disruption anywhere along the sensory process (Rawson 2006). Age-related loss of olfactory function may be gradual, paralleling neurodegeneration and changes in cognitive functioning and verbal memory (Kalogjera and Dzepina 2012). More severe olfactory dysfunction results from age-related changes exacerbated with chronic nasal/sinus diseases, head trauma, and repeated upper respiratory tract infections (Rawson 2006).

Odor identification tasks have been adopted as reasonable measures of olfactory dysfunction in population-based studies, having good correspondence with single odor threshold tasks and/or other suprathreshold olfactory measures (Cain and Rabin 1989; Doty et al. 1984b, 1994; Hummel et al. 1997; Koskinen et al. 2004). In healthy adults, rates of olfactory dysfunction from odor identification tasks are estimated to range from 13.9 to 32.9 % (Murphy et al. 2002; Bramerson et al. 2004; Vennemann et al. 2008; Schubert et al. 2012). Population-based studies with odor identification tasks consistently show age-related declines and that women outperform men (Wysocki and Gilbert 1989; Ship and

Weiffenbach 1993; Ship et al. 1996; Larsson et al. 2004; Karpa et al. 2010; Mullol et al. 2012).

Despite the evidence of age-related changes, olfactory evaluation is not a common practice in gerontological assessments (Elsawy and Higgins 2011) and the utility of self-reported olfactory function has been questioned. The prevalence of self-reported olfactory dysfunction shows age-related increases, yet is lower than the measured prevalence (Wysocki and Gilbert 1989; Hoffman et al. 1998). For example, only 9.5 % of the 2,400+ participants in the Epidemiology of Hearing Loss Study (EHLS) self-reported olfactory dysfunction despite a measured prevalence of 24.5 % (Murphy et al. 2002); only 20 % correctly identified having olfactory dysfunction (sensitivity of self-report), a rate that was lower in women than men, and decreased from younger to older age cohorts. Low sensitivity estimates, ranging from 19 to 23 %, have been reported by other population-based studies (Nordin et al. 1995; Shu et al. 2009; Wehling et al. 2011). In the EHLS, specificity (correctly identifying normosmia) was above 90 % for both men and women in all age cohorts. Similarly, in a recent Norwegian study of middle-aged and older adults, 81 % with olfactory dysfunction were unaware of the deficit (low sensitivity), yet specificity of self-reported olfactory function was 90.7 % (Wehling et al. 2011).

The question of interest is whether self-reported olfaction measures can achieve more favorable sensitivity and specificity than previously reported. Asking participants to simply rate their sense of smell nets good specificity but poor sensitivity (Nordin et al. 1995; Murphy et al. 2002; Shu et al. 2009; Wehling et al. 2011). Ship and Weiffenbach (1993) reported somewhat improved sensitivity by asking participants about changes in their ability to smell—those who tested as normosmic by odor identification test (Doty et al. 1984b) were more likely to rate “no change” or “better” smell perception, whereas those with olfactory dysfunction were more likely to rate “worse” smell perception (specificity 93 %; sensitivity 27 %). Similarly, Karpa and colleagues (2010) reported a sensitivity of 32 % by asking participants whether or not they had a normal sense of smell, and if not, the age at which they perceived the changes.

Perceptual confusion between retronasal olfaction and taste (Deems et al. 1991; de Araujo et al. 2003; Small and Prescott 2005), as well as discordance between orthonasal and retronasal function (Bojanowski and Hummel 2012), could explain poor sensitivity of self-rated olfaction. Querying about both changes in orthonasal and retronasal olfaction should improve the utility of self-reported olfaction and its relevance to dietary behaviors (Duffy et al. 1995). In the Appetite, Hunger and Sensory Perception Questionnaire (ASHP), multiple questions formed three domains of smell or taste function (present smell perception, smell change with age, present/changes in food taste perception) showing high internal consistency as well as good correlation with measured smell function (de Jong et al. 1999). More recently, in the Beaver Dam Offspring Study, participants with olfactory impairments (Schubert et al. 2012) were more likely to report loss of food flavors than those without olfactory impairments.

The US National Health and Nutrition Examination Survey (NHANES) for the first time includes a taste and smell component in the 2011–2014 data cycle, comprised of a home

interview followed by measured testing in a mobile examination center (MEC) (Duffy et al. 2012; CDC 2014). In the home interview, participants are asked to report their ability to smell at the time of the interview, as well as perceived changes in smell and flavor since they were 25 years old. Subsequently in the MEC, smell function is measured orthonasally with an eight-item odor identification test (Pocket Tests™, Sensonics, Inc., Haddon Heights, NJ). In light of the new NHANES chemosensory protocol, the present study mined an existing database of 121 healthy older women who underwent a similar protocol in their homes (Duffy et al. 1995, 1999; Chapo 2002). Using questions that ask about both current olfactory abilities as well as perceived changes in smell and flavor perception, the aim of the present study was to derive an index that has the highest correspondence (sensitivity and specificity) with measured dysfunction. As a secondary aim, we also tested whether adding a single threshold test with minimum stimulus control to an odor identification task improved the correspondence between measured and self-reported olfactory function in a community-based setting.

Materials and Methods

Participants

One hundred and twenty-one ostensibly healthy, nonsmoking, older women between 56 to 93 years of age (mean 73±7 years) participated in this observational study conducted in the women's homes. Only healthy older women were recruited to minimize influences of overall poor health in self-reported smell function as well as to avoid sex effects in olfactory functioning (Karpa et al. 2010) and gender influences on self-reported measures of health (Boerma et al. 2012). Older women are more representative of independent-living older adults as they outnumber older men and are more likely to live alone (AOA 2012). Finally, we wanted single-living older women to minimize social influences on self-reported olfactory function.

The women were recruited by poster and word-of-mouth from senior housing complexes in Connecticut. To participate, the women needed to have a high level of personal functioning as assessed by the Older Americans Resources and Services Multidimensional Functional Assessment Questionnaire (Fillenbaum 1988), a general multidimensional assessment of functional status. Specifically, they needed to pass a cognitive screen (Short Portable Mental Status Questionnaire) and have a score of at least "15," which corresponds to being only "mildly functionally impaired." Most of the women had completed high school (78 %) and were of non-Hispanic white race/ethnicity (95 %). Sixteen percent of women reported excellent physical health, 43 % reported good physical health whereas the rest reportedly had mild physical impairments. The study had University of Connecticut IRB approval. The women gave written informed consent and were compensated for their participation.

Procedure

All interviews and olfactory tests were conducted in the subject's home. Data were collected in the following order to avoid biasing the subject's response: the personal functional assessment, the self-rated olfactory survey, and then the measured smell test, which was repeated a week later for a subset of participants. In a subsample of 80 of the 121 women

who had a second visit, the smell test showed a high test-retest reliability of 0.81 (Duffy et al. 1995).

Self-Reported Olfactory Function—Professionals in nutrition, gerontology, social psychology, and psychophysics assessed the self-rated olfactory survey for content validity, instrument construction, and appropriateness. The interviewer-administered survey was pilot tested for clarity, feasibility, and understandability on a separate sample of older women. The survey asked participants to use seven-point scales to report their smell function at the time of the interview (very poor to excellent), changes in smell and flavor since they were 30 to 35 years of age (extremely weaker to extremely stronger), and questions about changes in the ability to sense the smell of specific odors (e.g., bacon cooking, natural gas). The age selected for comparing changes followed Doty et al. (1984a) who reported that the monotonic age-related decline in smell starts in the fourth decade of life. Only questions that had sufficient variability in response were analyzed for the complete study sample, including self-rated smell functioning at the time of the interview and smell and flavor changes noticed with aging. Although aging may associate with qualitative changes to specific odors (Wysocki and Gilbert 1989; Russell et al. 1993), querying individuals about these specific odor changes did not provide any additional information.

The self-rated questions were first analyzed as dichotomous variables for Chi-square analyses (Table 1). The individual survey questions that ranged from 1 (poor or extremely weaker) to 7 (excellent or extremely stronger) were dichotomized as followed: self-rated current smell ability (question 1, Table 1) into “below average” (score <4) and “average or above” (score ≥4); and self-rated smell (question 2, Table 1) and flavor (question 3, Table 1) change into “below same” (score <4) and “same or stronger” (score ≥4). Next, individual survey questions were constructed into four possible indices of self-rated olfaction for comparison against measured dysfunction (Table 1). One index was the sum of scores from all three survey questions. The other three indices were respective score summations for each possible combination of two survey questions. These four self-rated indices were dichotomized into self-rated dysfunction and self-rated normal for sensitivity-specificity comparison against measured dysfunction.

Two of the four indices showed the highest correspondence with measured dysfunction and are discussed in detail. One, the self-rated smell, was constructed from summing responses to “How would you rate your sense of smell right now?” and “How would you rate your sense of smell now compared to when you were 30–35 years old?” (α=0.75, and was categorized into self-rated dysfunction (score <8) and self-rated normal (score ≥8). The minimum score of 2 corresponded to “very poor” and “extremely weaker” sense of smell; the maximum score of 14 corresponded to “excellent” and “extremely stronger” sense of smell. Similarly, responses to changes in smell and flavor (Table 1, questions 2 and 3) were summed to calculate the other index, self-rated smell/flavor loss (α=0.62), with scores ranging from 2 (smell and flavor “extremely weaker”) to 14 (smell and flavor “extremely stronger”), and categorized into self-rated dysfunction (score <8) and self-rated normal (score ≥8).

Measured Olfaction—The Connecticut Chemosensory Clinical Research Center olfactory test (CCCRC) (Cain et al. 1988) served as a measure of olfactory function. For this test, threshold of 1-butanol (two-alternative forced-choice paradigm, ascending method) is measured first, followed by a seven-odor identification task (baby powder, chocolate, cinnamon, coffee, mothballs, peanut butter, and Ivory® Soap), and a trigeminal probe (Vicks Vapo-Steam®), which is not included in the scoring. For this study, olfactory function was classified from a composite score of both threshold and identification tasks, or from the identification task alone. The method for the composite scoring used in this study has been described previously (Duffy et al. 1999). In brief, composite scores range from 0 to 7, and calculated from the average of the two subscores (identification task and threshold task), also ranging from 0 to 7 (Cain et al. 1988; Duffy et al. 1999). A composite score of 7 implies detection of butanol at step 7 of dilution or better (out of 10 steps) and correct identification of all seven odorants. A composite score of 5 or better constituted "normosmia" for persons 65 years or over, whereas scores of less than 2 were designated "anosmia." Scores between 2 and 5 are typically divided into two clinical categories of severe and mild hyposmia (Cain et al. 1988; Duffy et al. 1999); however, the present study combined the two classifications into a single category of "microsmia." Since the odor identification task scores also range from 0 (no correct identification) to 7 (all correctly identified), 0 to <2 was treated as anosmia, 2 to 4.9 as microsmia, and 5 to 7 as normosmia.

Statistical Analyses

Statistical analyses were accomplished using SPSS (version 20.0); significance criterion was $p<0.05$. Means±standard error of the mean (SEM) are reported unless otherwise noted. Spearman (r_s) or Pearson (r) correlations were used for bivariate analyses among age, measured olfaction scores, and self-rated olfaction. Measured and self-rated olfaction data were treated as categorical to compare frequencies by Chi-square analyses and for calculating Cohen's κ, sensitivity, and specificity.

The sensitivity and specificity of the self-rated olfaction indices were calculated as follows:

$$\text{Sensitivity}=\text{TP}/(\text{TP}+\text{FN}) \text{ and } \text{Specificity}=\text{TN}/(\text{TN}+\text{FP}),$$

where TP, TN, FP, and FN are true positive (measured dysfunction), true negative (measured normosmia), false positive (incorrectly classified as dysfunction), and false negative (incorrectly classified as normosmia) respectively.

Results

Measured Olfactory Function

Threshold and identification scores were correlated as expected ($r=0.57$, $p<0.001$), and showed age-related declines (r's <0.3, $p<0.001$). Women older than 80 years had significantly lower identification (mean 4.60±0.49) and threshold (mean 3.89±0.52) scores compared to women younger than 70 years (6.08±0.20, 5.74±0.22, respectively, $p<0.001$).

By composite classification, 5 % were anosmic (scores 0 to 1.9), 25 % were microsmic (scores 2.0 to 4.9), and 70 % were normosmic (scores 5.0 to 7.0) in our study sample (Table 2). Although the odor identification classification showed substantial agreement with the

composite classification (Table 2; κ=0.72, 95 % CI 0.66–0.78; p>0.001), the identification task identified more women as normosmics (78.5 %) and fewer with microsmia (15 %). Merging anosmics and microsmics into one olfactory dysfunction group, the identification task compared to the composite task showed a sensitivity of 72 % (for identifying anosmia +microsmia) and specificity of 100 % (for identifying normosmia) (Table 2).

Self-Rated Olfaction

Analyzed as ordinal variables, the self-rated current smell ability correlated well with rated change in smell (r_S=0.54, p<0.001) and flavor perception (r_S=0.37, p<0.001). Ratings of change in smell perception also correlated with change in flavor perception (r_S=0.47, p<0.001). There was a significant negative correlation between age and self-rated olfactory function within the study group (r_S>0.21, p<0.05); women older than 80 years were more likely to report lower current smell ability and smell loss than those younger than 70 years (p<0.05).

The level of agreement between the dichotomized self-rated survey questions is reported in Table 3. Only 16 % of the women rated their current smell ability as “below average,” while 40 % reported “average” abilities. Thirty-eight percent of the women reported smell loss (Table 3). When considering either loss in smell or flavor functioning with aging, the frequency rose to 46 %. About one in four women reported loss of smell function with aging, yet felt that their current ability to smell was “average or above.” Only nine of the 121 women (7 %), thought their smell or flavor perception improved with aging.

Comparing Measured with Self-rated Smell Function

The goal of the highest sensitivity (correct assignment of dysfunction) and specificity (correct assignment of normosmia) was achieved by an index of individual self-rated questions (self-rated current smell ability, self-rated smell change, self-rated flavor change). Of the four possible indices derived from these questions, the sensitivities ranged from 61 to 77 % and specificities from 64 to 80 % and were the most favorable for the self-rated smell and self-rated smell/flavor loss (Table 4), described below.

Self-Rated Smell—This orthonasal index (self-rated current smell ability and self-rated smell change) achieved a sensitivity of 65 % and specificity of 77 % compared with the identification task. Nearly three of four women correctly identified themselves as with or without olfactory dysfunction using this index, whether compared against the composite or identification task (Table 4). However, women with mild microsmia were most likely to misidentify the dysfunction. The specificity of self-rated smell was nearly equivalent whether it was compared to the composite or identification task (78 vs. 77 %, respectively); hence, about one of five normosmic women incorrectly self-reported having a dysfunction. However, the sensitivity of self-rated smell was slightly better for the identification versus composite task (65 vs. 58 %, respectively).

Self-Rated Smell/Flavor Loss—This orthonasal/retronasal index (self-rated smell change and self-rated flavor change) yielded the highest sensitivity (77 %) and a reasonable specificity (64 %) with the identification task (Table 4). Compared to the self-rated smell,

this self-rated index had a lower specificity, but had greater self-recognition of dysfunction among the microsmics. More women with normosmia (about one of three) incorrectly reported dysfunction by the self-rated smell/flavor loss. As with self-rated smell, the sensitivity of the self-rated smell/flavor loss was slightly better when compared with the identification than the composite task (77 vs. 67 %, respectively).

Discussion

The present study examined the relationship between self-rated olfactory perception and measured olfaction in a group of independent-living, healthy older women, using a protocol similar to the one recently added in NHANES (Duffy et al. 2012; CDC 2014), and with all testing completed in the participants' homes. Internally reliable self-reported indices were constructed that reflected perceived current and change in orthonasal and retronasal olfaction with aging. These indices showed good agreement with measured olfactory function with improved sensitivity estimates than those previously reported (Ship and Weiffenbach 1993; Nordin et al. 1995; Murphy et al. 2002; Shu et al. 2009; Karpa et al. 2010; Wehling et al. 2011). Defining self-rated dysfunction by current and perceived loss with aging produced the highest correspondence with measured dysfunction. Substantial agreement was seen between classifications of olfactory function by the composite task (threshold, identification) and the identification task alone, yet the identification task showed a greater level of agreement with the indices of perceived olfactory function.

The frequency of olfactory dysfunction in our sample of older women (21.5 %) approximated those reported for other community-based studies using similar identification measures, including the EHLS (24.5 %; Murphy et al. 2002), a Norwegian study (24 %; Wehling et al. 2011), the Blue Mountain Eye Study (27 %; Karpa et al. 2010), the Skovde study (32.9 %; Bramerson et al. 2004), and the Dortmund study (29.6 %; Vennemann et al. 2008), but lower than that seen for older adults in assisted living facilities (50 %; Doty et al. 1984a), who may have been less healthy. The frequency of self-rated olfactory dysfunction, as defined by reporting "below average" for current smell ability, was 16 % in our sample of older women, slightly higher than that observed by studies using similar measures in a comparable age group: EHLS (9.5 %; Murphy et al. 2002), the Norwegian study (12 %;Wehling et al. 2011), the Blue Mountain Eye Study (11 %; Karpa et al. 2010), and a Korean population-based study (~8 %; Lee et al. 2013).

Improved Sensitivity with Indices of Current and Perceived Age-Related Changes in Orthonasal and Retronasal Function

The sensitivity (correctly identifying dysfunction) of self-reported olfactory function was much higher in our study compared to others (Ship and Weiffenbach 1993; Nordin et al. 1995; Murphy et al. 2002; Shu et al. 2009; Karpa et al. 2010; Wehling et al. 2011). Consistent with previous studies (Ship and Weiffenbach 1993; Karpa et al. 2010), asking individuals to rate change in their sense of smell with age was a better indicator of measured smell impairment than asking their current olfactory ability. That is, of those with smell impairments in our sample, 60 % noticed a loss of smell perception with age whereas only 36 % correctly identified their ability as "below average." Additionally, constructed indices

that captured current and perceived changes in orthonasal as well as retronasal function showed better correspondence with measured function than unitary questions. A self-rated index comprised of current smell function and perceived loss (self-rated smell) yielded the most favorable sensitivity (65 %) and specificity (77 %) to measured function. Furthermore, in analyses excluding participants (n=6) with mild hyposmia (4≤identification score <5), the sensitivities reached as high as 75 % for self-rated smell and 90 % for self-rated smell/flavor loss (data not shown).

Similar to studies on perceived versus measured hearing (Deepthi and Kasthuri 2012) or vision (Rubin et al. 2001), participants with severe dysfunction in smell were most likely to recognize the problem—five out of six anosmics by composite measure and all eight anosmics by identification test correctly rated their current smell ability as “below average.” Hence, sensory loss may need to reach a “critical point,” beyond which the loss is more consistently noticed. Losses above this “critical point” are identified less, presumably due to the gradual decline, thus contributing to low sensitivity estimates among mild hyposmics. Although older adults may have reduced absolute odor or olfactory flavor sensation, they may not perceive losses to overall food flavor because taste and oral somatosensory sensations remain relatively intact with aging (Mojet et al. 2003). Self-awareness of smell function could be lower than self-awareness of hearing or vision as smell is not assessed as routinely.

Lower Specificity—Variability in Olfactory Function or Measurement Issue?

The self-reported measures in our study produced somewhat lower specificities (64–77 %) than those reported previously (Ship and Weiffenbach 1993; Nordin et al. 1995; Murphy et al. 2002; Shu et al. 2009; Karpa et al. 2010; Wehling et al. 2011). Some older adults have low retronasal function despite normal orthonasal ability (Duffy et al. 1999), which may explain lower specificity of the self-rated smell/flavor loss index in the present study. Orthonasal and retronasal tests provide differential diagnosis of olfactory dysfunction (Bojanowski and Hummel 2012); hence, our orthonasal measure likely did not capture the full variability in retronasal function in our sample. Alternatively, smell losses associated with nasal sinus diseases, for example, may be intermittent (Mann and Lafreniere 2004) and would have been missed by our single assessment. The lower observed specificities also could be attributed to some older adults assuming losses with aging. It is worth noting that the majority of our participants (84 %) rated their sense of smell as at least “average.” However, approximately 25 % reported loss of smell perception with age, yet also rated their ability as “average or above.” These findings suggest that the term “average” to an older person may mean average for their age, including losses expected with age.

Olfactory Threshold Testing May Not be Necessary in Community-Based Studies

Compared to the composite (identification and threshold) measure, the identification task alone accurately detected both normosmia and severe olfactory dysfunction, yet misidentified some cases of microsmia as having no impairment. Eight of ten women incorrectly classified as normosmics by the identification task were mild hyposmics (4≤composite score <5). Only two of the 19 severe hyposmics (2≤composite score <4) were incorrectly identified as normosmics by the identification task alone (data not shown). Given

the good correspondence between odor threshold and identification from our study and others (Doty et al. 1984b; Hummel et al. 1997), it is reasonable to conclude that odor identification alone is a sufficient measure to classify olfactory dysfunction, particularly in testing situations where tight stimulus control is not feasible. Improved stimulus control and precision in a field setting may permit adding an intensity rating to an odor identification task (Minski and Duffy 2009; Rawal et al. 2013) and/or conducting a threshold task (Cain et al. 2013) to identify olfactory dysfunction and acuity. However, threshold tests currently have limited use in large population-based studies as they are time consuming and have low test-retest reliability due to variability in test administration and stimulus delivery (Heywood and Costanzo 1986).

Strengths, Limitations, and Conclusions

This community-based study found reasonable agreement between self-reported and measured olfactory function via self-rated indices that captured current and perceived change in smell and flavor. The odor identification task showed good agreement with the composite measure (threshold test and identification task) and better correspondence with self-reported function, supporting its use as a screening measure of olfactory dysfunction. The sensitivities of the self-rated indices were fairly high (75 to 90 %), particularly when excluding mild hyposmics. Since the primary interest of clinicians is to identify severe dysfunction, these findings suggest that our self-reported indices could serve as quick screeners to identify severe olfactory dysfunction in those who are otherwise healthy. That said, we may have seen a high level of agreement between perceived and measured olfactory function because our sample of older women were reportedly healthy with high level of personal functioning and were tested in a familiar environment. The generalizability of our findings to more diverse groups may be limited as the subject pool was small in size and relatively homogeneous. The results from the NHANES chemosensory protocol will provide US nationally representative data on the correspondence between similarly structured self-rated olfactory function and performance on an odor identification task.

In light of the high prevalence and associated risks of chemosensory dysfunction in older adults, the Federal Interagency Workgroup for Healthy People 2020 has added taste and smell disorder-related goals to its surveillance agenda, including increasing the proportion of adults with chemosensory disorders who seek medical attention for their disorder. Olfactory evaluation, however, is not common in routine health assessments. From our findings, clinicians could ask current and perceived changes in smell and flavor to identify severe olfactory dysfunction and could follow up with additional assessments (Croy et al. 2011; Pusswald et al. 2012) and evaluation if the dysfunction interferes with health, nutritional status, and/or well-being (quality of life). There are many qualitative aspects of smell impairments, such as presence of phantom or distorted smells, which are not captured by routine olfactory testing. Intermittent smell losses can be missed by single testing, reinforcing the need for assessing both measured and self-rated olfactory function. Intraindividual variation in olfactory function across time also is important in the interpretation of olfactory dysfunction prevalence in population-based studies (Schubert et al. 2009). Moreover, subjective health assessments are value-added to objective

measurements of health and have been previously shown to be good predictors of physiological health and mortality (Hunt et al. 1984; Seid et al. 2004).

Acknowledgments

We extend a special thanks to the study participants. This project was supported in part by funds from the US Department of Agriculture Hatch Project 396 [CONS00827 and PEN04332] and the NIH/NIDCD Interagency Agreement (Y1-DC-0013) with CDC/NCHS for support of the NHANES Chemosensory (Taste and Smell) Protocol.

Abbreviations

α	Cronbach's alpha, a coefficient of reliability (or consistency) across variables, not a statistical test
CCCRC	Connecticut Chemosensory Clinical Research Center olfactory test, a measure of olfactory function from a single odor threshold (*n*-butanol) and seven-odor identification task
EHLS	Epidemiology of Hearing Loss Study, a population-based, longitudinal cohort study based on community residents in Beaver Dam, WI, town or township
κ	Cohen's kappa, a statistical measure ranging from 0.0 to 1.0, with larger values indicating better inter-rater agreement or reliability; used to assess reliability when observing or coding qualitative or categorical variables
NHANES	The National Health and Nutrition Examination Survey, a federally sponsored examination survey to assess the health and nutritional status of adults and children in the civilian, noninstitutionalized population of the USA; it combines the collection of health interview (questionnaire) data in the home with subsequent physical examinations in a mobile examination center (MEC)
r	Pearson correlation coefficient or product-moment correlation, a measure of the linear correlation (or strength of linear dependence) between two variables; values range between −1.0 and +1.0
r_s	Spearman rank correlation coefficient r_s, a non-parametric alternative to the Pearson correlation coefficient; uses the rank-order values instead of the real number values assumed by two variables
SEM	Standard error of the mean
SPSS	Statistical Package for the Social Sciences, a software package used for statistical analysis (www-01.ibm.com/software/analytics/spss)

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Table 1

Self-rated olfactory function questions

1	How would you rate your sense of smell right now? 1=very poor; 2=poor; 3=below average; 4=average; 5=above average; 6=good; 7=excellent
2	How would you rate your sense of smell now compared to when you were 30 to 35 years old? 1=extremely weaker; 2=much weaker; 3=somewhat weaker; 4=the same; 5=somewhat stronger; 6=much stronger; 7=extremely stronger
3	How would you rate your ability to sense the flavor of food now compared to when you were 30 to 35 years old? 1=extremely weaker; 2=much weaker; 3=somewhat weaker; 4=the same; 5=somewhat stronger; 6=much stronger; 7=extremely stronger

Table 2

Olfactory function from composite (odor threshold measurement combined with identification task) task versus odor identification task alone

		Composite classification[a]			Total (%)
		Anosmia	**Microsmia**	**Normosmia**	
Identification classification[†]	Anosmia	5	3	0	8 (6.5 %)
	Microsmia	1	17	0	18 (15 %)
	Normosmia	0	10	85	95 (78.5 %)
Total (%)		6 (5 %)	30 (25 %)	85 (70 %)	121

κ=0.72, 95 % CI 0.66–0.78; p<0.001

[a] Anosmia (0–1.9); microsmia (2.0–4.9); normosmia (5.0–7.0)

Table 3

Joint distribution of self-rated current smell ability with self-rated change in smell and flavor with age among independent-living older women

	Self-rated change in smell[a]		Self-rated change in flavor[b]		
	Below same	**Same or stronger**	**Below same**	**Same or stronger**	**Total (%)**
Self-rated smell ability					
Below average	17	2	12	7	19 (16 %)
Average or above	29	73	24	78	102 (84 %)
Total (%)	46 (38 %)	75 (62 %)	36 (30 %)	85 (70 %)	121

[a] κ=0.39, 95 % CI 0.31–0.47; p<0.001

[b] κ=0.29, 95 % CI 0.20–0.38; p<0.001

Chemosens Percept. Author manuscript; available in PMC 2015 April 10.

Table 4

Distribution of older women by self-rated olfaction indices and measured olfaction for calculation of sensitivity and specificity

		Measured olfaction[b]						Total (%)
		Composite classification			Identification classification			
		Dysfunction		Normosmia	Dysfunction		Normosmia	
		Anosmia	Microsmia		Anosmia	Microsmia		
Self-rated smell[a]	Dysfunction	5	16	18	8	9	22	39 (32 %)
	Normal	1	14	67	0	9	73	82 (68 %)
Self-rated smell/flavor loss[a]	Dysfunction	6	18	30	8	12	34	54 (45 %)
	Normal	0	12	55	0	6	61	67 (55 %)
Total (%)		6 (5 %)	30 (25 %)	85 (70 %)	8 (6.5 %)	18 (15 %)	95 (78.5 %)	121 (100 %)

Sensitivity=measured dysfunction/(measured dysfunction+incorrectly classified as normosmia by self-rated); as an example, sensitivity of *self-rated smell* vs. identification task is [(8+9)/(8+9+9)]=65 %

Specificity=measured normal/(measured normosmia+incorrectly classified as dysfunction by self-rated); as an example, the specificity of *self-rated smell* vs. identification task is [73/(73+22)]=77 %

[a]Self-rated olfaction indices based on perceived function and changes in smell function or by perceived changes in smell and flavor (dysfunction—scores 0 to 7.9; normal—scores 8.0 to 14.0)

[b]Measured olfaction by composite task (single odor threshold averaged with odor identification task) or odor identification task alone (scores ranged from 0 to 7.0; dysfunction—0 to 4.9 and normosmia—scores 5.0 to 7.0)