Smell distortions: Prevalence, longevity and impact of parosmia in a population-based, longitudinal study spanning 10 years

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Abstract. Parosmia, experiences of distorted smell sensations, is a common consequence of covid-19. The phenomenon is not well understood in terms of its impact and long-term outcomes. We examined parosmia in a population-based sample from the Betula study that was conducted in Umeå in northern Sweden (baseline data collected in 1998-2000). We used a baseline sample of 2168 individuals aged 35-90 years and with no cognitive impairment at baseline. We investigated the prevalence of parosmia and, using regression analyses, its relationship to other olfactory and cognitive variables and quality of life. Benefitting from the longitudinal study design, we also assessed the persistence of parosmia over 5 and 10 years prospectively. Parosmia was prevalent in 5% of the population (n=104) and was often co-occurring with phantosmia (“olfactory hallucinations”), but was not associated with lower self-rated overall quality of life or poor performance on olfactory or cognitive tests. For some individuals, parosmia was retained 5 years (17%) or even 10 years later (10%). Thus, parosmia is relative common in the population, and can be persistent for some individuals. This work provides rare insights into the expected impact of, and recovery from parosmia, with implications for those suffering from qualitative olfactory dysfunction following covid-19.

Introduction

Parosmia is an olfactory disorder (OD) where odor perception is distorted and different stimuli trigger unpleasant odor sensations previously not associated with the stimuli (i.e. smelling freshly brewed coffee, but experiencing a rotten smell). Parosmia is, together with Phantosmia (experiencing an odor without the presence of a triggering source), referred to as qualitative ODs (Nordin et al., 1996; Nordin, Brämerson, Millqvist and Bende, 2007; Croy et al., 2014). Qualitative OD is less well understood than quantitative OD, such as hyposmia, reduced olfactory ability; and anosmia, complete loss of smell (Frasnelli and Hummel, 2005; Landis, Frasnelli, Croy and Hummel, 2010; Reden, Maroldt, Fritz, Zahnert, and Hummel, 2006). Olfactory disorders are common in the general population, especially in the older age-groups, but are often not diagnosed (Desiato et al., 2020). The overall prevalence of OD in the general population was estimated to 28.8% with objective measurements, and about 9.5% with subjective assessments (Desiato et al., 2020). A Swedish population-based study yielded an estimated parosmia prevalence of 4.0% in the adult population (Nordin et al., 2007).

The olfactory experiences in parosmia are unpleasant; rotten, burnt and sewage are examples of sensations reported by parosmics, and tobacco, coffee, perfume and citrus fruits are some of the most common triggers (Bonfils et al., 2005). The covid-19 pandemic has led to an increased awareness of, and interest in parosmia. Although patients with parosmia tend to describe their olfactory experience as being the smell of for example sewage, it seems that the actual sensation is novel (AbScent Anosmia Support, 2021). Patients resort to illustrating their parosmic sensation with names of odors that are common and unpleasant, to communicate the level of disgust experienced (AbScent Anosmia Support, 2021). Olfactory deficits are more common in men than in women (Desiato et al., 2020). Phantosmia on the other hand may be more common in women (Sjölund, Larsson, Olofsson, Seubert and Laukka, 2017). Parosmia is thought to similarly affect men and women (Croy, Yarina and Hummel, 2013; Landis et al., 2010; Nordin et al., 2007). Some studies found no association between parosmia and age (Cory et al., 2013; Landis et al., 2010), whereas others report higher prevalence in young adults (Nordin et al., 2007).

Parosmia often co-occurs with a quantitative OD (Bonfils, Avan, Faulcon and Malinvaud, 2005; Croy et al., 2013; Frasnelli and Hummel, 2005; Landis et al., 2010; Reden et al., 2006). Between 10% and 60% of the OD patient-group suffer from parosmia (Croy et al., 2014; Landis et al., 2010; Reden et al., 2006). Between 83% and 100% are thought to have also a quantitative OD (Bonfils et al., 2005; Frasnelli and Hummel, 2005; Landis et al., 2010), where hyposmia appears most commonly observed (Bonfils et al., 2005; Frasnelli and Hummel, 2005; Reden et al., 2006). The most common etiologies for parosmia are upper respiratory tract infection (URTI) (Bitter et al., 2011), head trauma (Iannilli, Leopold, Hornung and Hummel, 2019), sinonasal disease (Landis et al., 2010; Reden et al., 2006), neurological deficits, exposure to toxic chemicals, psychiatric connections and nasal operations (Bonfils et al., 2005). Covid-19 is a type of URTI (Sayin, Yaşar, and Yazici, 2020). In a recent comparison between covid-19-positive patients and patients with a different type of URTI, results showed that both parosmia and hyposmia were more frequent in the covid-19-positive group (Sayin et al., 2020). Hence, parosmia and quantitative ODs appear strongly associated, and the covid-19 pandemic has emphasized the need for understanding their long-term impact.

Research conducted before the covid-19 pandemic indicated that 57.1% of parosmia cases develop either simultaneously with, or within a few months following the onset of a quantitative OD (Bonfils et al., 2005). The longitudinal prognosis of parosmia is uncertain,

since there is little known about how persistent parosmia is over time. There are records of patients reportedly having had parosmia between three months to 22 years, though these are based on retrospective self-evaluations (Bonfils et al., 2005). Parosmia is associated with a lower volume of olfactory cortical regions, as well as behavioral deficits in odor discrimination and memory (Bitter et al., 2011). This morphological difference might help explain the distorted olfactory qualities (Bitter et al., 2011). In a study examining brain activation, patients with parosmia and hyposmia had a higher activation in areas associated with attention directing (in relation to smells), the processing of odor valence, and the perception of contempt and disgust (Iannilli et al., 2019). Generally, unpleasant odors result in a stronger brain activation since they are more important to identify than pleasant ones, due to their higher biological significance (Iannilli et al., 2019). Parosmia may thus either cause, or be a consequence of, a combination of atrophy and disrupted brain activation paths. It is critical to understand the persistence of parosmia, since it could be a chronic disease for some individuals.

Olfactory disorders have been associated with depression and a reduced quality of life (QoL). Patients with depression often perform worse than healthy controls on olfactory tests (Kohli et al., 2016). Patients with more severe depression are more likely to report parosmia and/or phantosmia (Croy et al., 2013). Between one fourth to one third of individuals with ODs exhibited symptoms of depression, whilst about a third experienced a lowered QoL (Croy, Nordin and Hummel, 2014). Furthermore, about one third of individuals with qualitative ODs reported high depression scores on Beck's Depression Inventory (BDI) (Croy et al., 2014). Severe self-rated qualitative OD is associated with more severe self-rated depression (Croy et al., 2013). About half of parosmic patients reported their quality of life as being severely affected due to their OD (Bonfils et al., 2005). Patients with parosmia and an olfactory deficit have difficulty coping with their olfactory dysfunction, compared to patients with only an olfactory deficit (Frasnelli and Hummel, 2005). Mild depression was significantly more frequent in the parosmic group, compared to a control group with only quantitative ODs (Frasnelli and Hummel, 2005). Patients may adapt to their OD over time, resulting in reduced depressive symptoms at follow-up (Croy et al. 2014). Thus, patients with ODs, and especially parosmia, more often experience a lowered quality of life due to their disorder, and are at higher risk of having depression. It is unclear to what extent an OD results in more depressive symptoms or if depression might also be affecting olfactory recovery. While olfactory loss may result in reduced food consumption, but also compensatory overeating (Croy et al., 2014), parosmia has negative effects on appetite, mood, or interpersonal relationships (Temmel et al., 2002). Food flavor is distorted in parosmia, and appetite is diminished (Bonfils et al., 2005; Temmel et al., 2002).

There is a lack of large-scale, prospective studies on parosmia in the general population. Given the current circumstances of the covid-19-pandemic, it is critical to estimate the persistence and impact of parosmia. We used population-based data from the longitudinal Betula study to investigate the prevalence of parosmia in a large sample of adults, and its development over 5 and 10 years. Additionally, we investigated associations between parosmia and demographic (sex, age, education), olfactory (self-rated ability to perceive weak odors, phantosmia, current disease in nose, performance on the Scandinavian Odor Identification Test, SOIT), cognitive ability (vocabulary and Mini-Mental State Examination, MMSE) and QoL.

The study was conducted with 5 aims. First, we examined the prevalence of parosmia in a population-based sample, with the hypothesis that the prevalence will be around 4%, mimicking the results from the study by Nordin et al. (2007). Second, the relationship between parosmia and sex, age and education will be investigated; we hypothesized that these variables

would not predict be associated with parosmia in this sample of individuals over 35 years of age (Cory et al., 2013; Landis et al., 2010; Nordin et al., 2007). Third, we investigated the relationship between parosmia and other olfactory variables, hypothesizing that parosmics will rate themselves having a worse olfactory ability, perform more poorly on an odor identification test, and report a higher frequency of phantosmia, than non-parosmics (Bonfils et al., 2005; Frasnelli and Hummel, 2005; Landis et al., 2010; Reden et al., 2007; Sjölund et al., 2017). Fourth, we compared QoL scores between the parosmic and non-parosmic population. We hypothesized that those with parosmia will provide lower ratings, since previous studies have shown a strong association between olfactory disorders, including parosmia, and QoL (Bonfils et al., 2005; Cory et al., 2014; Temmel et al., 2002), as well as depression (Cory et al., 2013, 2014; Kohli et al., 2016). and reduced appetite (Bonfils et al., 2005; Cory et al., 2014; Temmel et al., 2002). Lastly, we explored how parosmia persisted over 5 and 10 years.

Materials and methods

The Betula Study

The present data was collected as part of the Betula study, a prospective population-based study of aging, cognition, and health (Nilsson et al., 1997, 2004; Nyberg et al., 2020). In Betula, extensive psychological testing and health assessments are conducted every 5 years. The first test wave was conducted between 1988-90, and as of 2021 the latest wave was implemented in 2017. The Betula study includes assessments on a large number of variables (genetic, lifestyle, health, brain and cognitive) through interviews, tests and questionnaires, which all were administered by trained professionals (Nilsson et al., 1997, 2004; Nyberg et al., 2020). The data used in the present study was collected during the third wave of testing which occurred in 1998–2000 (baseline); this is when olfactory assessments were included in the testing battery. Additional data were obtained from the fourth (2003 – 2005; 5-year follow-up) and fifth wave (2008 – 2010; ten-year follow-up) of testing. The data were obtained from age-stratified independent random samples from the population of Umeå, a city with about 110,000 inhabitants, located in northern Sweden. Sample 1 were recruited at the first test wave (1988-90) of the Betula study and have been part of every test wave since. Sample 2 and Sample 3 were recruited at the second test wave (1993-95). Sample 2 was designed to mimic sample 1's age at the first test wave, and was also part of test wave three. Sample 3 mimicked sample 1's age at the current wave and was also part of all subsequent test waves. Sample 4 was only included at test wave 3, and was selected to mimic sample 1's age at wave 1. Accordingly, sample 1 were tested on two previous occasions, sample 2 and 3 had experience from one previous test wave, and sample 4 had no previous testing experience. The purpose of recruiting multiple samples was to model cohort-effects (e.g. the “Flynn effect”) on aging and cognition, but we aggregate data across samples.

Participants

Participants in the Betula study were recruited from the municipality of Umeå, Sweden. They were randomly selected from the population registry, stratified by age and gender. The age cohorts were split into 5-year intervals (35, 40, 45 ... 90) and the number of females and males selected for inclusion was proportional to the general population's female-male ratio in each age-group. The total data set for the current study (third, fourth and fifth wave) contained 4712 participants. For this study, individuals without data on the question regarding parosmia

at the third wave were excluded ($n = 2035$). In addition, participants scoring under the cut-off value of 26 points ($n = 468$) on the Mini-Mental State Examination (Folstein et al., 1975), with missing data on the QoL-questionnaire ($n = 5$) or with vocabulary assessment results three standard deviations lower than the group mean ($n = 36$) were excluded (see Figure 1). Thus, the final study sample consisted of 2168 individuals (53.2% female, between 35 and 90 years of age). The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the Faculty of Medicine and Odontology, Umeå University. All participants gave their written informed consent.

Assessment of parosmia

In the Betula study, parosmia was assessed through self-reports with the question “Does it happen that you smell something, for example a rose or an orange, that should have a smell that you recognize, but instead you feel a bad, tainted or burned smell?”. The question was answered with either “cannot”, “no” or “yes”. Participants were grouped as parosmics (yes) and non-parosmics (no).

Figure 1. Exclusion flowchart. MMSE, Mini-Mental State Examination. QoL, Quality of Life. Vocabulary, Vocabulary test.

Correlates of parosmia

Demographic variables. Demographic variables included sex, age and years of education, which was reported in 0.5-year intervals. Mean differences in age and educational background between the parosmic and non-parosmic population were examined.

Olfactory functions. In the Betula study, self-rated assessments of olfactory abilities were acquired through a questionnaire consisting of four questions concerning the respondent's ability to feel weak odors, parosmic and phantosmic experiences, and presence of diseases in the nose (at the time of the questionnaire). Ability to feel weak odors was examined through the question "How is your ability to feel weak odors?". The question was answered with either "cannot", "worse than normal", "normal" or "better". Participants were grouped as worse than normal (cannot, worse than normal) or normal (normal, better). Phantosmia was assessed with the question "Does it happen that you feel a bad, tainted or burned smell when there is nothing that could have caused it?", and the presence of a nose disease with the question "At present, do you have some type of disease in the nose, for example problems to breathe through the nose, infection in sinus, nasal polyps, or allergic symptoms in the nose?". The questions were answered with either "cannot", "no" or "yes". If there was a disease in the nose prevalent, participants were able to state what sort of disease it was. The Betula study includes a version of the Scandinavian Odor Identification Test (SOIT) (Nordin, Brämerson, Lidén and Bende, 1998). This version comprises 13 olfactory stimuli that are familiar to the Scandinavian population: pine-needle, juniper berry, violet, anise, clove, vanilla, almond (bitter), orange, cinnamon, lemon, lilac, tar, and apple. The intensity of the odors is fairly strong and a wide range of odor qualities are represented, such as floral, citrus, non-citrus fruity, sweet, woody, and spicy. Participants were presented a written list of four response alternatives for each stimulus, where one verbal label correctly represented the odor (see Bende and Nordin, 1997 for details). Each participant was randomly presented with one out of 10 different orders of the 13 olfactory stimuli. The odors and their corresponding response alternatives were identical for all participants. There was a 30 second inter-stimulus interval between odor items, to prevent effects of adaptation. SOIT has a low- to moderate correlation with several cognitive tests (Larsson, Nilsson, Olofsson and Nordin, 2004).

Cognitive functions. To control for cognitive influences on the SOIT performance and screen for individuals with cognitive deficits which might affect the overall reliability in test- and questionnaire results, a vocabulary test and the MMSE were used. The vocabulary test used in the Betula study was a 30-item multiple-choice test consisting of one target word and 5 alternatives, where the instructions were to identify the synonym to the target word out of the 5 alternatives (Dureman and Sälde, 1959). The test was self-paced with a time limit of 7 min. Hence the vocabulary test resembled the SOIT in that both tests used a multiple-choice format of matching a stimulus to one of several verbal response alternatives. In order to control for general cognitive deficits which might indicate dementia, the Mini-Mental State Examination was used. The MMSE tests cognitive state through examining the individual's orientation, perception, attention and calculation, recall, and language abilities (Folstein, Folstein and McHugh, 1975).

Quality of Life. The Betula study included a questionnaire consisting of 21 questions with the purpose of exploring subjective health status. Out of those, 5 questions were selected as a relevant measure of quality of life.

1. Do you feel well?
2. Are you troubled by loss of appetite?
3. Are you troubled by often feeling dispirited?
4. Are you troubled by often feeling lonely?
5. Are you troubled by anxiety, worries?

This set of questions were chosen because of their similarities to questions and questionnaires regarding mental health and quality of life used in other studies of olfactory dysfunction (Croy et al., 2014; Frasnelli & Hummel, 2005; Kohli et al. 2016; Temmel et al., 2002). All questions could be answered with either “no” or “yes”. Question 1 was reverse-coded. A higher value on the combined mean-score for the QoL-questions (QoL-sum) indicates a worse quality of life (intervals 0 - 5).

Statistical analysis

Hierarchical logistic regression analyses were used to examine the relationship between parosmia and the included predictors at baseline. The first block in the regression model (block 1) consisted of sex, age and educational background. Latter blocks consisted of olfactory functions (block 2) and cognitive ability (block 3). Nagelkerke’s pseudo-R² is reported for every step, as a measure of model fit. Omnibus chi-square test of model coefficients was used to test if the inclusion of additional blocks resulted in significantly improved model fit. Odds ratios (OR) including 95% confidence intervals and P-values for each contrast are reported. Independent one-way ANOVA was used to examine potential differences between the parosmic and non-parosmic populations scores on the QoL-questions. A *t*-test was used to compare the mean scores of the sum of the 5 QoL-questions between the two groups. Additional hierarchical logistic regression analyses were conducted with the purpose of investigating if the variables for the parosmic group at baseline had a relationship with the outcome of parosmia at the 5-year follow-up. This was to determine whether any variables could predict the persistence of parosmia at the 5-year follow-up. All statistical analyses were performed with the SPSS statistical software package (version 27.0 for Mac).

Results

The overall prevalence of parosmia was 4.8% ($n = 104$ of 2064). In order to identify which baseline-variables that were associated with parosmia at baseline, a block-wise hierarchical logistic regression analysis was performed. The hierarchical logistic regression results are presented in **Table 1**. The demographic variables (block 1) alone were not significantly associated with parosmia ($p = .06$). When olfactory variables were added (block 2) (Nagelkerke’s pseudo-R² = .151; $P = < .001$) the model fit significantly improved. After including also cognitive variables, the model was not improved further (Nagelkerke’s pseudo-R² = .155; $P = < .001$). In the final regression model, only three significant individual correlates were identified, all from block 2 (olfaction). Prevalent phantosmia was strongly associated with parosmia ($p = < .01$). The presence of a disease in the nose, and higher SOIT-scores also showed an association with parosmia ($p = < .05$). None of the demographic or cognitive variables contributed significantly to parosmia. Self-reported inability to perceive weak odors was not related to parosmia. We investigated whether people might have reported their parosmia as a disease of the nose, which would trivially explain the association between these two variables, by reviewing a free text variable where the disease of the nose was specified (notes by test administrator during the interview). A majority of those who reported having a disease of the nose reported a common cold, nasal congestion or allergies, but no person reported parosmia as the present nasal disease. This excludes the possibility that the statistical association between parosmia and disease of the nose were due to incorrect reporting. Parosmia was thus associated with phantosmia, disease of the nose, and, surprisingly, a slightly higher odor identification performance level.

A *t*-test was used to investigate potential differences between the parosmic and non-parosmic populations' sum of the quality of life scores. The 5 QoL-questions were analyzed individually by means of ANOVA-tests to control for eventual differences between the populations in each specific question. The *t*-test showed no significant differences of the sum of the QoL-questions, $t(2165) = -.95$, $p = .34$ (Levene's $p = .52$), between the parosmic ($M = 0.70$, $SD = 0.99$) and non-parosmic population ($M = 0.61$, $SD = 0.94$) with a small effect size (Cohen's $d = .10$). ANOVA-results indicated that there were no significant differences in answer frequencies for any QoL-questions between the parosmic and non-parosmic groups ("Feel well?" $F(1, 2165) = .88$ $p = .35$; "No appetite?" $F(1, 2166) = .00$ $p = .99$; "Often dispirited?" $F(1, 2166) = .07$ $p = .79$; "Often feel lonely?" $F(1, 2166) = .03$ $p = .87$; "Anxiety?" $F(1, 2166) = .93$ $p = .34$). There was thus no difference between the parosmic and non-parosmic groups in self-rated QoL.

Table 1
Block wise hierarchical logistic regression analysis for correlates of parosmia (n = 2115)

Characteristics	Nagelkerke's pseudo-R2	Model parameters		Model parameters, all factors included	
		OR	95% CI	OR	95% CI
1. Demographics	.011				
Sex		1.11	0.75-1.66	1.39	0.90-2.13
Age		0.99	0.97-1.01	0.99	0.97-1.01
Education		0.92*	0.87-0.98	0.94	0.87-1.01
2. Olfaction	.151 ^{***}				
Ability to feel weak odors		0.86	0.52-1.42	0.86	0.52-1.43
Phantosmia		9.95**	6.43-15.42	9.97**	6.42-15.50
Disease in nose		1.71*	1.03-2.83	1.75*	1.06-2.91
SOIT		1.12*	1.01-1.25	1.13*	1.02-1.26
3. Cognition	.155				
Language		0.97	0.92-1.03	0.97	0.92-1.03
MMSE		0.91	0.76-1.10	0.91	0.76-1.10

MMSE, Mini-Mental State Examination; SOIT, Scandinavian Odor-Identification Test.

^aSignificance was based on the omnibus chi-square test of model coefficients.

* $P < .05$, ** $P < .01$.

Next, we assessed how long the parosmia symptoms lasted, using data from follow-up test waves. A total of 946 individuals (constituting 43.6% out of the original 2168) participated in the 5-year follow-up and of those, 47 (5.0%) of the participants had parosmia at baseline. The smaller sample at follow-up is mostly due to the fact that the Betula study size varies across testing waves and not all participants are asked to return. Dropout is also present in all longitudinal studies, but Betula has a very high return rate overall, and the most common reason for dropping out is that participants are deceased, which becomes more common in older age groups (Nilsson et al., 2004). In *Table 2* the sample sizes from baseline, the 5-year follow-up,

and the ten-year follow-up are presented. At the 5-year follow-up, 45 (4.8%) individuals had self-rated parosmia, of which eight (17.8%) had parosmia at baseline and 37 (82.2%) had developed parosmia since baseline. Of the 47 individuals with parosmia at baseline who returned for the 5-year follow-up, 39 (83%) had recovered and eight (17.0%) had not recovered during the 5-year span. There were also new cases of parosmia. Of the 899 participants at the 5-year follow-up who reported not having parosmia at baseline, 37 (4.1%) had now developed parosmia. The results from the chi-square test showed that there was a significant association between having parosmia at baseline and having it at the 5-year follow-up ($p = < 0.01$). We investigated demographic, olfactory and cognitive variables at baseline that might predict the persistence of parosmia (self-rated parosmia at baseline and the 5-year follow-up) through a block-wise hierarchical logistic regression analysis. Results showed that phantosmia was the only significant predictor ($OR = 16.13, p = .025, 95\% CI = 1.42-183.45$). Having parosmia and phantosmia simultaneously increases the risk of having parosmia 5 years later.

There was also data from a ten-year follow-up, where 5 (13%) out of 39 individuals who had parosmia at baseline still had parosmia at the ten-year follow-up. Out of the eight individuals who had had parosmia at base-line and at the 5-year follow-up, only six participated in the ten-year follow-up. Four out of these six had parosmia at the ten-year follow-up (10% out of the 39). Interestingly, one individual reported no parosmia at the 5-year follow-up, but had been affected by parosmia again at the ten-year follow-up. This means that four (10%) out of the 39 individuals who had parosmia at baseline had reported parosmia at all three assessments over 10 years. This might indicate that if parosmia does not pass within 5 years, it is likely to still be prevalent after 10 years. Our results also show that it is possible to be affected by parosmia again, after having recovered from it, even though it is very rare. *Table 2* also shows that the overall prevalence of parosmia was stable at baseline and 5-year follow-up but declined at the 10-year follow-up, which could be due to attrition effects (healthier individuals are more likely to return for follow-up testing).

Table 2

Participants with and without parosmia at each test-wave and percentages of total participants compared to baseline.

	Parosmia, n		Total, n (%)
	No	Yes (%)	
Baseline	2064	104 (4.8%)	2168 (100)
5-year follow-up	901	45 (4.8%)	946 (43.6)
10-year follow-up	693	21 (2.9%)	714 (32.9)

Discussion

We investigated parosmia from several different perspectives, with the aim of providing new knowledge on how parosmia affects the general public; this will facilitate recovery prognoses for those affected by parosmia during the covid-19 pandemic. First, the prevalence of parosmia was investigated in a population-based sample. Second, the relationship between parosmia and demographic variables, and third, the relationship between parosmia and other olfactory variables were investigated. Fourth, the parosmics' self-rated quality of life was compared to that of the non-parosmic sample. Lastly, the persistence of parosmia over 5 (and ten) years was investigated.

The results showed that 4.8% of the population between 35 and 90 years of age had parosmia. For one sixth (17%) of those participating at the follow-ups, the disorder persisted over at least 5 years and for about a tenth (10%) it persisted for at least 10 years. Sex, age and education level was not associated with parosmia. The prevalence of phantosmia and a current nose disease, as well as somewhat higher scores on the Scandinavian odor identification test, was associated with parosmia. Parosmia was not associated with self-rated odor perception. Surprisingly, the parosmic population did not exhibit lower scores on QoL, and did not report a reduced appetite. Our prevalence estimates correspond to those obtained in the population-study by Nordin et al. (2007), where 4.0% of the population 20 years and older reported having parosmia. The current study excluded individuals with low scores on MMSE and the language-test to control for inaccurate self-ratings of parosmia due to misunderstanding of the question. Despite this, one can argue that the current study may be liable to over-diagnosing parosmia due to the fact that some individuals might have interpreted the question wrongly, whereas parosmia was evaluated through an interview with a clinical professional in the study by Nordin et al., (2007) and thus might be more reliable. The results thus indicating that parosmia is a rather common symptom in the general public, even before covid-19.

Little is known about the longevity of parosmia. This is the first study, to our knowledge, to present data on the persistence of parosmia over 5 and 10 years. Our results show that a sixth (17%) of individuals who reported parosmia at baseline had parosmia 5 years later, and 10% of parosmics at baseline still had parosmia at the ten-year follow-up. Although our long-term estimates of parosmia are affected by a shrinking sample size, the results suggest that having parosmia for 5 years means that it will likely persist over 10 years as well. We propose that the parosmic population in general does not experience a significantly reduced quality of life, compared to the non-parosmic population. Previous research has mainly focused on clinical populations (i.e. patients at smell and taste clinics), where results indicate that having an OD (including parosmia) is connected to also having symptoms of depression, or a lowered quality of life (Bonfils et al., 2005; Croy et al., 2013, 2014; Frasnelli and Hummel, 2005; Iannilli et al., 2019; Kohli et al., 2016; Temmel et al., 2002). One explanation to why the results of this study do not fit with those of previous studies is that the current study is based on a population-based sample instead of clinical samples. It can be argued that the parosmic population at large might not be as affected by their symptoms as much as those who seek medical attention (Frasnelli and Hummel, 2005; Bonfils et al., 2005; Croy et al., 2013). Thus, the results from previous studies account for parosmics with an impairment severe enough to seek out healthcare, whilst these results are more representative of parosmic population as a whole. Arguably, the typical individual experiencing parosmia due to covid-19 may be more alike the parosmics in this study, compared to the clinical populations with a reduced quality of life, who constitutes a subgroup.

The general consensus in the research field seems to be that parosmia in clinical samples is heavily associated with reduced olfactory functioning (Bonfils et al., 2005; Croy et al., 2013; Frasnelli and Hummel, 2005; Landis et al., 2010; Reden et al., 2006). The results from this study suggests instead that parosmia might be experienced in the general population independently of quantitative ODs. The most consistent association observed in this study was that between parosmia and phantosmia, corroborating results from previous work (e.g. Sjölund et al., 2017). This study has several limitations which need to be considered when interpreting the findings presented. First, as mentioned earlier, the fact that parosmia was evaluated through one questionnaire question is a limitation of the study, since it relies heavily on the participants' language comprehension and interpretation of their own olfactory function. Second, the data collection for this study was mainly conducted between 1998 and 2000 and extrapolations to

the current covid-pandemic context should be tempered. Third, this quantitative study does not provide a thorough understanding of the individual experiences of parosmia. The results in this study indicate that parosmics in general do not suffer more due to their disorder than the non-parosmic population, but this does not mean that individual cases follow the same pattern. There are certainly cases where parosmia leads to long-lasting problems, but our results suggest that the average parosmia case might have less extreme consequences.

Further research is needed regarding the range of intensity and impact of parosmia, considering that our results show it may last for over 10 years in 10% of parosmics, and that there are reports of parosmia persisting up to 22 years (Bonfils et al., 2005). Since parosmia seems to vary in duration between individuals, it raises the question whether there is a difference between the severity of symptoms and experienced suffering between those with short-term and long-term parosmia. The possible interactions between parosmia and phantosmia also need further investigation. Importantly, further research should consider parosmia as a spectrum, it would be helpful to develop an effective instrument that can evaluate the severity of parosmia.

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