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Taste loss as a distinct symptom of COVID-19: A systematic review and meta-analysis

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Taste loss as a distinct symptom of COVID-19: A systematic review and meta-analysis

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Abstract

Chemosensory scientists have been skeptical that reports of COVID-19 taste loss are genuine, in part because before COVID-19, taste loss was rare and often confused with smell loss. Therefore, to establish the predicted prevalence rate of taste loss in COVID-19 patients, we conducted a systematic review and meta-analysis of 376 papers published in 2020–2021, with 241 meeting all inclusion criteria. Additionally, we explored how methodological differences (direct vs. self-report measures) may affect these estimates. We hypothesized that direct prevalence measures of taste loss would be the most valid because they avoid the taste/smell confusion of self-report. The meta-analysis showed that, among 138,897 COVID-19-positive patients, 39.2% reported taste dysfunction (95% CI: 35.34–43.12%), and the prevalence estimates were slightly but not significantly higher from studies using direct (n = 18) versus self-report (n = 223) methodologies ($Q = 0.57$, $df = 1$, $p = 0.45$). Generally, males reported lower rates of taste loss than did females and taste loss was highest in middle-aged groups. Thus, taste loss is a bona fide symptom COVID-19, meriting further research into the most appropriate direct methods to measure it and its underlying mechanisms.

28 **Key words**: gustatory dysfunction, taste loss, ageusia, COVID-19, coronavirus

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Introduction

The novel coronavirus (COVID-19), a respiratory infection caused by severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2), was first identified in Wuhan, China, and has since spread throughout the world. When the World Health Organization first declared this a pandemic in March 2020, researchers and clinicians were not yet aware that the virus affected individuals' senses of smell and taste, but these symptoms soon became apparent via patient reports. As a result of COVID-19, affected people can experience chemosensory dysfunction in a variety of ways, including complete loss of smell or taste (anosmia or ageusia, respectively), partial loss of smell or taste (hyposmia or hypogeusia), and/or a distorted sense of smell or taste (e.g., parosmia, dysgeusia). These chemosensory dysfunctions can be distressing to the affected individuals and can last for extended times, with some patients experiencing resolution within a few weeks to a month (Lee et al., 2020b; Gerkin et al., 2021) and others with symptoms for 6 months or longer (Blomberg et al., 2021).

Previous meta-analyses examined smell and taste loss in COVID-19 patients, but often with a focus on onset and duration (Santos et al., 2021) or recovery (Boscutti et al., 2021) of chemosensory symptoms. Many focused only on smell loss (Hannum et al., 2020; Pang et al., 2020; Rocke et al., 2020) or general neurological symptoms (Abdullahi et al., 2020; Favas et al., 2020; Mair et al., 2021; Yassin et al., 2021). Very few continued to evaluate articles published in 2021 and often capped reviewing articles 6-10 months after March 2020, when the pandemic was declared, limiting the number of articles included (ranging from 5 to 59 articles total). Therefore, we decided to conduct a more comprehensive analysis, spanning a year and a half, to ensure a fuller coverage of the available research.

Additionally, taste loss is often neglected in research compared to smell loss, as there is a common notion that taste loss is not as "real" as smell loss. Some claim taste loss is indistinguishable from smell loss (Le Bon et al., 2021) or is confused with smell loss (Deems et al., 1991), specifically with retronasal smell perception (Hintschich et al., 2020a). For the general population, loss of taste can be difficult to distinguish from smell loss. Therefore, it may be difficult to know, based on self-report measures alone, whether or not a participant truly lost their sense of taste.

Thus, many chemosensory researchers may attribute the taste loss phenomena seen in the current reports of COVID-19-positive patients to deficiencies of self-report or subjective measures of taste loss. Therefore, we conducted a systematic review and meta-analysis to estimate the true prevalence of taste loss in COVID-19 patients across a wide sample of studies (n=241) and to evaluate effects of major methodological differences in data collection. In particular, we compared overall findings on taste loss as determined by individual taste tests (herein referred to as direct tests) with self-reports without direct sensory testing. We hypothesized that direct methodologies would support the presence of taste loss as a distinct symptom, and direct measures might even be higher than self-report despite the possible inflation of self-reported taste loss which is exacerbated by smell loss.

Currently scientists are using both direct and self-report measures to examine chemosensory dysfunction, with self-report far more common due to the pandemic restrictions, e.g., sensory laboratories where direct testing is often conducted are closed. For taste, direct tests include standardized and non-standardized tests that contain various sweet, salty, and sometimes bitter and sour stimuli given to participants via solutions, drops, strips, or sprays (Cao et al., 2021; Singer-Cornelius et al., 2021). Non-standardized direct taste measures created to study

COVID-19-related taste dysfunction include solution-based tests, often prepared at home by participants (Vaira et al., 2020f). Self-report measures include interviews with researchers and clinicians, electronic health records as well as surveys administered over the phone, online, or in person.

To understand taste loss as a symptom of COVID-19, we conducted a large systematic review and meta-analysis, examining how it has been measured (direct vs. self-report) and how the measurement type can affect prevalence rates. We tested the hypothesis that direct measures are at least as sensitive as self-report measures and would confirm taste loss as a distinct symptom and not merely misattributed smell loss.

Methods

Article Selection

This systematic review and meta-analysis followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines (Moher et al., 2009). Articles were selected via searches on Pubmed/Medline and Google Scholar, using the keyword "COVID-19" with "taste", "smell", and/or "olfaction", as well as "gustatory". Literature retrieval began on May 15, 2020, and concluded on June 1, 2021, resulting in 377 articles in total.

Initial screening of the articles included reading the titles and abstracts to assess their relevance. Articles with an abstract that reported chemosensory dysfunction in COVID-19-infected individuals were included in the systematic review (n = 376). Next, at least two authors read the articles initially deemed relevant, to evaluate whether they fit the inclusion criteria: reporting positive COVID-19 tests, written in the English language, and lack of population bias. COVID-19 must have been confirmed via nasopharyngeal swab, reverse transcription polymerase chain reaction (RT-PCR), or assessment by physician or other medical personnel.

The articles were then evaluated on whether they reported taste loss data specifically. In total, 135 articles were excluded based on such criteria as not evaluating taste loss, recruiting participants with chemosensory dysfunction, not testing for COVID-19, and presenting overlapping data (see Figure 1). In total, 241 articles were included in the final meta-analysis (corresponding citations described in "Included Articles" section at the end of the paper).

Data Extraction

We extracted from each article either the number or percentage of patients with taste dysfunction due to a SARS-CoV-2 infection. The prevalence of taste loss reported in each article was calculated by dividing the reported number of participants with taste loss as a symptom by the total number of COVID-19-positive participants. Additionally, measures of taste loss were labeled as "self-report" or "direct" to identify the method used to evaluate participants. Self-report measures included reported loss of taste via surveys, interviews, and electronic medical health records. Most articles (n = 223) used self-report methods. Table 1 summarizes the studies that used direct measures (n = 18), comprising actual taste tests administered either at home (Adamczyk et al., 2020; Hintschich et al., 2020a; Petrocelli et al., 2020b; Cao et al., 2021; Singer-Cornelius et al., 2021), at a testing facility (Altin et al., 2020; Bidkar et al., 2020a; Mazzatenta et al., 2020; Ramteke et al., 2020; Vaira et al., 2020a; Le Bon et al., 2021; Niklassen et al., 2021a; Salcan et al., 2021) or both in home and in a hospital environment (Vaira et al., 2020b, 2020c, 2020d, 2020f). Vaira et al. [2020e] had an unknown testing location. Many of the measures consisted of solution-based tests measuring four basic taste sensations: sweet, sour, salty, and bitter.

Although some authors reported exclusively smell loss or taste loss, many reported on both senses. Thus, it was necessary to include additional coding options for when authors reported the symptoms in tandem (e.g., "loss of smell or taste"). Therefore, articles were labeled as "taste only", "smell and/or taste", "smell and taste", "smell or taste", and "smell and/or taste; taste only" (in the event both values were reported, the numbers were summed), depending on how these symptoms were phrased in the article.

We also extracted demographic characteristics of each study, including the population mean and/or median age, sex (expressed as percentage of males in the population), and country of origin (for the geographic distribution of the study populations, see Supplementary Figure 1 (S1)).

Four authors performed the initial reading of full texts and the data extraction from the studies (R.D.H., A.K.T., S.S.M., R.J.K.). Two authors confirmed this information and resolved any inconsistencies (M.E.H., D.R.R.). Differences were resolved through a discussion and renewed consensus on the proposed solution from all authors who read that specific article.

Risk-of-Bias Assessment

We used a risk-of-bias assessment from Hoy et al. (2012) to examine the articles selected for the meta-analysis. The assessment contained nine questions, outlined in Supplementary Materials (see Supplementary Table (S2)). Responses were scored as 1 (no) or 0 (yes), with summary scores of low (0-3), moderate (4-6), and high (7-9). Two authors completed the risk-of-bias assessment of each article using the checklist developed by Hoy et al. (2012), as described and adapted by Tong et al. (2020) (S.S.M. and A.K.T.). One author resolved any discrepancies (M.E.H.).

Statistical Analysis

The meta-analysis was conducted using the meta package in R (Schwarzer et al., 2019). Generalized linear mixed models were used for the meta-analysis, as recommended for the analysis of binary outcomes and proportions (Bakbergenuly and Kulinskaya, 2018; Schwarzer et al., 2019). Heterogeneity (e.g., between study variance) was assessed using Cochran's Q, I^2, and tau squared (τ^2). We concluded there was evidence for heterogeneity when the p-value for Cochran's Q was less than 0.05 and if the I^2 was greater than 50% (Higgins and Thompson, 2002). Tau squared (τ^2), a measure of between study variance, was estimated using the maximum likelihood approach and has no associated test-statistic.

An overall pooled prevalence estimates were computed and reported for a random-effects model with the parameters described for all 241 studies. While both fixed and random-effect models were computed, excess the heterogeneity among our studies (see the Results section) suggested that unmeasured effects contribute to variance in our data more than would be expected from sampling error. The extreme diversity of taste loss as reported in individual studies (0 to 93.4%) suggested that the random-effects model was more appropriate.

Subgroup analysis was performed for studied employing direct methods (n = 18) and self-report methods (n = 223) to assess taste function in COVID-19–positive individuals. Additionally, the average age of participants and their sex (percentage of male subjects in each study) were included as covariates in univariate mixed-regression models. Subgroup analysis for age was arbitrarily categorized into five groupings: adolescents (0-18 years old), young adults (19-35 years old), middle-aged adults (36-50 years old), older adults (51-65 years old), and elderly adults (65+ years old). Finally, studies that used direct tests were separated, and subgroup analysis was performed for each type of collection methodology: solution based (N=12), strip based (N=5), and other (N=1). For continuous variables (e.g., age), the transformed beta

coefficients are reported. The transformation for the generalized linear mixed models uses a logit transformation for each proportion, so the models are interpreted as the log(odds) or log(p/1 – p), where p is equal to the prevalence for each study. Back-transformation into the prevalence estimates were done for subgroup analysis (e.g., age).

All statistical analyses were performed using R 4.0.5 (R Core, 2021) and RStudio 1.4.1106 (RStudio Team, 2020). Visualization of the meta-analysis is displayed as an orchard plot adapted from Nakagawa et al. (2020). The R scripts and compiled data used for this analysis are available without restriction at GitHub (https://github.com/vramirez4/COVID19-TasteLoss).

Results

Risk-of-Bias Assessment

Each of the 241 articles included in this meta-analysis were reviewed for risk of bias. Among these articles, none had a high risk of bias, 142 studies had a moderate risk, and 99 studies had a low risk (see Supplementary Table S2 for the full assessment).

Prevalence of taste loss in COVID-19-positive patients

Among the 241 studies, the sample sizes ranged from 11 to over 40,000 patients with COVID-19. The number of cases of taste loss per study ranged from 0 to 4,668, with raw prevalence estimates ranging from 0% to 93.4%. Collectively, the meta-analysis included 138,785 patients who tested positive for COVID-19. Of these, 32,918 patients had some form of taste loss after infection with SARS-CoV-2. Heterogeneity among the prevalence estimates across all studies (n = 241) yielded a significant Cochran's Q (Q = 29388.75, degrees of freedom [df] = 240, P < 0.001), and an I^2 estimate of 99.2%, and τ^2 estimate of 1.5. The pooled estimate for taste loss prevalence in COVID-19-positive patients following meta-analysis for the overall cohort was 36.90% (95% CI: 33.27–40.69%).

Effect of methodology (direct vs. self-report) on prevalence estimate

We employed a subgroup analysis to determine the effect of direct versus self-report approaches on taste loss prevalence (see Figure 2). Eighteen studies used direct methods to assess taste loss, comprising 2,240 COVID-19 patients, with 1,092 reported cases of taste loss. Per study, the prevalence of taste loss ranged from 0% to 84% among COVID-19-positive patients. For studies using direct approaches, the pooled estimate of the prevalence for the random-effect model was 42.0% (95% CI: 30.0-55.0%). Cochran's Q was significant ($Q = 187.93$, $df = 17$, $P < 0.001$), and an I^2 of 91.0% was obtained, confirming heterogeneity of the data collected via direct measures. The τ^2 for the direct methodologies was 1.2.

A total of 223 studies used self-report methods (e.g., questionnaire, interview), comprising 136,545 subjects, with 31,826 cases of taste loss. The reported prevalence of taste loss ranged from 1% to 93% per study. The pooled estimate of the prevalence under the random-effect models was 36.53% (95% CI: 32.8%-40.5%). Similar to the direct subgroup, Cochran's Q was significant ($Q = 29188.14$, $df = 222$, $P < 0.001$), and the I^2 value was 99.2%, confirming that the studies differed in prevalence across the self-report studies. The τ^2 for self-reported studies was 1.5.

A test of heterogeneity between groups was employed using Cochran's Q, which revealed that the differences between methodologies were not statistically significant ($Q = 0.66$, $df = 1$, $p = 0.4157$) under the random-effects model. While our analysis showed that the prevalence of taste loss was higher when measured directly than by self-report, there was no significant effect of measurement method on the prevalence estimates of taste loss.

Effect of age and sex on taste loss prevalence

Additional analyses were undertaken to assess the effect of age and sex. Univariate mixed models for each covariate revealed that both age and sex had significant effects on the prevalence of taste loss. After categorizing each study by mean age group, we conducted the meta-analysis for those 210 studies that reported the ages of the participants (see Table 2). Among this subset of studied the pooled prevalence was 37.16% and demonstrated significant heterogeneity with ($Q=33943.46$, $df = 209$, $p<0.001$), $I^2 = 98.9$, and $\tau^2 =1.5$. The prevalence estimates per age category ranged from 11% in studies with average ages younger than 18 years to 44% in studies with average ages between 36 and 50 years. Heterogeneity in these studies was high ($I^2 = 96.4$-98.9%) both within groups ($Q = 14106.77$, $df = 205$, $p<0.0001$) and between groups ($Q = 32.19$, $df = 4$, $p<0.0001$). The results demonstrated that both the youngest and oldest age groups report the lowest prevalence of taste loss, while age groups between 18 and 65 years had pooled estimates ranging from 32% to 44%, with the highest in the middle-age (36-50 years) group. Similarly, it appeared that age accounted for some of the overall heterogeneity among some groups as measured by reductions in τ^2 among studies who contained mostly adolescent and elderly individuals.

The effects of sex were similarly examined. A univariate mixed model using percentage of males in each study as a covariate found an effect of $\beta = -0.0296$ ($p < 0.001$) for each percent increase. Overall, the higher the percentage of males in a study, the lower the prevalence of taste loss.

Effect of type of direct approach on taste loss prevalence

When we compared the types of direct report test (e.g., solution-based test, taste strip-based test), we found a significant difference in prevalence rates (see Table 3). We classified studies into three categories: taste strip testing (n=5), taste solution testing (n = 12), and “other”

(n = 1) for methods that do not employ either solution or strips. Pooled prevalence for solution-based tests was 54.25% (95% CI: 45.01-63.19%) and for taste strips was 24.63% (95% CI: 13.10-41.46%). There was reduced heterogeneity in the subgroups compared to the overall meta-analysis: solution-based testing, I^2 = 88.8%; and strip-based testing, I^2 = 76.8%. Measurements of τ^2, were 0.3807 and 0.5991 for solution-based testing and strip-based testing respectively. There was significant heterogeneity between our pooled estimates (Q = 8.68, df = 2, p = 0.01). Together, our results demonstrate that studies using solution-based taste tests, on average, result in higher prevalence of taste loss in COVID-19 patients than do studies using strips or other methods.

Discussion

Despite the occurrence of true taste loss in a variety of diseases such as cancer (Nolden et al., 2019), as well as in the general population (Rawal et al., 2016), taste loss has often been confused with smell loss (Le Bon et al., 2021). However, the current coronavirus pandemic suggests that in reality, taste loss is its own unique feature of the illness. The present meta-analysis found an overall taste loss prevalence of 37 % among 138,897 COVID-19-positive participants, which aligns with other meta-analyses of taste loss prevalence, ranging from 38% (Agyeman et al., 2020) to 49% (Hajikhani et al., 2020). This high prevalence is not due to confusion with smell loss because direct taste measures yield similar (or even slightly higher) prevalence than self-report. Therefore self-reports of taste loss appear to be valid among people with COVID-19 as they are among other groups (Jang et al., 2021).

The COVID-19 pandemic created an urgent need for direct taste measures suitable for the pandemic research environment, e.g., home testing, and researchers were innovative, but each developed their own method which makes it difficult to compare results (see Table 1). However,

despite the differences in methods, we can draw one general conclusion, which is that the form of the tastants matters (taste solutions are better than taste strips) but this general conclusion must be tentative given that the forms of delivery were not compared directly using the same approach, e.g., thresholds or identification.

The present meta-analysis found that around 4 in every 10 COVID-19 patients experience taste loss. We also found age and sex effects: females experienced higher rates of taste loss than males, aligning with other meta-analyses reporting a similar effect (von Bartheld et al., 2020; Amorim Dos Santos et al., 2021; Saniasiaya et al., 2021). Females may be more susceptible to taste loss because they are in general are more sensitive than males and have more sensory capacity to lose. Additionally, we found that COVID-19 associated taste loss peaks in middle age aligning with the general consensus across other COVID-19 meta-analyses (Agyeman et al., 2020; von Bartheld et al., 2020). Why the youngest and oldest groups report less taste loss than do middle-age adults is not currently known.

Although COVID-19 has intensified awareness of taste loss and furthered chemosensory research, scientists are still unsure of the biological mechanisms behind this symptom. The amount of SARS-CoV-2 virus in saliva is positively related to loss of taste: the more virus, the more taste loss (Huang et al., 2021; Taziki Balajelini et al., 2021), although this observation is controversial (Jain et al., 2020). Taste cells may be attacked directly by the virus because studies of expression patterns for ACE2, the receptor protein known to transport the SARS-CoV-2 virus into cells, and for TMPRSS2, the protein essential for processing the SARS-CoV-2 spike protein, showed both are expressed in the supporting cells of taste bud (Sakaguchi et al., 2020; Huang et al., 2021), including taste receptor cells themselves, at least in one patient (Doyle et al., 2021). There may also be direct effects on the brain that contribute to taste loss (Douaud et al., 2021).

Limitations and Future Research

In many of the included articles, clinicians and researchers collected self-reported taste loss information in tandem with smell loss (e.g., participants responding yes to "Loss of taste and smell" on a symptom screener), which can confound the results. Therefore, we explored any differences in how taste loss was collected, reflecting how it was reported in the articles (e.g., "smell and taste" vs. "taste only"), and found no significant impact on the prevalence rate (see Supplementary Materials S3). This result indicates that taste loss is a common and pervasive symptom of COVID-19. Additionally, far more articles in this meta-analysis used self-report tests (n = 223) than direct tests (n = 18). This disparity may have prevented us from capturing significant differences between the two methods.

Nearly all of the articles included in this meta-analysis were nonspecific to different tastes, instead summarizing scores across multiple stimuli (e.g., sweet and salty) and reporting taste loss as a whole (though in one study participants self-reported taste-specific dysfunction: salt taste loss, 29.3%; sweet taste, 25.9%; general taste, 34.5% [El Kady et al., 2021]). However, specific taste sensitivities can be difficult to assess via self-report. Members of the general population, untrained in chemosensory science, may have difficulties identifying whether or not they truly lost a specific taste. Therefore, it is important to use direct measures to distinguish dysfunctions of specific tastes.

There are clear opportunities for advancements of standardized direct taste tests to measure taste loss. Of the 18 studies that used direct tests in general, only five used standardized tests, representing just 2.06% of the 242 studies examined in this systematic review: Taste Strips by Burghart Messtechnik (Hintschich et al., 2020a; Le Bon et al., 2021; Niklassen et al., 2021a; Singer-Cornelius et al., 2021) and the Brief Self-Administered Waterless Empirical Taste Test

(SA-WETT) by Sensonics International (Cao et al., 2021). Three other studies using direct tests were examined during the systematic review but were excluded for not meeting the inclusion criteria: reporting on a case study (Lee and Lee, 2020), recruiting patients with chemosensory dysfunction (Le Bon et al., 2020), and not reporting the required taste loss prevalence data (Huart et al., 2020). Among these three studies, Lee and Lee (2020) used a non-standardized direct test, and Huart et al. (2020) and Le Bon et al. (2020) used the Taste Strips – although this represents a missed opportunity to analyze more studies that used standardized tests, including these two articles would have increased the rate of standardized test use among all 241 studies to just 2.89% (N=7).

As of September 2021, 220 million individuals have been infected with SARS-CoV- 2 virus, with large number of recovered individuals with persistent symptoms included taste loss. It is well documented that disease-related or age-related or chemosensory loss have profound effects on an individual's quality of life. Unlike other disorders such as vision and hearing for which preventative and screening guidelines exist (United States Preventive Services Taskforce), they are not available for taste and smell disorders. The COVID-19 pandemic further highlighted this existing gap, lack of standardized measures and clinical guidelines for screening, assessing, and monitoring the taste system making it difficult for clinicians to track progression of disease. Assessment of taste function in patients with and without confirmed COVID-19 needs to become standard of practice for clinicians. This is particularly important for at least two reasons: 1) having baseline measures help clinicians assess trends over time, and 2) given the interrelatedness between the sense of smell and taste, objective measures of taste collected during clinical assessments may help dissociate whether it is a smell or taste problem. For patients who report changes in taste function during screening questionnaires, full testing with

standardized objective chemosensory tools should be performed. It is critical that clinicians are aware that most patients with chemosensory dysfunction complain of taste alterations, therefore, a closer inquiry of patient's reports regarding the specific taste quality (i.e., sweet, bitter, sour, and salt, fat) affected is important to further distinguish between taste and perception of flavor.

Conclusion

The COVID-19 pandemic demanded an urgent response from scientists and clinicians, who have been working to understand the novel virus and the symptoms it inflicts. Of the many unique features of this virus, smell and taste dysfunctions are among the most prominent. Yet as taste loss joined smell loss as a more prolific topic in scientific literature, many initially speculated that taste loss rates were overestimated due to confusion between taste and smell in self-reports. However, our meta-analysis found a prevalence rate for taste loss of 36.9% among 138,897 COVID-19-positive individuals (95% CI: 33.27–40.69%), supported by direct methods, reflecting the validity of this distinct symptom. Dysfunction in the sense of taste was, and still is, a difficult reality for millions of people affected by the virus and merits further research to fully understand the mechanisms behind this phenomenon and how to properly assess and address it. Among the population of 138,897 COVID-19-positive individuals included in this meta-analysis, only 257 of them, across five separate studies, were assessed using standardized taste tests. Future research should include the development of fast and accurate taste tests, studies that measure taste and smell function separately to dissociate olfacto-gustatory interactions, as well as the employment of standardized taste tests in clinical settings to examine taste dysfunction. In addition, clinical trials are needed to elucidate frequency of screening and age at which to start and stop screening for chemosensory disorders. Finally, more mechanistic studies to understand

taste and smell disorders associated with COVID-19 to aid in developing new therapeutic options for patients with long-lasting impairment of their chemical senses.

Included Articles

In total, 241 were included in the present systematic review and meta-analysis (Gamper et al., 2012; Liu et al., 2016; Adamczyk et al., 2020; Adedeji et al., 2020; Adorni et al., 2020; Aggarwal et al., 2020; Al-Ani and Acharya, 2020; Altin et al., 2020; Andrews et al., 2020; Anna et al., 2020; Asai et al., 2020; Bastiani et al., 2020; Beltran-Corbellini et al., 2020; Bergquist et al., 2020; Biadsee et al., 2020; Bidkar et al., 2020b; Boscolo-Rizzo et al., 2020a, 2020b, 2020c, 2021; Boudjema et al., 2020; Brandao Neto et al., 2020; Bulgurcu et al., 2020; Calica Utku et al., 2020; Carignan et al., 2020; Chary et al., 2020; Chen et al., 2020; Chiesa-Estomba et al., 2020; Cho et al., 2020; Chung et al., 2020; Cocco et al., 2020; Dawson et al., 2020; Dell'Era et al., 2020; De Maria et al., 2020; Durrani et al., 2020; Elimian et al., 2020; Farah Yusuf Mohamud et al., 2020; Fistera et al., 2020; Fontanet et al., 2020; Freni et al., 2020; Garg et al., 2020; Gelardi et al., 2020; Giacomelli et al., 2020; Gorzkowski et al., 2020; Gozen et al., 2020; GÜner et al., 2020; Gudbjartsson et al., 2020; Guillen Martinez et al., 2020; Haehner et al., 2020; Hintschich et al., 2020b; Horvath et al., 2020; Iversen et al., 2020; Izquierdo-Domínguez et al., 2020; Jain et al., 2020; Jalessi et al., 2020; Kacem et al., 2020; Karadas et al., 2020; Kempker et al., 2020; Kim et al., 2020; Klopfenstein et al., 2020; Konstantinidis et al., 2020; Krishnasamy et al., 2020; Kronborg et al., 2020; Kumar et al., 2020, 2021a, 2021b; Lagi et al., 2020; Lan et al., 2020; Lapostolle et al., 2020; La Torre et al., 2020; Lechien et al., 2020b, 2020c, 2020a, 2021, 2021, 2021; Lechner et al., 2020; Lee et al., 2020a, 2020b, 2021; Levinson et al., 2020; Liang et al., 2020; Liguori et al., 2020; Lindahl et al., 2020; Lombardi et al., 2020, 2021; Luers et al., 2020; Lv et al., 2020; Maechler et al., 2020; Magnavita et al., 2020; Makda et al., 2020; Mao et al.,

2020; Martin-Sanz et al., 2020; Mazzatenta et al., 2020; Meini et al., 2020; Menni et al., 2020; Mercante et al., 2020; Merkely et al., 2020; Merza et al., 2020; Moein et al., 2020; Morshed et al., 2020; Murat et al., 2020; Nakagawa et al., 2020, 2020; Nakakubo et al., 2020; Nakanishi et al., 2020; Noh et al., 2020; Otte et al., 2020; Ozcelik Korkmaz et al., 2020; Paderno et al., 2020; Patel et al., 2020; Perlman et al., 2020; Petersen et al., 2020; Petrocelli et al., 2020b, 2020a; Pinna et al., 2020; Printza et al., 2020, 2021; Qiu et al., 2020; Rajkumar et al., 2020; Ramteke et al., 2020, 2020; Rojas-Lechuga et al., 2020; Roland et al., 2020; Romero-Sanchez et al., 2020; Rubel et al., 2020; Sakalli et al., 2020; Salepci et al., 2020; Sayin et al., 2020a, 2020b; Schirinzi et al., 2020; Schmithausen et al., 2020; Seo et al., 2020; Shoer et al., 2020; Sierpinski et al., 2020; Smith et al., 2020; Somekh et al., 2020; Speth et al., 2020; Spinato et al., 2020; Stavem et al., 2020; Sun et al., 2020; Teklu et al., 2020; Tham et al., 2020; Tsivgoulis et al., 2020; Tudrej et al., 2020; Vacchiano et al., 2020; Vaira et al., 2020e, 2020f, 2020b, 2020c, 2020d, 2020a, 2020b; Van Loon et al., 2020; Vena et al., 2020; Villarreal et al., 2020; Wagner et al., 2020; Waterfield et al., 2020; Wee et al., 2020; Weiss et al., 2020; Weng et al., 2020; Yan et al., 2020a, 2020b; Zayet et al., 2020a, 2020b; Zimmerman et al., 2020; Akinbami et al., 2021; Alharbi et al., 2021; AlShakhs et al., 2021; Amano et al., 2021; Arslan et al., 2021; Ashrafi et al., 2021; Bagnasco et al., 2021; Barillari et al., 2021; Besli et al., 2021; Bianco et al., 2021; Breyer et al., 2021; Callejon-Leblic et al., 2021; Cao et al., 2021; Carcamo Garcia et al., 2021; Concheiro-Guisan et al., 2021; Dini et al., 2021; Dixon et al., 2021; El Kady et al., 2021; Fisher et al., 2021; Fleischer et al., 2021; Galluzzi et al., 2021; Gianola et al., 2021; Gibbons et al., 2021; Gonzalez et al., 2021; Gupta et al., 2021a, 2021b; Gurrola et al., 2021; Hijazi et al., 2021; Ismail et al., 2021; Jethani et al., 2021; Kamel et al., 2021; Kandakure et al., 2021; Karaarslan et al., 2021; Karni et al., 2021; Kavaz et al., 2021; Ladoire et al., 2021; Lampl et al., 2021; Makaronidis et al., 2021;

Mannan et al., 2021; Moeller et al., 2021; Monti et al., 2021; Morlock et al., 2021; Niklassen et al., 2021b; Ninchritz-Becerra et al., 2021; Nishanth et al., 2021; Noviello et al., 2021; Oda et al., 2021; Omezli and Torul, 2021; O'Keefe et al., 2021; O'Sullivan et al., 2021; Ozcan et al., 2021; Parcha et al., 2021; Perula de Torres et al., 2021; Polat et al., 2021; Rodebaugh et al., 2021; Rousseau et al., 2021; Sahoo et al., 2021; Salcan et al., 2021; Savtale et al., 2021; Sbrana et al., 2021; Schwab et al., 2021; Sehanobish et al., 2021; Singer-Cornelius et al., 2021; Soh et al., 2021; Song et al., 2021a, 2021b; Tarifi et al., 2021; Thakur et al., 2021; Trachootham et al., 2021; İşlek and Balcı, 2021; van den Besselaar et al., 2021; Wierdsma et al., 2021; Yadav et al., 2021; Zejda et al., 2021; Zifko et al., 2021; Zou et al., 2021)

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Captions

Figure 1. CONSORT flow diagram demonstrating the article selection process for this systematic review and meta-analysis.

Table 1. Overview of the direct approaches to assess taste loss in participants.

Figure 2. Orchard plot following the guidelines outlined by Nakagawa et al. The point estimate of the pooled prevalence (trunk) is represented by the bold blue or red dot. The confidence interval of the pooled prevalence estimate (branch) is represented by the bold black line, and the prediction interval (twig) is represented by the thin black line. Individual prevalence estimates from each study are represented by the scattered colored points (slightly transparent circles, called fruits). Each fruit is scaled by the precision of the point estimate of prevalence for each study, or the inverse of the standard error.

Table 2. Random-effect estimate of age group on COVID-19 taste loss prevalence using generalized linear mixed models.

Table 3. Random-effect estimate of direct testing type on COVID-19 taste loss prevalence using generalized linear mixed models.

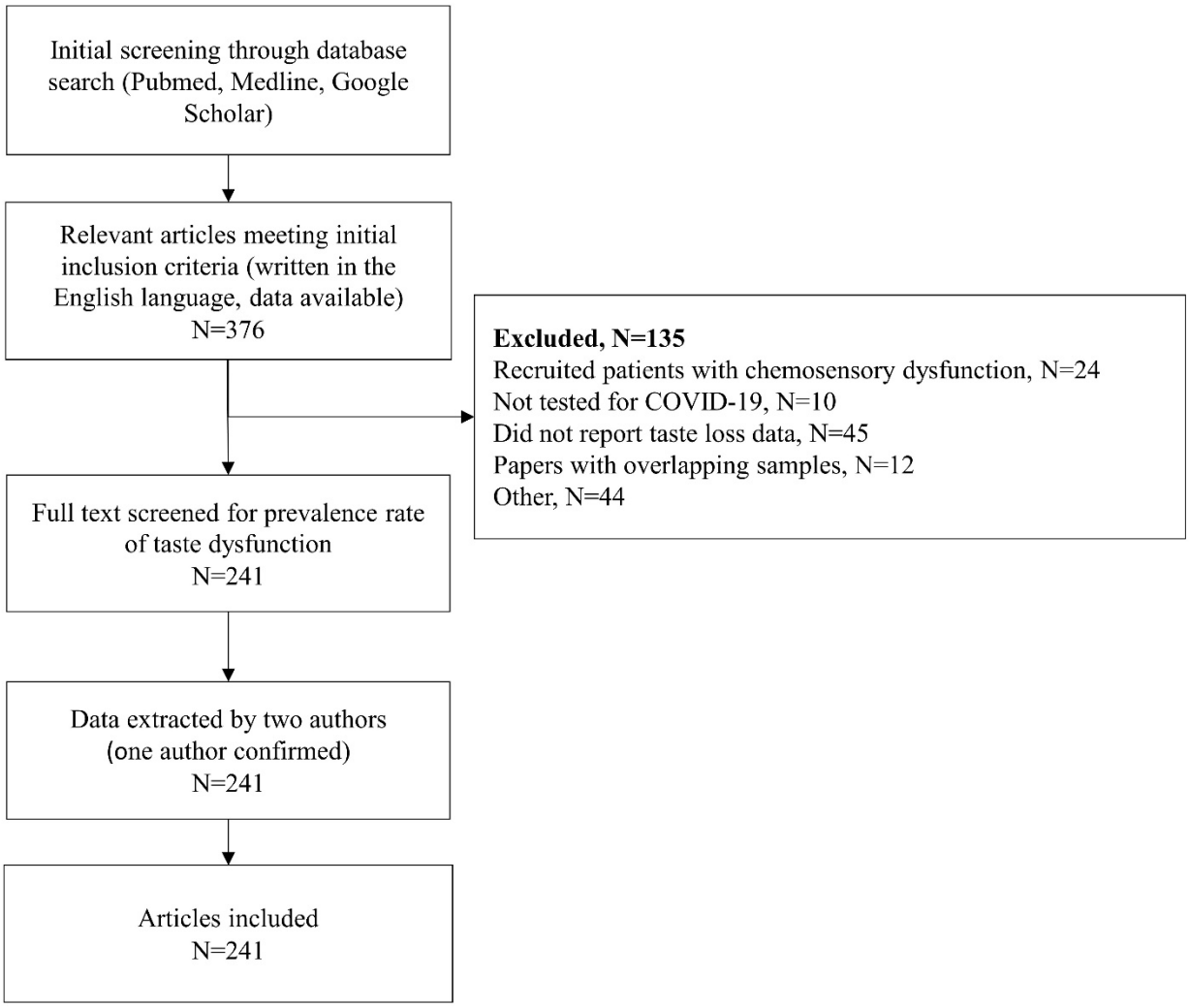

Figure 1. CONSORT flow diagram demonstrating the article selection process for this systematic review and meta-analysis.

437 **Table 1. Overview of the direct approaches to assess taste loss in participants.**

				Taste Quality Measured				
Test	***Article***	***Test Method***	***Test Objective***	*Salty*	*Sweet*	*Sour*	*Bitter*	*Umami*
Four-solution test	Vaira et al., 2020a–2020f Petrocelli et al., 2020[A]	1 mL of each solution, plus deionized water as control, placed on the participant's tongue via cotton swab. Quarantined patients prepared their own solutions.	Identification	☑	☑	☑	☑	☐
Four-solution test & Taste Strips	Altin et al., 2020 Salcan et al., 2021	Participants swallowed and identified the solution. Next, paper strips dipped into each solution and placed on the participant's tongue.	Identification Duration	☑	☑	☑	☑	☑
Two-solution test (1)	Bidkar et al., 2020	Two drops (2 mL) of each solution placed on the participant's tongue via pipette.	Identification	☑	☑	☐	☐	☐
Two-solution test (2)	Mazzatenta et al., 2020	200 µl of each solution dropped onto participant's tongue.	Detection	☑	☑	☐	☐	☑
Taste Strips by BMG[B]	Hintschich et al., 2020 Singer-Cornelius et al., 2021 Le Bon et al., 2021 Niklassen et al., 2021[C]	Taste strips (provided by Burghart Messtechnik GmbH) placed on the participant's tongue.	Identification and threshold concentration	☑	☑	☑	☑	☐

Taste sprays	Niklassen et al., 2021[C]	Each solution sprayed onto participant's tongue.	Identification	☑	☑	☑	☑	☐
Tastant capsules	Adamczyk et al., 2020	Each of ten 0.33 mL gelatin capsules (one tasteless and nine with tastant) dissolved on participant's tongue.	Description	☑	☑	☑	☑	☐
Brief Self-Administered Waterless Empirical Taste Test (SA-WETT)[B]	Cao et al., 2021	27 disposable plastic strips that contain dried solutions of each taste (and some tasteless strips) self-placed on participant's tongue.	Identification	☑	☑	☑	☑	☑
Chemosensory Test by India Protocol	Ramteke et al., 2020	Authors used coconut oil, chocolates, and flavored milk to test smell and taste function. No further details are provided.	N/A	N/A				

[A] These studies used a sweet solution concentration that is double what was used in the other four-solution tests.
[B] Validated test.
[C] Niklassen et al. (2021) used both Taste Strips and taste sprays with participants.

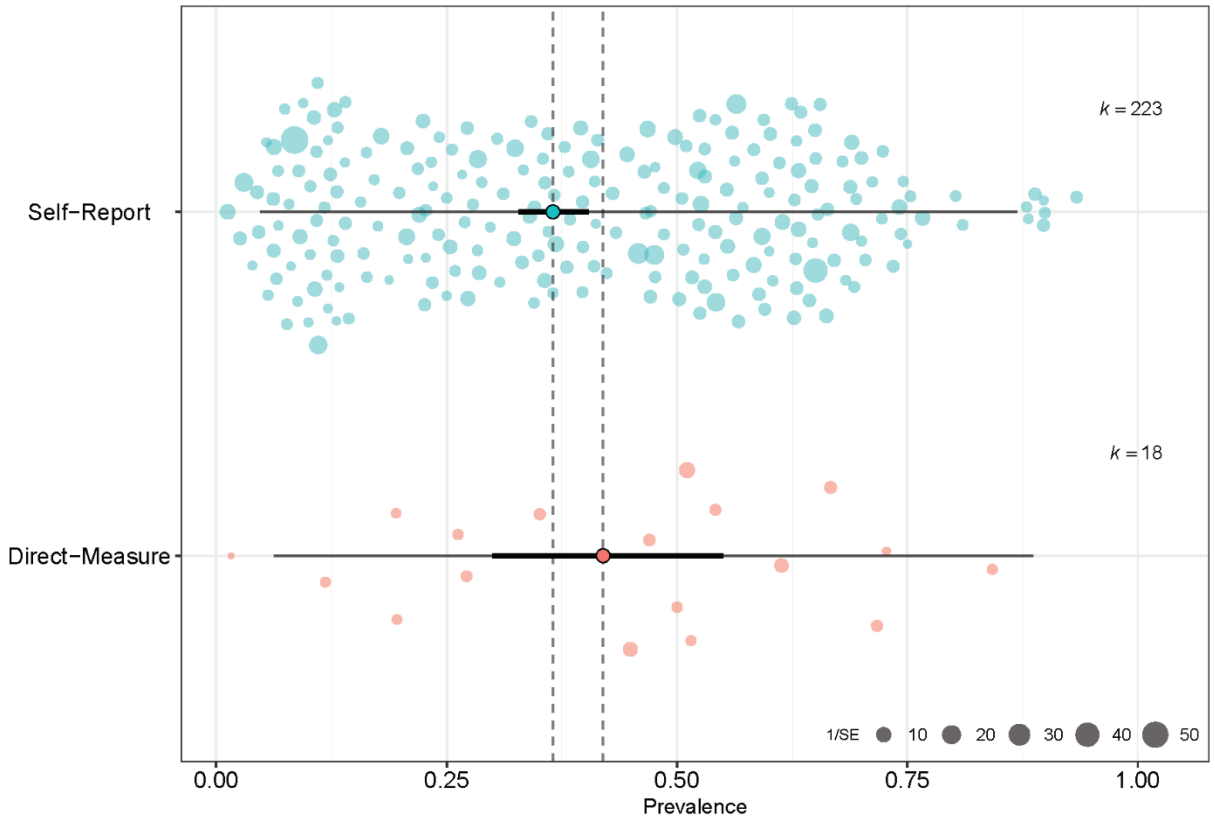

Figure 2. Orchard plot of taste loss and COVID-19. The point estimate of the pooled prevalence (trunk) is represented by the bold turquoise or pink dot. The confidence interval of the pooled prevalence estimate (branch) is represented by the bold black line, and the prediction interval (twig) is represented by the thin black line. Individual prevalence estimates from each study are represented by the scattered colored points (slightly transparent circles). Each point is scaled by the precision of the point estimate of prevalence for each study, i.e., inverse of the standard error.

455 **Table 2.** Random-effect estimate of age group on COVID-19 taste loss prevalence using
456 generalized linear mixed models.
457

Age Category	*k*	*Proportion*	*95%-CI*	*Q*	I^2	Tau^2
Adolescent	9	0.12	0.06-0.20	382.58	97.90%	0.828
Young Adults	20	0.32	0.1984-0.4640	1482.59	98.70%	1.961
Middle Age	118	0.44	0.3864-0.4954	10517.56	98.90%	1.4649
Eldery	8	0.18	0.0803-0.3570	193.64	96.40%	1.6031
Older	55	0.35	0.2882-0.4067	1522.64	96.50%	0.9307

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Table 3. Random-effect estimate of direct testing type on COVID-19 taste loss prevalence using generalized linear mixed models.

Direct Testing Type	*k*	*Proportion*	*95%-CI*	*Q*	I^2	Tau^2
Solution	11	0.5602	0.4666-0.6497	87.62	88.60%	0.3566
Strip	5	0.2183	0.1510-0.3048	14.45	72.30%	0.1663
Other	2	0.0539	0.0000-0.9868	0	0.00%	17.9895

References

Abdullahi, A., Candan, S.A., Abba, M.A., Bello, A.H., Alshehri, M.A., Afamefuna Victor, E., Umar, N.A., and Kundakci, B. 2020. Neurological and Musculoskeletal Features of COVID-19: A Systematic Review and Meta-Analysis. Front Neurol. 11:687.

Adamczyk, K., Herman, M., Frączek, J., Piec, R., Szykuła-Piec, B., Zaczyński, A., Wójtowicz, R., Bojanowski, K., Rusyan, E., Król, Z., et al. 2020. Sensitivity and specificity of prediction models based on gustatory disorders in diagnosing COVID-19 patients: a case-control study. Infectious Diseases (except HIV/AIDS).

Adedeji, I.A., Abdu, Y.M., Bashir, M.F., Adamu, A.S., Gwarzo, G.D., Yaro, B.S., Musa, A.A., Hassan, Z.I., Maigoro, A.M., and Jibrin, Y.B. 2020. Profile of children with COVID-19 infection: a cross sectional study from North-East Nigeria. Pan Afr Med J. 35:145.

Adorni, F., Prinelli, F., Bianchi, F., Giacomelli, A., Pagani, G., Bernacchia, D., Rusconi, S., Maggi, S., Trevisan, C., Noale, M., et al. 2020. Self-reported symptoms of SARS-CoV-2 infection in a non-hospitalized population: results from the large Italian web-based EPICOVID19 cross-sectional survey. JMIR Public Health Surveill.

Aggarwal, S., Garcia-Telles, N., Aggarwal, G., Lavie, C., Lippi, G., and Henry, B.M. 2020. Clinical features, laboratory characteristics, and outcomes of patients hospitalized with coronavirus disease 2019 (COVID-19): Early report from the United States. Diagn Berl. 7:91–96.

Agyeman, A.A., Chin, K.L., Landersdorfer, C.B., Liew, D., and Ofori-Asenso, R. 2020. Smell and Taste Dysfunction in Patients With COVID-19: A Systematic Review and Meta-analysis. Mayo Clin Proc. 95:1621–1631.

Akinbami, L.J., Petersen, L.R., Sami, S., Vuong, N., Lukacs, S.L., Mackey, L., Atas, J., and LaFleur, B.J. 2021. COVID-19 symptoms and SARS-CoV-2 antibody positivity in a large survey of first responders and healthcare personnel, May-July 2020. Clin Infect Dis.

Al-Ani, R.M., and Acharya, D. 2020. Prevalence of Anosmia and Ageusia in Patients with COVID-19 at a Primary Health Center, Doha, Qatar. Indian J Otolaryngol Head Neck Surg. 1–7.

Alharbi, H., You, S., and Katz, J. 2021. Should anosmia and dysgeusia be a concern for oral and maxillofacial surgeons during the COVID-19 pandemic? Oral Maxillofac Surg.

AlShakhs, A., Almomen, A., AlYaeesh, I., AlOmairin, A., AlMutairi, A.A., Alammar, Z., Almomen, H., and Almomen, Z. 2021. The Association of Smell and Taste Dysfunction with COVID19, And Their Functional Impacts. Indian J Otolaryngol Head Neck Surg. 1–6.

Altin, F., Cingi, C., Uzun, T., and Bal, C. 2020. Olfactory and gustatory abnormalities in COVID-19 cases. Eur Arch Otorhinolaryngol. 277:2775–2781.

499 Amano, Y., Kage, H., Tanaka, G., Gonoi, W., Nakai, Y., Kurokawa, R., Inui, S., Okamoto, K.,
500 Harada, S., Iwabu, M., et al. 2021. Diagnostic prediction of COVID-19 based on clinical and
501 radiological findings in a relatively low COVID-19 prevalence area. Respir Investig.

502 Amorim Dos Santos, J., Normando, A.G.C., Carvalho da Silva, R.L., Acevedo, A.C., De Luca Canto,
503 G., Sugaya, N., Santos-Silva, A.R., and Guerra, E.N.S. 2021. Oral Manifestations in Patients with
504 COVID-19: A Living Systematic Review. J Dent Res. 100:141–154.

505 Andrews, P.J., Pendolino, A.L., Ottaviano, G., Scarpa, B., Grant, J., Gaudioso, P., Bordin, A.,
506 Marchese-Ragona, R., Leoni, D., Cattelan, A., et al. 2020. Olfactory and taste dysfunction among
507 mild-to-moderate symptomatic COVID-19 positive health care workers: An international survey.
508 Laryngoscope Investig Otolaryngol. 5:1019–1028.

509 Anna, F., Goyard, S., Lalanne, A.I., Nevo, F., Gransagne, M., Souque, P., Louis, D., Gillon, V.,
510 Turbiez, I., Bidard, F.-C., et al. 2020. High seroprevalence but short-lived immune response to
511 SARS-CoV-2 infection in Paris. Eur J Immunol. n/a.

512 Arslan, G., Aktürk, H., and Duman, M. 2021. Clinical Characteristics of Pediatric COVID-19 and
513 Predictors of PCR Positivity. Pediatr Int.

514 Asai, N., Sakanashi, D., Nakamura, A., Kishino, T., Kato, H., Hagihara, M., Shiota, A., Koizumi, Y.,
515 Yamagishi, Y., and Mikamo, H. 2020. Clinical manifestations and radiological features by chest
516 computed tomographic findings of a novel coronavirus disease-19 pneumonia among 92
517 patients in Japan. J Microbiol Immunol Infect.

518 Ashrafi, F., Ommi, D., Zali, A., Khani, S., Soheili, A., Arab-Ahmadi, M., Behnam, B., Nohesara, S.,
519 Semnani, F., Fatemi, A., et al. 2021. Neurological Manifestations and their Correlated Factors in
520 COVID-19 Patients; a Cross-Sectional Study. Arch Acad Emerg Med. 9:e34.

521 Bagnasco, D., Passalacqua, G., Braido, F., Tagliabue, E., Cosini, F., Filauro, M., Ioppi, A.,
522 Carobbio, A., Mocellin, D., Riccio, A.M., et al. 2021. Quick Olfactory Sniffin' Sticks Test (Q-Sticks)
523 for the detection of smell disorders in COVID-19 patients. World Allergy Organ J. 14:100497.

524 Bakbergenuly, I., and Kulinskaya, E. 2018. Meta-analysis of binary outcomes via generalized
525 linear mixed models: a simulation study. BMC Med Res Methodol. 18:70.

526 Barillari, M.R., Bastiani, L., Lechien, J.R., Mannelli, G., Molteni, G., Cantarella, G., Coppola, N.,
527 Costa, G., Trecca, E.M.C., Grillo, C., et al. 2021. A structural equation model to examine the
528 clinical features of mild-to-moderate COVID-19: A multicenter Italian study. J Med Virol.
529 93:983–994.

530 Bartheld, C.S. von, Hagen, M.M., and Butowt, R. 2020. Prevalence of Chemosensory
531 Dysfunction in COVID-19 Patients: A Systematic Review and Meta-analysis Reveals Significant
532 Ethnic Differences. ACS Chem Neurosci. 11:2944–2961.

Bastiani, L., Fortunato, L., Pieroni, S., Bianchi, F., Adorni, F., Prinelli, F., Giacomelli, A., Pagani, G., Maggi, S., Trevisan, C., et al. 2020. EPICOVID19: Psychometric assessment and validation of a short diagnostic scale for a rapid Covid-19 screening based on reported symptoms. J Med Internet Res.

Beltran-Corbellini, A., Chico-Garcia, J.L., Martinez-Poles, J., Rodriguez-Jorge, F., Natera-Villalba, E., Gomez-Corral, J., Gomez-Lopez, A., Monreal, E., Parra-Diaz, P., Cortes-Cuevas, J.L., et al. 2020. Acute-onset smell and taste disorders in the context of COVID-19: a pilot multicentre polymerase chain reaction based case-control study. Eur J Neurol.

Bergquist, S.H., Partin, C., Roberts, D.L., O'Keefe, J.B., Tong, E.J., Zreloff, J., Jarrett, T.L., and Moore, M.A. 2020. Non-hospitalized Adults with COVID-19 Differ Noticeably from Hospitalized Adults in Their Demographic, Clinical, and Social Characteristics. SN Compr Clin Med. 1–9.

Besli, G.E., Öcal Demir, S., Girit, S., Arman, T., Duyu, M., and Arslanoglu, S. 2021. COVID-19 in children: A single center experience from Istanbul, Turkey. Med J BAKIRKOY. 17:64–71.

Besselaar, J.H. van den, Sikkema, R.S., Koene, F., Buul, L.W. van, Oude Munnink, B.B., Frénay, I., Te Witt, R., Koopmans, M.P.G., Hertogh, C., and Buurman, B.M. 2021. Are presymptomatic SARS-CoV-2 infections in nursing home residents unrecognized symptomatic infections? Sequence and metadata from weekly testing in an extensive nursing home outbreak. Age Ageing.

Biadsee, A., Biadsee, A., Kassem, F., Dagan, O., Masarwa, S., and Ormianer, Z. 2020. Olfactory and Oral Manifestations of COVID-19: Sex-Related Symptoms-A Potential Pathway to Early Diagnosis. Otolaryngol Head Neck Surg. 194599820934380.

Bianco, M.R., Modica, D.M., Drago, G.D., Azzolina, A., Mattina, G., De Natale, M., Rossi, G., Amata, M., Canzoneri, G., Manganaro, G., et al. 2021. Alteration of Smell and Taste in Asymptomatic and Symptomatic COVID-19 Patients in Sicily, Italy. Ear Nose Throat J. 100:182S-185S.

Bidkar, V., Mishra, M., Selvaraj, K., Joshi, P., H, S.B., Dabhekar, S., Prathipati, K.K., Rathod, B.S., Shendre, P., and Gondode, P. 2020a. Testing Olfactory and Gustatory Dysfunctions among Quarantine COVID-19 Suspects. Indian J Otolaryngol Head Neck Surg Off Publ Assoc Otolaryngol India. 1–6.

Bidkar, V., Mishra, M., Selvaraj, K., Joshi, P., H, S.B., Dabhekar, S., Prathipati, K.K., Rathod, B.S., Shendre, P., and Gondode, P. 2020b. Testing Olfactory and Gustatory Dysfunctions among Quarantine COVID-19 Suspects. Indian J Otolaryngol Head Neck Surg. 1–6.

Blomberg, B., Mohn, K.G.-I., Brokstad, K.A., Zhou, F., Linchausen, D.W., Hansen, B.-A., Lartey, S., Onyango, T.B., Kuwelker, K., Sævik, M., et al. 2021. Long COVID in a prospective cohort of home-isolated patients. Nat Med. 1–7.

568 Boscolo-Rizzo, P., Borsetto, D., Fabbris, C., Spinato, G., Frezza, D., Menegaldo, A., Mularoni, F.,
569 Gaudioso, P., Cazzador, D., Marciani, S., et al. 2020a. Evolution of Altered Sense of Smell or
570 Taste in Patients With Mildly Symptomatic COVID-19. JAMA Otolaryngol Head Neck Surg.

571 Boscolo-Rizzo, P., Borsetto, D., Spinato, G., Fabbris, C., Menegaldo, A., Gaudioso, P., Nicolai, P.,
572 Tirelli, G., Da Mosto, M.C., Rigoli, R., et al. 2020b. New onset of loss of smell or taste in
573 household contacts of home-isolated SARS-CoV-2-positive subjects. Eur Arch Otorhinolaryngol.

574 Boscolo-Rizzo, P., Guida, F., Polesel, J., Marcuzzo, A.V., Antonucci, P., Capriotti, V., Sacchet, E.,
575 Cragnolini, F., D'Alessandro, A., Zanelli, E., et al. 2021. Self-reported smell and taste recovery in
576 COVID-19 patients: a one-year prospective study. MedRxiv. 2021.03.18.21253862.

577 Boscolo-Rizzo, P., Polesel, J., Spinato, G., Fabbris, C., Calvanese, L., Menegaldo, A., Borsetto, D.,
578 and Hopkins, C. 2020c. Predominance of an altered sense of smell or taste among long-lasting
579 symptoms in patients with mildly symptomatic COVID-19. Rhinology.

580 Boscutti, A., Delvecchio, G., Pigoni, A., Cereda, G., Ciappolino, V., Bellani, M., Fusar-Poli, P., and
581 Brambilla, P. 2021. OLFACTORY AND GUSTATORY DYSFUNCTIONS IN SARS-CoV-2 INFECTION:
582 Brain Behav Immun - Health. 100268.

583 Boudjema, S., Finance, J., Coulibaly, F., Meddeb, L., Tissot-Dupont, H., Michel, M., Lagier, J.C.,
584 Million, M., Radulesco, T., Michel, J., et al. 2020. Olfactory and gustative disorders for the
585 diagnosis of COVID-19. Travel Med Infect Dis. 37:101875.

586 Brandao Neto, D., Fornazieri, M.A., Dib, C., Di Francesco, R.C., Doty, R.L., Voegels, R.L., and
587 Pinna, F.R. 2020. Chemosensory Dysfunction in COVID-19: Prevalences, Recovery Rates, and
588 Clinical Associations on a Large Brazilian Sample. Otolaryngol Head Neck Surg.
589 194599820954825.

590 Breyer, M.K., Breyer-Kohansal, R., Hartl, S., Kundi, M., Weseslindtner, L., Stiasny, K.,
591 Puchhammer-Stockl, E., Schrott, A., Fodinger, M., Binder, M., et al. 2021. Low SARS-CoV-2
592 seroprevalence in the Austrian capital after an early governmental lockdown. Sci Rep.
593 11:10158.

594 Bulgurcu, S., Oztutgan, T., Baz, E., Yonem, A., Koc, N.G., Erkul, E., and Cekin, E. 2020.
595 Assessment of Smell and Taste Disorders in COVID-19: A Cross-sectional Study. J Craniofac Surg.

596 Calica Utku, A., Budak, G., Karabay, O., Guclu, E., Okan, H.D., and Vatan, A. 2020. Main
597 symptoms in patients presenting in the COVID-19 period. Scott Med J. 36933020949253.

598 Callejon-Leblic, M.A., Moreno-Luna, R., Del Cuvillo, A., Reyes-Tejero, I.M., Garcia-Villaran, M.A.,
599 Santos-Pena, M., Maza-Solano, J.M., Martin-Jimenez, D.I., Palacios-Garcia, J.M., Fernandez-
600 Velez, C., et al. 2021. Loss of Smell and Taste Can Accurately Predict COVID-19 Infection: A
601 Machine-Learning Approach. J Clin Med. 10.

602 Cao, A.C., Nimmo, Z.M., Mirza, N., Cohen, N.A., Brody, R.M., and Doty, R.L. 2021. Objective
603 screening for olfactory and gustatory dysfunction during the COVID-19 pandemic: A prospective
604 study in healthcare workers using self-administered testing. World J Otorhinolaryngol - Head
605 Neck Surg. S2095881121000159.

606 Carcamo Garcia, M.H., Garcia Choza, D.D., Salazar Linares, B.J., and Diaz, M.M. 2021.
607 Neurological manifestations of patients with mild-to-moderate COVID-19 attending a public
608 hospital in Lima, Peru. ENeurologicalSci. 23.

609 Carignan, A., Valiquette, L., Grenier, C., Musonera, J.B., Nkengurutse, D., Marcil-Heguy, A.,
610 Vettese, K., Marcoux, D., Valiquette, C., Xiong, W.T., et al. 2020. Anosmia and dysgeusia
611 associated with SARS-CoV-2 infection: an age-matched case-control study. CMAJ. 192:E702–
612 E707.

613 Chary, E., Carsuzaa, F., Trijolet, J.P., Capitaine, A.L., Roncato-Saberan, M., Fouet, K., Cazenave-
614 Roblot, F., Catroux, M., Allix-Beguec, C., and Dufour, X. 2020. Prevalence and Recovery From
615 Olfactory and Gustatory Dysfunctions in Covid-19 Infection: A Prospective Multicenter Study.
616 Am J Rhinol Allergy. 34:686–693.

617 Chen, A., Agarwal, A., Ravindran, N., To, C., Zhang, T., and Thuluvath, P.J. 2020. Are
618 Gastrointestinal Symptoms Specific for COVID-19 Infection? A Prospective Case-Control Study
619 from the United States. Gastroenterology.

620 Chiesa-Estomba, C.M., Lechien, J.R., Portillo-Mazal, P., Martinez, F., Cuauro-Sanchez, J., Calvo-
621 Henriquez, C., and Saussez, S. 2020. Olfactory and gustatory dysfunctions in COVID-19. First
622 reports of Latin-American ethnic patients. Am J Otolaryngol. 41:102605.

623 Cho, R.H., To, Z.W., Yeung, Z.W., Tso, E.Y., Fung, K.S., Chau, S.K., Leung, E.Y., Hui, T.S., Tsang,
624 S.W., Kung, K.N., et al. 2020. COVID-19 Viral Load in the Severity of and Recovery from Olfactory
625 and Gustatory Dysfunction. Laryngoscope.

626 Chung, T.W., Sridhar, S., Zhang, A.J., Chan, K.H., Li, H.L., Wong, F.K., Ng, M.Y., Tsang, R.K., Lee,
627 A.C., Fan, Z., et al. 2020. Olfactory Dysfunction in Coronavirus Disease 2019 Patients:
628 Observational Cohort Study and Systematic Review. Open Forum Infect Dis. 7:ofaa199.

629 Cocco, A., Amami, P., Desai, A., Voza, A., Ferreli, F., and Albanese, A. 2020. Neurological
630 features in SARS-CoV-2-infected patients with smell and taste disorder. J Neurol.

631 Concheiro-Guisan, A., Fiel-Ozores, A., Novoa-Carballal, R., González-Duran, M.L., Portugués de
632 la Red, M., Martínez-Reglero, C., Fernández-Pinilla, I., and González-Guijarro, I. 2021. Subtle
633 olfactory dysfunction after SARS-CoV-2 virus infection in children. Int J Pediatr
634 Otorhinolaryngol. 140.

635 Dawson, P., Rabold, E.M., Laws, R.L., Conners, E.E., Gharpure, R., Yin, S., Buono, S., Dasu, T.,
636 Bhattacharyya, S., Westergaard, R.P., et al. 2020. Loss of Taste and Smell as Distinguishing
637 Symptoms of COVID-19. MedRxiv. 2020.05.13.20101006.

638 De Maria, A., Varese, P., Dentone, C., Barisione, E., and Bassetti, M. 2020. High prevalence of
639 olfactory and taste disorder during SARS-CoV-2 infection in outpatients. J Med Virol.

640 Deems, D.A., Doty, R.L., Settle, R.G., Moore-Gillon, V., Shaman, P., Mester, A.F., Kimmelman,
641 C.P., Brightman, V.J., and Snow, J.B. 1991. Smell and taste disorders, a study of 750 patients
642 from the University of Pennsylvania Smell and Taste Center. Arch Otolaryngol Head Neck Surg.
643 117:519–528.

644 Dell'Era, V., Farri, F., Garzaro, G., Gatto, M., Aluffi Valletti, P., and Garzaro, M. 2020. Smell and
645 taste disorders during COVID-19 outbreak: A cross-sectional study on 355 patients. Head Neck.

646 Dini, G., Montecucco, A., Rahmani, A., Barletta, C., Pellegrini, L., Debarbieri, N., Orsi, A.,
647 Caligiuri, P., Varesano, S., Manca, A., et al. 2021. Clinical and epidemiological characteristics of
648 COVID-19 during the early phase of the SARS-CoV-2 pandemic: a cross-sectional study among
649 medical school physicians and residents employed in a regional reference teaching hospital in
650 Northern Italy. Int J Occup Med Env Health.

651 Dixon, B.E., Wools-Kaloustian, K.K., Fadel, W.F., Duszynski, T.J., Yiannoutsos, C., Halverson, P.K.,
652 and Menachemi, N. 2021. Symptoms and symptom clusters associated with SARS-CoV-2
653 infection in community-based populations: Results from a statewide epidemiological study.
654 PLoS One. 16:e0241875.

655 Douaud, G., Lee, S., Alfaro-Almagro, F., Arthofer, C., Wang, C., McCarthy, P., Lange, F.,
656 Andersson, J.L.R., Griffanti, L., Duff, E., et al. 2021. Brain imaging before and after COVID-19 in
657 UK Biobank.

658 Doyle, M.E., Appleton, A., Liu, Q.-R., Yao, Q., Mazucanti, C.H., and Egan, J.M. 2021. Human Type
659 II Taste Cells Express Angiotensin-Converting Enzyme 2 and Are Infected by Severe Acute
660 Respiratory Syndrome Coronavirus 2 (SARS-CoV-2). Am J Pathol. 191:1511–1519.

661 Durrani, M., Haq, I.U., Kalsoom, U., and Yousaf, A. 2020. Chest X-rays findings in COVID 19
662 patients at a University Teaching Hospital - A descriptive study. Pak J Med Sci. 36:S22–S26.

663 El Kady, D.M., Gomaa, E.A., Abdella, W.S., Ashraf Hussien, R., Abd ElAziz, R.H., and Khater,
664 A.G.A. 2021. Oral manifestations of COVID -19 patients: An online survey of the Egyptian
665 population. Clin Exp Dent Res. cre2.429.

666 Elimian, K.O., Ochu, C.L., Ebhodaghe, B., Myles, P., Crawford, E.E., Igumbor, E., Ukponu, W.,
667 Olayinka, A., Aruna, O., Dan-Nwafor, C., et al. 2020. Patient characteristics associated with
668 COVID-19 positivity and fatality in Nigeria: retrospective cohort study. BMJ Open. 10:e044079.

669 Farah Yusuf Mohamud, M., Garad Mohamed, Y., Mohamed Ali, A., and Ali Adam, B. 2020. Loss
670 of Taste and Smell are Common Clinical Characteristics of Patients with COVID-19 in Somalia: A
671 Retrospective Double Centre Study. Infect Drug Resist. 13:2631–2635.

672 Favas, T.T., Dev, P., Chaurasia, R.N., Chakravarty, K., Mishra, R., Joshi, D., Mishra, V.N., Kumar,
673 A., Singh, V.K., Pandey, M., et al. 2020. Neurological manifestations of COVID-19: a systematic
674 review and meta-analysis of proportions. Neurol Sci. 1–34.

675 Fisher, D.L., Pavel, A., and Malnick, S. 2021. Rapid recovery of taste and smell in a patient with
676 SARS-CoV-2 following convalescent plasma therapy. QJM Int J Med.

677 Fistera, D., Pabst, D., Hartl, A., Schaarschmidt, B.M., Umutlu, L., Dolff, S., Holzner, C., Kill, C., and
678 Risse, J. 2020. Separating the wheat from the chaff-COVID-19 in a German emergency
679 department: a case-control study. Int J Emerg Med. 13:44.

680 Fleischer, M., Kohrmann, M., Dolff, S., Szepanowski, F., Schmidt, K., Herbstreit, F., Gungor, C.,
681 Stolte, B., Steiner, K.M., Stadtler, C., et al. 2021. Observational cohort study of neurological
682 involvement among patients with SARS-CoV-2 infection. Ther Adv Neurol Disord.
683 14:1756286421993701.

684 Fontanet, A., Tondeur, L., Madec, Y., Grant, R., Besombes, C., Jolly, N., Fernandes Pellerin, S.,
685 Ungeheuer, M.-N., Cailleau, I., Kuhmel, L., et al. 2020. Cluster of COVID-19 in northern France: A
686 retrospective closed cohort study. MedRxiv. 2020.04.18.20071134.

687 Freni, F., Meduri, A., Gazia, F., Nicastro, V., Galletti, C., Aragona, P., Galletti, C., Galletti, B., and
688 Galletti, F. 2020. Symptomatology in head and neck district in coronavirus disease (COVID-19):
689 A possible neuroinvasive action of SARS-CoV-2. Am J Otolaryngol. 41:102612.

690 Galluzzi, F., Rossi, V., Bosetti, C., and Garavello, W. 2021. Risk Factors for Olfactory and
691 Gustatory Dysfunctions in Patients with SARS-CoV-2 Infection. Neuroepidemiology. 1–8.

692 Gamper, E.-M., Giesinger, J.M., Oberguggenberger, A., Kemmler, G., Wintner, L.M., Gattringer,
693 K., Sperner-Unterweger, B., Holzner, B., and Zabernigg, A. 2012. Taste alterations in breast and
694 gynaecological cancer patients receiving chemotherapy: Prevalence, course of severity, and
695 quality of life correlates. Acta Oncol. 51:490–496.

696 Garg, R., Jain, R., Sodani, A., Chouksey, D., Dosi, R., Athale, S., Goyal, N., Rathi, P., Singh, H., and
697 Telang, K. 2020. Neurological Symptoms as Initial Manifestation of Covid-19 - An Observational
698 Study. Ann Indian Acad Neurol. 23:482–486.

699 Gelardi, M., Trecca, E., Cassano, M., and Ciprandi, G. 2020. Smell and taste dysfunction during
700 the COVID-19 outbreak: a preliminary report. Acta Biomed. 91:230–231.

701 Gerkin, R.C., Ohla, K., Veldhuizen, M.G., Joseph, P.V., Kelly, C.E., Bakke, A.J., Steele, K.E.,
702 Farruggia, M.C., Pellegrino, R., Pepino, M.Y., et al. 2021. Recent Smell Loss Is the Best Predictor
703 of COVID-19 Among Individuals With Recent Respiratory Symptoms. Chem Senses. 46.

704 Giacomelli, A., Pezzati, L., Conti, F., Bernacchia, D., Siano, M., Oreni, L., Rusconi, S., Gervasoni,
705 C., Ridolfo, A.L., Rizzardini, G., et al. 2020. Self-reported olfactory and taste disorders in SARS-
706 CoV-2 patients: a cross-sectional study. Clin Infect Dis.

Gianola, S., Bargeri, S., Campanini, I., Corbetta, D., Gambazza, S., Innocenti, T., Meroni, R., Castellini, G., and Turolla, A. 2021. The Spread of COVID-19 Among 15,000 Physical Therapists in Italy: A Cross-Sectional Study. Phys Ther.

Gibbons, C., Hussain, M., O'Keeffe, D.T., and Simpkin, A.J. 2021. An analysis of patient self-reported COVID-19 symptoms during the first wave of the pandemic in Ireland. Ir J Med Sci.

Gonzalez, C., Garcia-Huidobro, F.G., Lagos, A.E., Aliaga, R., Fuentes-Lopez, E., Diaz, L.A., Garcia-Salum, T., Salinas, E., Toro, A., Callejas, C.A., et al. 2021. Prospective assessment of smell and taste impairment in a South-American coronavirus disease 2019 (COVID-19) cohort: Association with the need for hospitalization and reversibility of dysfunction. Int Forum Allergy Rhinol.

Gorzkowski, V., Bevilacqua, S., Charmillon, A., Jankowski, R., Gallet, P., Rumeau, C., and Nguyen, D.T. 2020. Evolution of olfactory disorders in COVID-19 patients. Laryngoscope.

Gozen, E.D., Aliyeva, C., Tevetoglu, F., Karaali, R., Balkan, Yener, H.M., and Ozdogan, H.A. 2020. Evaluation of Olfactory Function With Objective Tests in COVID-19-Positive Patients: A Cross-Sectional Study. Ear Nose Throat J. 145561320975510.

Gudbjartsson, D.F., Helgason, A., Jonsson, H., Magnusson, O.T., Melsted, P., Norddahl, G.L., Saemundsdottir, J., Sigurdsson, A., Sulem, P., Agustsdottir, A.B., et al. 2020. Spread of SARS-CoV-2 in the Icelandic Population. N Engl J Med. 382:2302–2315.

Guillen Martinez, A., Andreu Galvez, M., Rodriguez Sanz, S., Hernandez Ruiz, P., Garcia Morillas, A., and Esteban Sanchez, T. 2020. Incidence of smell and taste disorders and associated factors in patients with mild to moderate COVID-19. Otolaryngol Pol. 75:1–5.

GÜner, H.R., HasanoĞlu, İ., Kayaaslan, B., Aypak, A., Kaya Kalem, A., Eser, F., Özdemİr, B., SaricaoĞlu, E.M., Ayhan, M., Aybar Bİlİr, Y., et al. 2020. COVID-19 experience of the major pandemic response center in the capital: Results of the pandemic's first month in Turkey. Turk J Med Sci.

Gupta, S., Kumbhat, P., and Seervi, M. 2021a. Olfactory and Gustatory Dysfunction in Covid-19: An Observational Study in a Tertiary Care Institute of Western Rajasthan. Indian J Otolaryngol Head Neck Surg. 1–5.

Gupta, V., Banavara Rajanna, L., Upadhyay, K., Bhatia, R., Madhav Reddy, N., Malik, D., and Srivastava, A. 2021b. Olfactory and Gustatory Dysfunction in COVID-19 Patients from Northern India: A Cross-Sectional Observational Study. Indian J Otolaryngol Head Neck Surg. 1–8.

Gurrola, J.G., Chang, J.L., Roland, L.T., Loftus, P.A., and Cheung, S.W. 2021. Short-term chemosensory distortions and phantoms in COVID-19. Laryngoscope Investig Otolaryngol.

Haehner, A., Draf, J., Draeger, S., With, K. de, and Hummel, T. 2020. Predictive value of sudden olfactory loss in the diagnosis of COVID-19. MedRxiv. 2020.04.27.20081356.

741 Hajikhani, B., Calcagno, T., Nasiri, M.J., Jamshidi, P., Dadashi, M., Goudarzi, M., Eshraghi, A.A.,
742 and Mirsaeidi, M. 2020. Olfactory and gustatory dysfunction in COVID-19 patients: A
743 meta-analysis study. Physiol Rep. 8:e14578.

744 Hannum, M., E., Ramirez, V., A., Lipson, S., J., Herriman, R., D., Toskala, A., K., Lin, C., Joseph, P.,
745 V., and Reed, D., R. 2020. Objective Sensory Testing Methods Reveal a Higher Prevalence of
746 Olfactory Loss in COVID-19-Positive Patients Compared to Subjective Methods: A Systematic
747 Review and Meta-Analysis. Chem Senses. 45:856–874.

748 Higgins, J.P.T., and Thompson, S.G. 2002. Quantifying heterogeneity in a meta-analysis. Stat
749 Med. 21:1539–1558.

750 Hijazi, L.O., Alaraifi, A.K., and Alsaab, F. 2021. Otolaryngology manifestations of COVID-19 in
751 pediatric patients. Int J Pediatr Otorhinolaryngol. 144:110701.

752 Hintschich, C.A., Wenzel, J.J., Hummel, T., Hankir, M.K., Kühnel, T., Vielsmeier, V., and Bohr, C.
753 2020a. Psychophysical tests reveal impaired olfaction but preserved gustation in COVID-19
754 patients. Int Forum Allergy Rhinol. 10:1105–1107.

755 Hintschich, C.A., Wenzel, J.J., Hummel, T., Hankir, M.K., Kühnel, T., Vielsmeier, V., and Bohr, C.
756 2020b. Psychophysical tests reveal impaired olfaction but preserved gustation in COVID-19
757 patients. Int Forum Allergy Rhinol.

758 Horvath, L., Lim, J.W.J., Taylor, J.W., Saief, T., Stuart, R., Rimmer, J., and Michael, P. 2020. Smell
759 and taste loss in COVID-19 patients: assessment outcomes in a Victorian population. Acta
760 Otolaryngol. 1–5.

761 Hoy, D., Brooks, P., Woolf, A., Blyth, F., March, L., Bain, C., Baker, P., Smith, E., and Buchbinder,
762 R. 2012. Assessing risk of bias in prevalence studies: modification of an existing tool and
763 evidence of interrater agreement. J Clin Epidemiol. 65:934–939.

764 Huang, N., Pérez, P., Kato, T., Mikami, Y., Okuda, K., Gilmore, R.C., Conde, C.D., Gasmi, B., Stein,
765 S., Beach, M., et al. 2021. SARS-CoV-2 infection of the oral cavity and saliva. Nat Med. 27:892–
766 903.

767 Huart, C., Philpott, C., Konstantinidis, I., Altundag, A., Whitcroft, K.L., Trecca, E.M.C., Cassano,
768 M., Rombaux, Ph., and Hummel, T. 2020. Comparison of COVID-19 and common cold
769 chemosensory dysfunction. Rhinology. 58:623–625.

770 İşlek, A., and Balcı, M.K. 2021. Diagnostic Value of Butanol Threshold Test in COVID-19 Related
771 Olfactory Dysfunction. Indian J Otolaryngol Head Neck Surg.

772 Ismail, F., Farag, A., Haq, S., and Kamal, M.A. 2021. Clinical Characteristics of the First 100
773 Patients of COVID-19 in Tobruk, Libya: A Brief Report From Low-Resource Settings. Disaster
774 Med Public Health Prep. 1–4.

Iversen, K., Bundgaard, H., Hasselbalch, R.B., Kristensen, J.H., Nielsen, P.B., Pries-Heje, M., Knudsen, A.D., Christensen, C.E., Fogh, K., Norsk, J.B., et al. 2020. Risk of COVID-19 in health-care workers in Denmark: an observational cohort study. Lancet Infect Dis.

Izquierdo-Domínguez, A., Rojas-Lechuga, M.J., Chiesa-Estomba, C., Calvo-Henríquez, C., Ninchritz-Becerra, E., Soriano-Reixach, M., Poletti-Serafini, D., Villarreal, I.M., Maza-Solano, J.M., Moreno-Luna, R., et al. 2020. Smell and taste dysfunctions in COVID-19 are associated with younger age in ambulatory settings - a multicenter cross-sectional study. J Investig Allergol Clin Immunol. 0.

Jain, A., Kumar, L., Kaur, J., Baisla, T., Goyal, P., Pandey, A.K., Das, A., and Parashar, L. 2020. Olfactory and taste dysfunction in coronavirus disease 2019 patients: its prevalence and outcomes. J Laryngol Otol. 1–10.

Jalessi, M., Barati, M., Rohani, M., Amini, E., Ourang, A., Azad, Z., Hosseinzadeh, F., Cavallieri, F., Ghadirpour, R., Valzania, F., et al. 2020. Frequency and outcome of olfactory impairment and sinonasal involvement in hospitalized patients with COVID-19. Neurol Sci.

Jang, S.S., Choi, J.S., Kim, J.H., Kim, N., and Ference, E.H. 2021. Discordance Between Subjective and Objective Measures of Smell and Taste in US Adults. Otolaryngol--Head Neck Surg Off J Am Acad Otolaryngol-Head Neck Surg. 1945998211018386.

Jethani, B., Gupta, M., Wadhwani, P., Thomas, R., Balakrishnan, T., Mathew, G., Mathur, M., Rao, B.P., Shukla, D., Khullar, A., et al. 2021. Clinical Characteristics and Remedy Profiles of Patients with COVID-19: A Retrospective Cohort Study. Homeopathy.

Kacem, I., Gharbi, A., Harizi, C., Souissi, E., Safer, M., Nasri, A., Letaief, H., Akkari, M., Hechaichi, A., Mrabet, S., et al. 2020. Characteristics, onset, and evolution of neurological symptoms in patients with COVID-19. Neurol Sci.

Kamel, F.O., Magadmi, R.M., Alqutub, S.T., Badawi, M., Al-Sayes, F., Badawi, M., Madni, T.A., Alhothali, A., Abozinadah, E.A., and Adam, S. 2021. Clinical and hematologic presentations of adults with COVID-19 patients in Jeddah: A case control study. J Infect Public Health. 14:709–716.

Kandakure, V.T., Valvi, H.R., Khokle, P., More, M.S., and Chouhan, R. 2021. Prevalence and Recovery from Newly Onset Anosmia and Ageusia in Covid 19 Patients at our Teritary Care Centre. Indian J Otolaryngol Head Neck Surg.

Karaarslan, F., Demircioğlu Güneri, F., and Kardeş, S. 2021. Postdischarge rheumatic and musculoskeletal symptoms following hospitalization for COVID-19: prospective follow-up by phone interviews. Rheumatol Int. 41:1263–1271.

Karadas, O., Ozturk, B., and Sonkaya, A.R. 2020. A prospective clinical study of detailed neurological manifestations in patients with COVID-19. Neurol Sci. 41:1991–1995.

Karni, N., Klein, H., Asseo, K., Benjamini, Y., Israel, S., Nammary, M., Olshtain-Pops, K., Nir-Paz, R., Hershko, A., Muszkat, M., et al. 2021. Self-Rated Smell Ability Enables Highly Specific Predictors of COVID-19 Status: A Case-Control Study in Israel. Open Forum Infect Dis. 8:ofaa589.

Kavaz, E., Tahir, E., Bilek, H.C., Kemal, O., Deveci, A., and Aksakal Tanyel, E. 2021. Clinical significance of smell and taste dysfunction and other related factors in COVID-19. Eur Arch Otorhinolaryngol.

Kempker, R.R., Kempker, J.A., Peters, M., Rebolledo, P.A., Carroll, K., Toomer, L., Wang, Y.F.W., Ray, S.M., and Hunter, M. 2020. Loss of Smell and Taste Among Healthcare Personnel Screened for Coronavirus 2019. Clin Infect Dis.

Kim, G.U., Kim, M.J., Ra, S.H., Lee, J., Bae, S., Jung, J., and Kim, S.H. 2020. Clinical characteristics of asymptomatic and symptomatic patients with mild COVID-19. Clin Microbiol Infect. 26:948 e1-948 e3.

Klopfenstein, T., Zahra, H., Kadiane-Oussou, N.J., Lepiller, Q., Royer, P.Y., Toko, L., Gendrin, V., and Zayet, S. 2020. New loss of smell and taste: Uncommon symptoms in COVID-19 patients on Nord Franche-Comte cluster, France. Int J Infect Dis.

Konstantinidis, I., Delides, A., Tsakiropoulou, E., Maragoudakis, P., Sapounas, S., and Tsiodras, S. 2020. Short-Term Follow-Up of Self-Isolated COVID-19 Patients with Smell and Taste Dysfunction in Greece: Two Phenotypes of Recovery. ORL J Otorhinolaryngol Relat Spec. 1–9.

Krishnasamy, N., Natarajan, M., Ramachandran, A., Vivian Thangaraj, J.W., Etherajan, T., Rengarajan, J., Shanmugasundaram, M., Kandasamy, A., Ramamoorthy, R., Velusamy, A., et al. 2020. Clinical Outcomes among Asymptomatic or Mildly Symptomatic COVID-19 Patients in an Isolation Facility in Chennai, India. Am J Trop Med Hyg.

Kronborg, T.M., Kimer, N., Junker, A.E., Werge, M.P., Gluud, L.L., and Ytting, H. 2020. Experience from a COVID-19 first-line referral clinic in Greater Copenhagen. Dan Med J. 67.

Kumar, A.A., Lee, S.W.Y., Lock, C., and Keong, N.C.H. 2021a. Geographical Variations in Host Predisposition to COVID-19 Related Anosmia, Ageusia, and Neurological Syndromes. Front Med. 8.

Kumar, L., Kahlon, N., Jain, A., Kaur, J., Singh, M., and Pandey, A.K. 2021b. Loss of smell and taste in COVID-19 infection in adolescents. Int J Pediatr Otorhinolaryngol. 142:110626.

Kumar, N., Bhartiya, S., Desai, S., Mutha, A., Beldar, A., and Singh, T. 2020. Seroprevalence of Antibodies Against SARS-CoV-2 Among Health Care Workers in Mumbai, India. Asia Pac J Public Health. 1010539520977307.

La Torre, G., Massetti, A.P., Antonelli, G., Fimiani, C., Fantini, M., Marte, M., Faticoni, A., Previte, C.M., Turriziani, O., Pugliese, F., et al. 2020. Anosmia and Ageusia as Predictive Signs of COVID-19 in Healthcare Workers in Italy: A Prospective Case-Control Study. J Clin Med. 9.

Ladoire, S., Goussot, V., Redersdorff, E., Cueff, A., Ballot, E., Truntzer, C., Ayati, S., Bengrine-Lefevre, L., Bremaud, N., Coudert, B., et al. 2021. Seroprevalence of SARS-CoV-2 among the staff and patients of a French cancer centre after first lockdown: The canSEROcov study. Eur J Cancer. 148:359–370.

Lagi, F., Piccica, M., Graziani, L., Vellere, I., Botta, A., Tilli, M., Ottino, L., Borchi, B., Pozzi, M., Bartalesi, F., et al. 2020. Early experience of an infectious and tropical diseases unit during the coronavirus disease (COVID-19) pandemic, Florence, Italy, February to March 2020. Euro Surveill. 25.

Lampl, B.M.J., Buczovsky, M., Martin, G., Schmied, H., Leitzmann, M., and Salzberger, B. 2021. Clinical and epidemiological data of COVID-19 from Regensburg, Germany: a retrospective analysis of 1084 consecutive cases. Infection.

Lan, F.Y., Filler, R., Mathew, S., Buley, J., Iliaki, E., Bruno-Murtha, L.A., Osgood, R., Christophi, C.A., Fernandez-Montero, A., and Kales, S.N. 2020. COVID-19 symptoms predictive of healthcare workers' SARS-CoV-2 PCR results. PLoS One. 15:e0235460.

Lapostolle, F., Schneider, E., Vianu, I., Dollet, G., Roche, B., Berdah, J., Michel, J., Goix, L., Chanzy, E., Petrovic, T., et al. 2020. Clinical features of 1487 COVID-19 patients with outpatient management in the Greater Paris: the COVID-call study. Intern Emerg Med. 15:813–817.

Le Bon, S., Payen, L., Prunier, L., Steffens, Y., Horoi, M., Vaira, L.A., Hopkins, C., Lechien, J.R., and Saussez, S. 2021. Making scents of loss of taste in COVID-19: Is self-reported loss of taste due to olfactory dysfunction? A prospective study using psychophysical testing. Int Forum Allergy Rhinol. alr.22815.

Le Bon, S.-D., Pisarski, N., Verbeke, J., Prunier, L., Cavelier, G., Thill, M.-P., Rodriguez, A., Dequanter, D., Lechien, J.R., Le Bon, O., et al. 2020. Psychophysical evaluation of chemosensory functions 5 weeks after olfactory loss due to COVID-19: a prospective cohort study on 72 patients. Eur Arch Otorhinolaryngol.

Lechien, J.R., Cabaraux, P., Chiesa-Estomba, C.M., Khalife, M., Plzak, J., Hans, S., Martiny, D., Calvo-Henriquez, C., Hopkins, C., and Saussez, S. 2020a. Objective olfactory testing in patients presenting with sudden onset olfactory dysfunction as the first manifestation of confirmed COVID-19 infection.

Lechien, J.R., Chiesa-Estomba, C.M., Beckers, E., Mustin, V., Ducarme, M., Journe, F., Marchant, A., Jouffe, L., Barillari, M.R., Cammaroto, G., et al. 2021. Prevalence and 6-month recovery of olfactory dysfunction: a multicentre study of 1363 COVID-19 patients. J Intern Med. n/a.

878 Lechien, J.R., Chiesa-Estomba, C.M., Hans, S., Barillari, M.R., Jouffe, L., and Saussez, S. 2020b.
879 Loss of Smell and Taste in 2013 European Patients With Mild to Moderate COVID-19. Ann Intern
880 Med.

881 Lechien, J.R., Chiesa-Estomba, C.M., Place, S., Van Laethem, Y., Cabaraux, P., Mat, Q., Huet, K.,
882 Plzak, J., Horoi, M., Hans, S., et al. 2020c. Clinical and epidemiological characteristics of 1420
883 European patients with mild-to-moderate coronavirus disease 2019. J Intern Med. 288:335–
884 344.

885 Lechner, M., Liu, J., Counsell, N., Ta, N.H., Rocke, J., Anmolsingh, R., Eynon-Lewis, N., Paun, S.,
886 Hopkins, C., Khwaja, S., et al. 2020. Course of symptoms for loss of sense of smell and taste over
887 time in one thousand forty-one healthcare workers during the Covid-19 pandemic: Our
888 experience. Clin Otolaryngol. n/a.

889 Lee, D.J., Daliyot, D., Wang, R., Lockwood, J., Das, P., Zimlichman, E., and Lee, J.M. 2021.
890 Comparative Study of Chemosensory Dysfunction in COVID-19 in 2 Geographically Distinct
891 Regions. Ear Nose Throat J. 1455613211000170.

892 Lee, D.J., Lockwood, J., Das, P., Wang, R., Grinspun, E., and Lee, J.M. 2020a. Self-reported
893 anosmia and dysgeusia as key symptoms of coronavirus disease 2019. CJEM. 1–8.

894 Lee, J.-M., and Lee, S.J. 2020. Olfactory and Gustatory Dysfunction in a COVID-19 Patient with
895 Ankylosing Spondylitis Treated with Etanercept: Case Report. J Korean Med Sci. 35.

896 Lee, Y., Min, P., Lee, S., and Kim, S.W. 2020b. Prevalence and Duration of Acute Loss of Smell or
897 Taste in COVID-19 Patients. J Korean Med Sci. 35:e174.

898 Levinson, R., Elbaz, M., Ben-Ami, R., Shasha, D., Levinson, T., Choshen, G., Petrov, K., Gadoth, A.,
899 and Paran, Y. 2020. Anosmia and dysgeusia in patients with mild SARS-CoV-2 infection.
900 MedRxiv. 2020.04.11.20055483.

901 Liang, Y., Xu, J., Chu, M., Mai, J., Lai, N., Tang, W., Yang, T., Zhang, S., Guan, C., Zhong, F., et al.
902 2020. Neurosensory dysfunction: A diagnostic marker of early COVID-19. Int J Infect Dis.
903 98:347–352.

904 Liguori, C., Pierantozzi, M., Spanetta, M., Sarmati, L., Cesta, N., Iannetta, M., Ora, J., Mina, G.G.,
905 Puxeddu, E., Balbi, O., et al. 2020. Subjective neurological symptoms frequently occur in
906 patients with SARS-CoV2 infection. Brain Behav Immun. 88:11–16.

907 Lindahl, J.F., Hoffman, T., Esmaeilzadeh, M., Olsen, B., Winter, R., Amer, S., Molnar, C., Svalberg,
908 A., and Lundkvist, A. 2020. High seroprevalence of SARS-CoV-2 in elderly care employees in
909 Sweden. Infect Ecol Epidemiol. 10:1789036.

910 Liu, G., Zong, G., Doty, R.L., and Sun, Q. 2016. Prevalence and risk factors of taste and smell
911 impairment in a nationwide representative sample of the US population: a cross-sectional
912 study. BMJ Open. 6:e013246.

913 Lombardi, A., Consonni, D., Carugno, M., Bozzi, G., Mangioni, D., Muscatello, A., Castelli, V.,
914 Palomba, E., Cantu, A.P., Ceriotti, F., et al. 2020. Characteristics of 1,573 healthcare workers
915 who underwent nasopharyngeal swab for SARS-CoV-2 in Milano, Lombardy, Italy. Clin Microbiol
916 Infect.

917 Lombardi, A., Mangioni, D., Consonni, D., Cariani, L., Bono, P., Cantu, A.P., Tiso, B., Carugno, M.,
918 Muscatello, A., Lunghi, G., et al. 2021. Seroprevalence of anti-SARS-CoV-2 IgG among healthcare
919 workers of a large university hospital in Milan, Lombardy, Italy: a cross-sectional study. BMJ
920 Open. 11:e047216.

921 Luers, J.C., Rokohl, A.C., Loreck, N., Wawer Matos, P.A., Augustin, M., Dewald, F., Klein, F.,
922 Lehmann, C., and Heindl, L.M. 2020. Olfactory and Gustatory Dysfunction in Coronavirus
923 Disease 19 (COVID-19). Clin Infect Dis.

924 Lv, H., Zhang, W., Zhu, Z., Xiong, Q., Xiang, R., Wang, Y., Shi, W., Deng, Z., and Xu, Y. 2020.
925 Prevalence and recovery time of olfactory and gustatory dysfunctions of hospitalized patients
926 with COVID19 in Wuhan, China. Int J Infect Dis.

927 Maechler, F., Gertler, M., Hermes, J., Loon, W. van, Schwab, F., Piening, B., Rojansky, S.,
928 Hommes, F., Kausch, F., Lindner, A.K., et al. 2020. Epidemiological and clinical characteristics of
929 SARS-CoV-2 infections at a testing site in Berlin, Germany, March and April 2020 - A cross-
930 sectional study. Clin Microbiol Infect.

931 Magnavita, N., Tripepi, G., and Di Prinzio, R.R. 2020. Symptoms in Health Care Workers during
932 the COVID-19 Epidemic. A Cross-Sectional Survey. Int J Env Res Public Health. 17.

933 Mair, M., Singhavi, H., Pai, A., Singhavi, J., Gandhi, P., Conboy, P., Baker, A., and Das, S. 2021. A
934 Meta-Analysis of 67 Studies with Presenting Symptoms and Laboratory Tests of COVID-19
935 Patients. The Laryngoscope. 131:1254–1265.

936 Makaronidis, J., Firman, C., Magee, C.G., Mok, J., Balogun, N., Lechner, M., Carnemolla, A., and
937 Batterham, R.L. 2021. Distorted chemosensory perception and female sex associate with
938 persistent smell and/or taste loss in people with SARS-CoV-2 antibodies: a community based
939 cohort study investigating clinical course and resolution of acute smell and/or taste loss in
940 people with and without SARS-CoV-2 antibodies in London, UK. BMC Infect Dis. 21:221.

941 Makda, A., Kumar, S., Kumar, A., Kumar, V., and Rizwan, A. 2020. The Frequency of Neurological
942 Symptoms in COVID-19 Patients at a Tertiary Care Hospital in Pakistan. Cureus. 12:e10360.

943 Mannan, A., Mehedi, H.M.H., Chy, N., Qayum, M.O., Akter, F., Rob, M.A., Biswas, P., Hossain, S.,
944 and Ayub, M. 2021. A multi-centre, cross-sectional study on coronavirus disease 2019 in
945 Bangladesh: clinical epidemiology and short-term outcomes in recovered individuals. New
946 Microbes New Infect. 40:100838.

947 Mao, L., Wang, M., Chen, S., He, Q., Chang, J., Hong, C., Zhou, Y., Wang, D., Li, Y., Jin, H., et al.
948 2020. Neurological Manifestations of Hospitalized Patients with COVID-19 in Wuhan, China: a
949 retrospective case series study. MedRxiv. 2020.02.22.20026500.

950 Martin-Sanz, E., Riestra, J., Yebra, L., Larran, A., Mancino, F., Yanes-Diaz, J., Garrote, M.,
951 Colmenero, M., Montiel, E., Molina, C., et al. 2020. Prospective study in 355 patients with
952 suspected COVID-19 infection. Value of cough, subjective hyposmia, and hypogeusia.
953 Laryngoscope.

954 Mazzatenta, A., Neri, G., D'Ardes, D., De Luca, C., Marinari, S., Porreca, E., Cipollone, F.,
955 Vecchiet, J., Falcicchia, C., Panichi, V., et al. 2020. Smell and Taste in Severe CoViD-19: Self-
956 Reported vs. Testing. Front Med. 7:753.

957 Meini, S., Suardi, L.R., Busoni, M., Roberts, A.T., and Fortini, A. 2020. Olfactory and gustatory
958 dysfunctions in 100 patients hospitalized for COVID-19: sex differences and recovery time in
959 real-life. Eur Arch Otorhinolaryngol.

960 Menni, C., Valdes, A.M., Freidin, M.B., Sudre, C.H., Nguyen, L.H., Drew, D.A., Ganesh, S.,
961 Varsavsky, T., Cardoso, M.J., El-Sayed Moustafa, J.S., et al. 2020. Real-time tracking of self-
962 reported symptoms to predict potential COVID-19. Nat Med.

963 Mercante, G., Ferreli, F., De Virgilio, A., Gaino, F., Di Bari, M., Colombo, G., Russo, E.,
964 Costantino, A., Pirola, F., Cugini, G., et al. 2020. Prevalence of Taste and Smell Dysfunction in
965 Coronavirus Disease 2019. JAMA Otolaryngol Head Neck Surg.

966 Merkely, B., Szabo, A.J., Kosztin, A., Berenyi, E., Sebestyen, A., Lengyel, C., Merkely, G., Karady,
967 J., Varkonyi, I., Papp, C., et al. 2020. Novel coronavirus epidemic in the Hungarian population, a
968 cross-sectional nationwide survey to support the exit policy in Hungary. Geroscience. 42:1063–
969 1074.

970 Merza, M.A., Haleem Al Mezori, A.A., Mohammed, H.M., and Abdulah, D.M. 2020. COVID-19
971 outbreak in Iraqi Kurdistan: The first report characterizing epidemiological, clinical, laboratory,
972 and radiological findings of the disease. Diabetes Metab Syndr. 14:547–554.

973 Moein, S.T., Hashemian, S.M.R., Mansourafshar, B., Khorram-Tousi, A., Tabarsi, P., and Doty,
974 R.L. 2020. Smell dysfunction: a biomarker for COVID-19. Int Forum Allergy Rhinol. n/a.

975 Moeller, A.L., Mills, E.H.A., Collatz Christensen, H., Gnesin, F., Blomberg, S., Zylyftari, N., Jensen,
976 B., Ringgren, K.B., Broccia, M.D., Boggild, H., et al. 2021. Symptom presentation of SARS-CoV-2-
977 positive and negative patients: a nested case-control study among patients calling the
978 emergency medical service and medical helpline. BMJ Open. 11:e044208.

979 Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G., and Group, T.P. 2009. Preferred Reporting
980 Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLOS Med.
981 6:e1000097.

982 Monti, G., Leggieri, C., Fominskiy, E., Scandroglio, A.M., Colombo, S., Tozzi, M., Moizo, E., Mucci,
983 M., Crivellari, M., Pieri, M., et al. 2021. Two months quality of life of COVID-19 invasively
984 ventilated survivors; an Italian single-center study. Acta Anaesthesiol Scand.

985 Morlock, R., Morlock, A., Downen, M., and Shah, S.N. 2021. COVID-19 prevalence and
986 predictors in United States adults during peak stay-at-home orders. PLoS One. 16:e0245586.

987 Morshed, M.S., Mosabbir, A.A., Chowdhury, P., Ashadullah, S.M., and Hossain, M.S. 2020.
988 Clinical manifestations of patients with Coronavirus Disease 2019 (COVID- 19) attending at
989 hospitals in Bangladesh. MedRxiv.

990 Murat, S., Dogruoz Karatekin, B., Icagasioglu, A., Ulasoglu, C., İçten, S., and Incealtin, O. 2020.
991 Clinical presentations of pain in patients with COVID-19 infection. Ir J Med Sci 1971 -.

992 Nakagawa, S., Lagisz, M., O'Dea, R.E., Rutkowska, J., Yang, Y., Noble, D.W., and Senior, A.M.
993 2020. The Orchard Plot: Cultivating a Forest Plot for Use in Ecology, Evolution and Beyond.
994 Research Synthesis Methods. 12:4–12.

995 Nakakubo, S., Suzuki, M., Kamada, K., Yamashita, Y., Nakamura, J., Horii, H., Sato, K.,
996 Matsumoto, M., Abe, Y., Tsuji, K., et al. 2020. Proposal of COVID-19 Clinical Risk Score for the
997 management of suspected COVID-19 cases: a case control study. BMC Infect Dis. 20:858.

998 Nakanishi, H., Suzuki, M., Maeda, H., Nakamura, Y., Ikegami, Y., Takenaka, Y., Mori, Y., Hasuo,
999 T., and Hasegawa, C. 2020. Differential Diagnosis of COVID-19: Importance of Measuring Blood
1000 Lymphocytes, Serum Electrolytes, and Olfactory and Taste Functions. Tohoku J Exp Med.
1001 252:109–119.

1002 Niklassen, A.S., Draf, J., Huart, C., Hintschich, C., Bocksberger, S., Trecca, E.M.C., Klimek, L., Bon,
1003 S.D.L., Altundag, A., and Hummel, T. 2021a. COVID-19: Recovery from Chemosensory
1004 Dysfunction. A Multicentre study on Smell and Taste. The Laryngoscope. 131:1095–1100.

1005 Niklassen, A.S., Draf, J., Huart, C., Hintschich, C., Bocksberger, S., Trecca, E.M.C., Klimek, L., Le
1006 Bon, S.D., Altundag, A., and Hummel, T. 2021b. COVID-19: Recovery from chemosensory
1007 dysfunction. A multicentre study on smell and taste. Laryngoscope.

1008 Ninchritz-Becerra, E., Soriano-Reixach, M.M., Mayo-Yánez, M., Calvo-Henríquez, C., Martínez-
1009 Ruiz de Apodaca, P., Saga-Gutiérrez, C., Parente-Arias, P., Villareal, I.M., Viera-Artiles, J., Poletti-
1010 Serafini, D., et al. 2021. Subjective evaluation of smell and taste dysfunction in patients with
1011 mild COVID-19 in Spain. Med Clínica Engl Ed. 156:61–64.

1012 Nishanth, D., Jhuma, S., Nitesh, G., Ramesh chand, M., Charanjit, S., Gupta, D.K., and Sen, M.K.
1013 2021. COVID-19 with and without anosmia/dysgeusia: A case-control study. J Med Virol. n/a.

1014 Noh, J.Y., Yoon, J.G., Seong, H., Choi, W.S., Sohn, J.W., Cheong, H.J., Kim, W.J., and Song, J.Y.
1015 2020. Asymptomatic infection and atypical manifestations of COVID-19: Comparison of viral
1016 shedding duration. J Infect.

1017 Nolden, A.A., Hwang, L.-D., Boltong, A., and Reed, D.R. 2019. Chemosensory Changes from
1018 Cancer Treatment and Their Effects on Patients' Food Behavior: A Scoping Review. Nutrients.
1019 11:2285.

1020 Noviello, D., Costantino, A., Muscatello, A., Bandera, A., Consonni, D., Vecchi, M., and Basilisco,
1021 G. 2021. Functional gastrointestinal and somatoform symptoms five months after SARS-CoV-2
1022 infection: A controlled cohort study. Neurogastroenterol Motil. e14187.

1023 Oda, Y., Shiraishi, S., Shimada, M., and Kurai, O. 2021. Clinical profiles and outcome of patients
1024 with COVID-19 in a specialized hospital in Japan. J Anesth.

1025 O'Keefe, J.B., Tong, E.J., O'Keefe, G.D., and Tong, D.C. 2021. Description of symptom course in a
1026 telemedicine monitoring clinic for acute symptomatic COVID-19: a retrospective cohort study.
1027 BMJ Open. 11:e044154.

1028 Omezli, M.M., and Torul, D. 2021. Evaluation of the xerostomia, taste and smell impairments
1029 after Covid-19. Med Oral Patol Oral Cir Bucal.

1030 O'Sullivan, G., Jacob, S., Barrett, P.M., and Gallagher, J. 2021. Covid-19 presentation among
1031 symptomatic healthcare workers in Ireland. Occup Med.

1032 Otte, M.S., Eckel, H.N.C., Poluschkin, L., Klussmann, J.P., and Luers, J.C. 2020. Olfactory
1033 dysfunction in patients after recovering from COVID-19. Acta Otolaryngol. 1–4.

1034 Ozcan, E., Yavuzer, S., Borku Uysal, B., Islamoglu, M.S., Ikitimur, H., Unal, O.F., Akpinar, Y.E.,
1035 Seyhan, S., Koc, S., Yavuzer, H., et al. 2021. The Relationship Between Positivity for COVID-19
1036 RT-PCR and Symptoms, Clinical Findings, and Mortality in Turkey. Expert Rev Mol Diagn.

1037 Ozcelik Korkmaz, M., Egilmez, O.K., Ozcelik, M.A., and Guven, M. 2020. Otolaryngological
1038 manifestations of hospitalised patients with confirmed COVID-19 infection. Eur Arch
1039 Otorhinolaryngol.

1040 Paderno, A., Schreiber, A., Grammatica, A., Raffetti, E., Tomasoni, M., Gualtieri, T., Taboni, S.,
1041 Zorzi, S., Lombardi, D., Deganello, A., et al. 2020. Smell and taste alterations in Covid-19: a
1042 cross-sectional analysis of different cohorts. Int Forum Allergy Rhinol.

1043 Pang, K.W., Chee, J., Subramaniam, S., and Ng, C.L. 2020. Frequency and Clinical Utility of
1044 Olfactory Dysfunction in COVID-19: a Systematic Review and Meta-analysis. Curr Allergy Asthma
1045 Rep. 20:76.

1046 Parcha, V., Booker, K.S., Kalra, R., Kuranz, S., Berra, L., Arora, G., and Arora, P. 2021. A
1047 retrospective cohort study of 12,306 pediatric COVID-19 patients in the United States. Sci Rep.
1048 11:10231.

1049 Patel, A., Charani, E., Ariyanayagam, D., Abdulaal, A., Denny, S.J., Mughal, N., and Moore, L.S.P.
1050 2020. New-onset anosmia and ageusia in adult patients diagnosed with SARS-CoV-2 infection.
1051 Clin Microbiol Infect.

1052 Perlman, A., Vodonos Zilberg, A., Bak, P., Dreyfuss, M., Leventer-Roberts, M., Vurembrand, Y.,
1053 Jeffries, H.E., Fisher, E., Steuerman, Y., Namir, Y., et al. 2020. Digital and Remote Care among
1054 71,619 Individuals Seeking COVID-19 Health Information and Services: A Retrospective Cohort
1055 Study. J Med Internet Res.

1056 Perula de Torres, L.A., Gonzalez-Lama, J., Jimenez Garcia, C., Sanchez Montero, R., Rider
1057 Garrido, F., Ortega Lopez, Y., Pajares Conde, D., Ramirez Baena, M., Parraga Martinez, I.,
1058 Romero-Rodriguez, E., et al. 2021. Frequency and predictive validity of olfactory and taste
1059 dysfunction in patients with SARS-CoV-2 infection. Med Clin Barc.

1060 Petersen, M.S., Kristiansen, M.F., Hanusson, K.D., Danielsen, M.E., Steig, B. á, Gaini, S., Strøm,
1061 M., and Weihe, P. 2020. Long COVID in the Faroe Islands - a longitudinal study among non-
1062 hospitalized patients. Clin Infect Dis.

1063 Petrocelli, M., Ruggiero, F., Baietti, A.M., Pandolfi, P., Salzano, G., Salzano, F.A., Lechien, J.R.,
1064 Saussez, S., De Riu, G., and Vaira, L.A. 2020a. Remote psychophysical evaluation of olfactory
1065 and gustatory functions in early-stage coronavirus disease 2019 patients: the Bologna
1066 experience of 300 cases. J Laryngol Otol. 1–12.

1067 Petrocelli, M., Ruggiero, F., Baietti, A.M., Pandolfi, P., Salzano, G., Salzano, F.A., Lechien, J.R.,
1068 Saussez, S., Riu, G.D., and Vaira, L.A. 2020b. Remote psychophysical evaluation of olfactory and
1069 gustatory functions in early-stage coronavirus disease 2019 patients: the Bologna experience of
1070 300 cases. J Laryngol Otol. 134:571–576.

1071 Pinna, P., Grewal, P., Hall, J.P., Tavarez, T., Dafer, R.M., Garg, R., Osteraas, N.D., Pellack, D.R.,
1072 Asthana, A., Fegan, K., et al. 2020. Neurological manifestations and COVID-19: Experiences from
1073 a tertiary care center at the Frontline. J Neurol Sci. 415:116969.

1074 Polat, B., Yilmaz, N.H., Altin, G., Atakcan, Z., and Mert, A. 2021. Olfactory and Gustatory
1075 Dysfunctions in COVID-19 Patients: From a Different Perspective. J Craniofac Surg. Publish
1076 Ahead of Print.

1077 Printza, A., Katotomichelakis, M., Metallidis, S., Panagopoulos, P., Sarafidou, A., Petrakis, V., and
1078 Constantinidis, J. 2020. The clinical course of smell and taste loss in COVID-19 hospitalized
1079 patients. Hippokratia. 24:66–71.

1080 Printza, A., Katotomichelakis, M., Valsamidis, K., Metallidis, S., Panagopoulos, P., Panopoulou,
1081 M., Petrakis, V., and Constantinidis, J. 2021. Smell and Taste Loss Recovery Time in COVID-19
1082 Patients and Disease Severity. J Clin Med. 10.

1083 Qiu, C., Cui, C., Hautefort, C., Haehner, A., Zhao, J., Yao, Q., Zeng, H., Nisenbaum, E.J., Liu, L.,
1084 Zhao, Y., et al. 2020. Olfactory and Gustatory Dysfunction as an Early Identifier of COVID-19 in

1085 Adults and Children: An International Multicenter Study. Otolaryngol Head Neck Surg.
1086 194599820934376.

1087 R Core, T. 2021. R: A language and environment for statistical computing.

1088 Rajkumar, I., Anand, K.H., Revathishree, K., Shoba, K., and Srinivasan, K. 2020. Contemporary
1089 Analysis of Olfactory Dysfunction in Mild to Moderate Covid 19 Patients in A Tertiary Health
1090 Care Centre. Indian J Otolaryngol Head Neck Surg. 1–5.

1091 Ramteke, S., Tikkas, R., Goel, M., Mandraha, S., and Shrivastava, J. 2020. Paediatric COVID-19:
1092 Milder Presentation-A Silver Lining in Dark Cloud. J Trop Pediatr. 67.

1093 Rawal, S., Hoffman, H.J., Bainbridge, K.E., Huedo-Medina, T.B., and Duffy, V.B. 2016. Prevalence
1094 and Risk Factors of Self-Reported Smell and Taste Alterations: Results from the 2011–2012 US
1095 National Health and Nutrition Examination Survey (NHANES). Chem Senses. 41:69–76.

1096 Rocke, J., Hopkins, C., Philpott, C., and Kumar, N. 2020. Is loss of sense of smell a diagnostic
1097 marker in COVID-19: A systematic review and meta-analysis. Clin Otolaryngol. 45:914–922.

1098 Rodebaugh, T.L., Frumkin, M.R., Reiersen, A.M., Lenze, E.J., Avidan, M.S., Miller, J.P., Piccirillo,
1099 J.F., Zorumski, C.F., and Mattar, C. 2021. Acute Symptoms of Mild to Moderate COVID-19 Are
1100 Highly Heterogeneous Across Individuals and Over Time. Open Forum Infect Dis. 8.

1101 Rojas-Lechuga, M.J., Izquierdo-Dominguez, A., Chiesa-Estomba, C., Calvo-Henriquez, C.,
1102 Villarreal, I.M., Cuesta-Chasco, G., Bernal-Sprekelsen, M., Mullol, J., and Alobid, I. 2020.
1103 Chemosensory dysfunction in COVID-19 out-patients. Eur Arch Otorhinolaryngol.

1104 Roland, L.T., Gurrola, J.G., Loftus, P.A., Cheung, S.W., and Chang, J.L. 2020. Smell and taste
1105 symptom-based predictive model for COVID-19 diagnosis. Int Forum Allergy Rhinol.

1106 Romero-Sanchez, C.M., Diaz-Maroto, I., Fernandez-Diaz, E., Sanchez-Larsen, A., Layos-Romero,
1107 A., Garcia-Garcia, J., Gonzalez, E., Redondo-Penas, I., Perona-Moratalla, A.B., Del Valle-Perez,
1108 J.A., et al. 2020. Neurologic manifestations in hospitalized patients with COVID-19: The
1109 ALBACOVID registry. Neurology. 95:e1060–e1070.

1110 Rousseau, M.C., Hully, M., Milh, M., Juzeau, D., Pollez, B., Peudenier, S., Bahi Buisson, N.,
1111 Gautheron, V., Chabrol, B., and Billette de Villemeur, T. 2021. Clinical characteristics of COVID-
1112 19 infection in polyhandicapped persons in France. Arch Pédiatrie.

1113 RStudio Team. 2020. RStudio: Integrated Development for R. RStudio. Boston, MA: RStudio,
1114 PBC.

1115 Rubel, K., Sharma, D., Campiti, V., Yedlicka, G., Burgin, S.J., Illing, E.A., Kroenke, K., and Ting, J.Y.
1116 2020. COVID-19 Status Differentially Affects Olfaction: A Prospective Case-Control Study. OTO
1117 Open. 4:2473974X20970176.

1118 Sahoo, P.R., Sahu, M., Surapaneni, P.S., Maiti, A., Vankamamidi, R., Panda, N., and Biswal, R.N.
1119 2021. Evolution of olfactory and gustatory dysfunctions in COVID-19 patients in India. Eur Arch
1120 Otorhinolaryngol.

1121 Sakaguchi, W., Kubota, N., Shimizu, T., Saruta, J., Fuchida, S., Kawata, A., Yamamoto, Y.,
1122 Sugimoto, M., Yakeishi, M., and Tsukinoki, K. 2020. Existence of SARS-CoV-2 Entry Molecules in
1123 the Oral Cavity. Int J Mol Sci. 21:6000.

1124 Sakalli, E., Temirbekov, D., Bayri, E., Alis, E.E., Erdurak, S.C., and Bayraktaroglu, M. 2020. Ear
1125 nose throat-related symptoms with a focus on loss of smell and/or taste in COVID-19 patients.
1126 Am J Otolaryngol. 41:102622.

1127 Salcan, İ., Karakeçili, F., Salcan, S., Ünver, E., Akyüz, S., Seçkin, E., and Cingi, C. 2021. Is taste and
1128 smell impairment irreversible in COVID-19 patients? Eur Arch Otorhinolaryngol. 278:411–415.

1129 Salepci, E., Turk, B., Ozcan, S.N., Bektas, M.E., Aybal, A., Dokmetas, I., and Turgut, S. 2020.
1130 Symptomatology of COVID-19 from the otorhinolaryngology perspective: a survey of 223 SARS-
1131 CoV-2 RNA-positive patients. Eur Arch Otorhinolaryngol.

1132 Saniasiaya, J., Islam, M.A., and Abdullah, B. 2021. Prevalence and Characteristics of Taste
1133 Disorders in Cases of COVID-19: A Meta-analysis of 29,349 Patients. Otolaryngol Neck Surg.
1134 165:33–42.

1135 Santos, R.E.A., Silva, M.G. da, Monte Silva, M.C.B. do, Barbosa, D.A.M., Gomes, A.L. do V.,
1136 Galindo, L.C.M., Silva Aragão, R. da, and Ferraz-Pereira, K.N. 2021. Onset and duration of
1137 symptoms of loss of smell/taste in patients with COVID-19: A systematic review. Am J
1138 Otolaryngol. 42:102889.

1139 Savtale, S., Hippargekar, P., Bhise, S., and Kothule, S. 2021. Prevalence of
1140 Otorhinolaryngological Symptoms in Covid 19 Patients. Indian J Otolaryngol Head Neck Surg.

1141 Sayin, I., Yasar, K.K., and Yazici, Z.M. 2020a. Taste and Smell Impairment in COVID-19: An AAO-
1142 HNS Anosmia Reporting Tool-Based Comparative Study. Otolaryngol Head Neck Surg.
1143 194599820931820.

1144 Sayin, P., Altinay, M., Cinar, A.S., and Ozdemir, H.M. 2020b. Taste and Smell Impairment in
1145 Critically Ill Patients With COVID-19: An Intensive Care Unit Study. Ear Nose Throat J.
1146 145561320977464.

1147 Sbrana, M.F., Fornazieri, M.A., Bruni-Cardoso, A., Avelino-Silva, V.I., Schechtman, D., Voegels,
1148 R.L., Malnic, B., Glezer, I., and Rezende Pinna, F. de. 2021. Olfactory Dysfunction in Frontline
1149 Health Care Professionals During COVID-19 Pandemic in Brazil. Front Physiol. 12:622987.

1150 Schirinzi, A., Cazzolla, A.P., Lovero, R., Lo Muzio, L., Testa, N.F., Ciavarella, D., Palmieri, G.,
1151 Pozzessere, P., Procacci, V., Di Serio, F., et al. 2020. New Insights in Laboratory Testing for
1152 COVID-19 Patients: Looking for the Role and Predictive Value of Human epididymis secretory

protein 4 (HE4) and the Innate Immunity of the Oral Cavity and Respiratory Tract. Microorganisms. 8.

Schmithausen, R.M., Dohla, M., Schobetaler, H., Diegmann, C., Schulte, B., Richter, E., Eis-Hubinger, A.M., and Streeck, H. 2020. Characteristic Temporary Loss of Taste and Olfactory Senses in SARS-CoV-2-positive-Individuals with Mild Symptoms. Pathog Immun. 5:117–120.

Schwab, J., Jensen, C.D., and Fjaeldstad, A.W. 2021. Sustained Chemosensory Dysfunction during the COVID-19 Pandemic. ORL J Otorhinolaryngol Relat Spec. 1–10.

Schwarzer, G., Chemaitelly, H., Abu-Raddad, L.J., and Rücker, G. 2019. Seriously misleading results using inverse of Freeman-Tukey double arcsine transformation in meta-analysis of single proportions. Res Synth Methods. 10:476–483.

Sehanobish, E., Barbi, M., Fong, V., Kravitz, M., Sanchez Tejera, D., Asad, M., Matsumura, C., Ferastraoaru, D., O'Neill, M., Karagic, M., et al. 2021. COVID-19-Induced Anosmia and Ageusia Are Associated With Younger Age and Lower Blood Eosinophil Counts. Am J Rhinol Allergy.

Seo, M.Y., Seok, H., Hwang, S.J., Choi, H.K., Jeon, J.H., Sohn, J.W., Park, D.W., Lee, S.H., and Choi, W.S. 2020. Trend of Olfactory and Gustatory Dysfunction in COVID-19 Patients in a Quarantine Facility. J Korean Med Sci. 35:e375.

Shoer, S., Karady, T., Keshet, A., Shilo, S., Rossman, H., Gavrieli, A., Meir, T., Lavon, A., Kolobkov, D., Kalka, I., et al. 2020. Who should we test for COVID-19? A triage model built from national symptom surveys. MedRxiv. 2020.05.18.20105569.

Sierpinski, R., Pinkas, J., Jankowski, M., Zgliczynski, W.S., Wierzba, W., Gujski, M., and Szumowski, L. 2020. Sex differences in the frequency of gastrointestinal symptoms and olfactory or taste disorders in 1942 nonhospitalized patients with coronavirus disease 2019 (COVID-19). Pol Arch Intern Med. 130:501–505.

Singer-Cornelius, T., Cornelius, J., Oberle, M., Metternich, F.U., and Brockmeier, S.J. 2021. Objective gustatory and olfactory dysfunction in COVID-19 patients: a prospective cross-sectional study. Eur Arch Otorhinolaryngol.

Smith, D.S., Richey, E.A., and Brunetto, W.L. 2020. A Symptom-Based Rule for Diagnosis of COVID-19. SN Compr Clin Med. 1–8.

Soh, S.H.L., See, A., Teo, N.W.Y., Tan, H.K., Palaniappan, G., Lim, M.L.A., Kadir, H.B.A., and Toh, S.T. 2021. Prevalence of olfactory and taste dysfunction in COVID-19 patients: a community care facility study. Eur Arch Otorhinolaryngol.

Somekh, I., Yakub Hanna, H., Heller, E., Bibi, H., and Somekh, E. 2020. Age-Dependent Sensory Impairment in Covid-19 Infection and Its Correlation with Ace2 Expression. Pediatr Infect J.

1186 Song, J., Deng, Y., Wang, H., Wang, Z., Liao, B., Ma, J., He, C., Pan, L., Liu, Y., Alobid, I., et al.
1187 2021a. Self-reported Taste and Smell Disorders in Patients with COVID-19: Distinct Features in
1188 China. Curr Med Sci. 41:14–23.

1189 Song, S.W., Kim, D., Park, J.Y., and Lee, S. 2021b. Symptoms and Characteristics Which Require
1190 Attention During COVID-19 Screening at a Port of Entry. J Korean Med Sci. 36:e14.

1191 Speth, M.M., Singer-Cornelius, T., Obere, M., Gengler, I., Brockmeier, S.J., and Sedaghat, A.R.
1192 2020. Olfactory Dysfunction and Sinonasal Symptomatology in COVID-19: Prevalence, Severity,
1193 Timing, and Associated Characteristics. Otolaryngol Head Neck Surg. 194599820929185.

1194 Spinato, G., Fabbris, C., Polesel, J., Cazzador, D., Borsetto, D., Hopkins, C., and Boscolo-Rizzo, P.
1195 2020. Alterations in Smell or Taste in Mildly Symptomatic Outpatients With SARS-CoV-2
1196 Infection. JAMA.

1197 Stavem, K., Ghanima, W., Olsen, M.K., Gilboe, H.M., and Einvik, G. 2020. Persistent symptoms
1198 1.5-6 months after COVID-19 in non-hospitalised subjects: a population-based cohort study.
1199 Thorax.

1200 Sun, J., He, W.-T., Wang, L., Lai, A., Ji, X., Zhai, X., Li, G., Suchard, M.A., Tian, J., Zhou, J., et al.
1201 2020. COVID-19: Epidemiology, Evolution, and Cross-Disciplinary Perspectives. Trends Mol Med.
1202 26:483–495.

1203 Tarifi, A., Al Shdaifat, A.A., Al-Shudifat, A.M., Azab, M., Ismail, J., Bashir, R., Amro, A., Altarifi, A.,
1204 and Khader, Y. 2021. Clinical, SinoNasal, and Long-Term Smell and Taste Outcomes in Mildly
1205 Symptomatic COVID-19 Patients. Int J Clin Pr. e14260.

1206 Taziki Balajelini, M.H., Rajabi, A., Mohammadi, M., Nikoo, H.R., Tabarraei, A., Mansouri, M., and
1207 Hosseini, S.M. 2021. Virus load and incidence of olfactory, gustatory, respiratory,
1208 gastrointestinal disorders in COVID-19 patients: A retrospective cohort study. Clin Otolaryngol
1209 Off J ENT-UK Off J Neth Soc Oto-Rhino-Laryngol Cervico-Facial Surg.

1210 Teklu, S., Sultan, M., Azazh, A., Worku, A., Redae, B., Walelegn, M., Tefera, M., Argaw, R.,
1211 Waganew, W., Yifru, S., et al. 2020. Clinical and Socio-demographic Profile of the First 33
1212 COVID-19 Cases Treated at Dedicated Treatment Center in Ethiopia. Ethiop J Health Sci. 30:645–
1213 652.

1214 Thakur, K., Sagayaraj, A., Prasad, K.C., and Gupta, A. 2021. Olfactory Dysfunction in COVID-19
1215 Patients: Findings from a Tertiary Rural Centre. Indian J Otolaryngol Head Neck Surg. 1–7.

1216 Tham, A.C., Thein, T.-L., Lee, C.S., Tan, G.S.E., Manauis, C.M., Siow, J.K., Leo, Y.S., and Lim, M.Y.
1217 2020. Olfactory taste disorder as a presenting symptom of COVID-19: a large single-center
1218 Singapore study. Eur Arch Otorhinolaryngol.

1219 Tong, J.Y., Wong, A., Zhu, D., Fastenberg, J.H., and Tham, T. 2020. The Prevalence of Olfactory
1220 and Gustatory Dysfunction in COVID-19 Patients: A Systematic Review and Meta-analysis.
1221 Otolaryngol Neck Surg. 163:3–11.

1222 Trachootham, D., Thongyen, S., Lam-Ubol, A., Chotechuang, N., Pongpirul, W., and
1223 Prasithsirikul, W. 2021. Simultaneously Complete but Not Partial Taste and Smell Losses were
1224 Associated with SAR-CoV-2 Infection. Int J Infect Dis.

1225 Tsivgoulis, G., Fragkou, P.C., Delides, A., Karofylakis, E., Dimopoulou, D., Sfikakis, P.P., and
1226 Tsiodras, S. 2020. Quantitative evaluation of olfactory dysfunction in hospitalized patients with
1227 Coronavirus [2] (COVID-19). J Neurol. 267:2193–2195.

1228 Tudrej, B., Sebo, P., Lourdaux, J., Cuzin, C., Floquet, M., Haller, D.M., and Maisonneuve, H. 2020.
1229 Self-Reported Loss of Smell and Taste in SARS-CoV-2 Patients: Primary Care Data to Guide
1230 Future Early Detection Strategies. J Gen Intern Med.

1231 United States Preventive Services Taskforce. Recommended Topics for Vision and Hearing.

1232 Vacchiano, V., Riguzzi, P., Volpi, L., Tappata, M., Avoni, P., Rizzo, G., Guerra, L., Zaccaroni, S.,
1233 Cortelli, P., Michelucci, R., et al. 2020. Early neurological manifestations of hospitalized COVID-
1234 19 patients. Neurol Sci.

1235 Vaira, L.A., Deiana, G., Fois, A.G., Pirina, P., Madeddu, G., Vito, A.D., Babudieri, S., Petrocelli, M.,
1236 Serra, A., Bussu, F., et al. 2020a. Objective evaluation of anosmia and ageusia in COVID-19
1237 patients: Single-center experience on 72 cases. Head Neck. 42:1252–1258.

1238 Vaira, L.A., Hopkins, C., Petrocelli, M., Lechien, J.R., Chiesa-Estomba, C.M., Salzano, G.,
1239 Cucurullo, M., Salzano, F.A., Saussez, S., Boscolo-Rizzo, P., et al. 2020b. Smell and taste recovery
1240 in coronavirus disease 2019 patients: a 60-day objective and prospective study. J Laryngol Otol.
1241 134:703–709.

1242 Vaira, L.A., Hopkins, C., Petrocelli, M., Lechien, J.R., Soma, D., Giovanditto, F., Rizzo, D., Salzano,
1243 G., Piombino, P., Saussez, S., et al. 2020c. Do olfactory and gustatory psychophysical scores
1244 have prognostic value in COVID-19 patients? A prospective study of 106 patients. J Otolaryngol -
1245 Head Neck Surg. 49:56.

1246 Vaira, L.A., Hopkins, C., Salzano, G., Petrocelli, M., Melis, A., Cucurullo, M., Ferrari, M.,
1247 Gagliardini, L., Pipolo, C., Deiana, G., et al. 2020d. Olfactory and gustatory function impairment
1248 in COVID-19 patients: Italian objective multicenter-study. Head Neck. 42:1560–1569.

1249 Vaira, L.A., Lechien, J.R., Salzano, G., Salzano, F.A., Maglitto, F., Saussez, S., and De Riu, G.
1250 2020e. Gustatory Dysfunction: A Highly Specific and Smell-Independent Symptom of COVID-19.
1251 Indian J Otolaryngol Head Neck Surg.

1252 Vaira, L.A., Salzano, G., Petrocelli, M., Deiana, G., Salzano, F.A., and Riu, G.D. 2020f. Validation
1253 of a self-administered olfactory and gustatory test for the remotely evaluation of COVID-19
1254 patients in home quarantine. Head Neck. 42:1570–1576.

1255 Van Loon, N., Verbrugghe, M., Cartuyvels, R., and Ramaekers, D. 2020. Diagnosis of COVID-19
1256 Based on Symptomatic Analysis of Hospital Healthcare Workers in Belgium: Observational Study
1257 in a Large Belgian Tertiary Care Center during Early COVID-19 Outbreak. J Occup Env Med.

1258 Vena, A., Berruti, M., Adessi, A., Blumetti, P., Brignole, M., Colognato, R., Gaggioli, G., Giacobbe,
1259 D.R., Bracci-Laudiero, L., Magnasco, L., et al. 2020. Prevalence of Antibodies to SARS-CoV-2 in
1260 Italian Adults and Associated Risk Factors. J Clin Med. 9.

1261 Villarreal, I.M., Morato, M., Martinez-RuizCoello, M., Navarro, A., Garcia-Chilleron, R., Ruiz, A.,
1262 Almeida, I.V. de, Mazon, L., and Plaza, G. 2020. Olfactory and taste disorders in healthcare
1263 workers with COVID-19 infection. Eur Arch Otorhinolaryngol.

1264 Wagner, T., Shweta, F.N.U., Murugadoss, K., Awasthi, S., Venkatakrishnan, A.J., Bade, S.,
1265 Puranik, A., Kang, M., Pickering, B.W., O'Horo, J.C., et al. 2020. Augmented Curation of Clinical
1266 Notes from a Massive EHR System Reveals Symptoms of Impending COVID-19 Diagnosis.
1267 MedRxiv. 2020.04.19.20067660.

1268 Waterfield, T., Watson, C., Moore, R., Ferris, K., Tonry, C., Watt, A., McGinn, C., Foster, S.,
1269 Evans, J., Lyttle, M.D., et al. 2020. Seroprevalence of SARS-CoV-2 antibodies in children: a
1270 prospective multicentre cohort study. Arch Dis Child.

1271 Wee, L.E., Chan, Y.F.Z., Teo, N.W.Y., Cherng, B.P.Z., Thien, S.Y., Wong, H.M., Wijaya, L., Toh, S.T.,
1272 and Tan, T.T. 2020. The role of self-reported olfactory and gustatory dysfunction as a screening
1273 criterion for suspected COVID-19. Eur Arch Otorhinolaryngol.

1274 Weiss, J.J., Attuquayefio, T.N., White, E.B., Li, F., Herz, R.S., White, T.L., Campbell, M., Geng, B.,
1275 Datta, R., Wyllie, A.L., et al. 2020. Tracking Smell Loss to Identify Healthcare Workers with SARS-
1276 CoV-2 Infection. MedRxiv. 2020.09.07.20188813.

1277 Weng, C.H., Saal, A., Butt, W.W.W., and Chan, P.A. 2020. Characteristics and clinical outcomes
1278 of COVID-19 in Hispanic/Latino patients in a community setting: A retrospective cohort study. J
1279 Med Virol.

1280 Wierdsma, N.J., Kruizenga, H.M., Konings, L.A., Krebbers, D., Jorissen, J.R., Joosten, M.I., Aken,
1281 L.H. van, Tan, F.M., Bodegraven, A.A. van, Soeters, M.R., et al. 2021. Poor nutritional status, risk
1282 of sarcopenia and nutrition related complaints are prevalent in COVID-19 patients during and
1283 after hospital admission. Clin Nutr ESPEN. 43:369–376.

1284 Yadav, V., Bhagat, S., Sharma, D.K., Sibia, R.P.S., Pandav, R., and Sandhu, V.P. 2021. Olfactory
1285 and Gustatory Dysfunction in COVID-19 Patients: A Tertiary Care Institute Experience in India.
1286 Indian J Otolaryngol Head Neck Surg. 1–8.

1287 Yan, C.H., Faraji, F., Prajapati, D.P., Boone, C.E., and DeConde, A.S. 2020a. Association of
1288 chemosensory dysfunction and Covid-19 in patients presenting with influenza-like symptoms.
1289 Int Forum Allergy Rhinol. n/a.

1290 Yan, C.H., Faraji, F., Prajapati, D.P., Ostrander, B.T., and DeConde, A.S. 2020b. Self-reported
1291 olfactory loss associates with outpatient clinical course in COVID-19. Int Forum Allergy Rhinol.

1292 Yassin, A., Nawaiseh, M., Shaban, A., Alsherbini, K., El-Salem, K., Soudah, O., and Abu-Rub, M.
1293 2021. Neurological manifestations and complications of coronavirus disease 2019 (COVID-19): a
1294 systematic review and meta-analysis. BMC Neurol. 21:138.

1295 Zayet, S., Kadiane-Oussou, N.J., Lepiller, Q., Zahra, H., Royer, P.Y., Toko, L., Gendrin, V., and
1296 Klopfenstein, T. 2020a. Clinical features of COVID-19 and influenza: a comparative study on
1297 Nord Franche-Comte cluster. Microbes Infect. 22:481–488.

1298 Zayet, S., Klopfenstein, T., Mercier, J., Kadiane-Oussou, N.J., Lan Cheong Wah, L., Royer, P.Y.,
1299 Toko, L., and Gendrin, V. 2020b. Contribution of anosmia and dysgeusia for diagnostic of
1300 COVID-19 in outpatients. Infection.

1301 Zejda, J.E., Brożek, G.M., Kowalska, M., Barański, K., Kaleta-Pilarska, A., Nowakowski, A., Xia, Y.,
1302 and Buszman, P. 2021. Seroprevalence of Anti-SARS-CoV-2 Antibodies in a Random Sample of
1303 Inhabitants of the Katowice Region, Poland. Int J Environ Res Public Health. 18.

1304 Zifko, U., Schmiedlechner, T., Saelens, J., Zifko, K., Wagner, M., Assadian, O., Grisold, W., and
1305 Stingl, H. 2021. Covid-19: Involvement of the nervous system. Identifying neurological
1306 predictors defining the course of the disease. J Neurol Sci. 425:117438.

1307 Zimmerman, R.K., Nowalk, M.P., Bear, T., Taber, R., Clarke, K.S., Sax, T.M., Eng, H., Clarke, L.G.,
1308 and Balasubramani, G.K. 2020. Proposed clinical indicators for efficient screening and testing
1309 for COVID-19 infection using Classification and Regression Trees (CART) analysis. Hum Vaccin
1310 Immunother. 1–4.

1311 Zou, L., Yu, T., Zhang, Y., Dai, L., Zhang, Z., and Zhang, Z. 2021. Olfactory and Gustatory
1312 Dysfunctions in Patients With COVID-19 in Wuhan, China.

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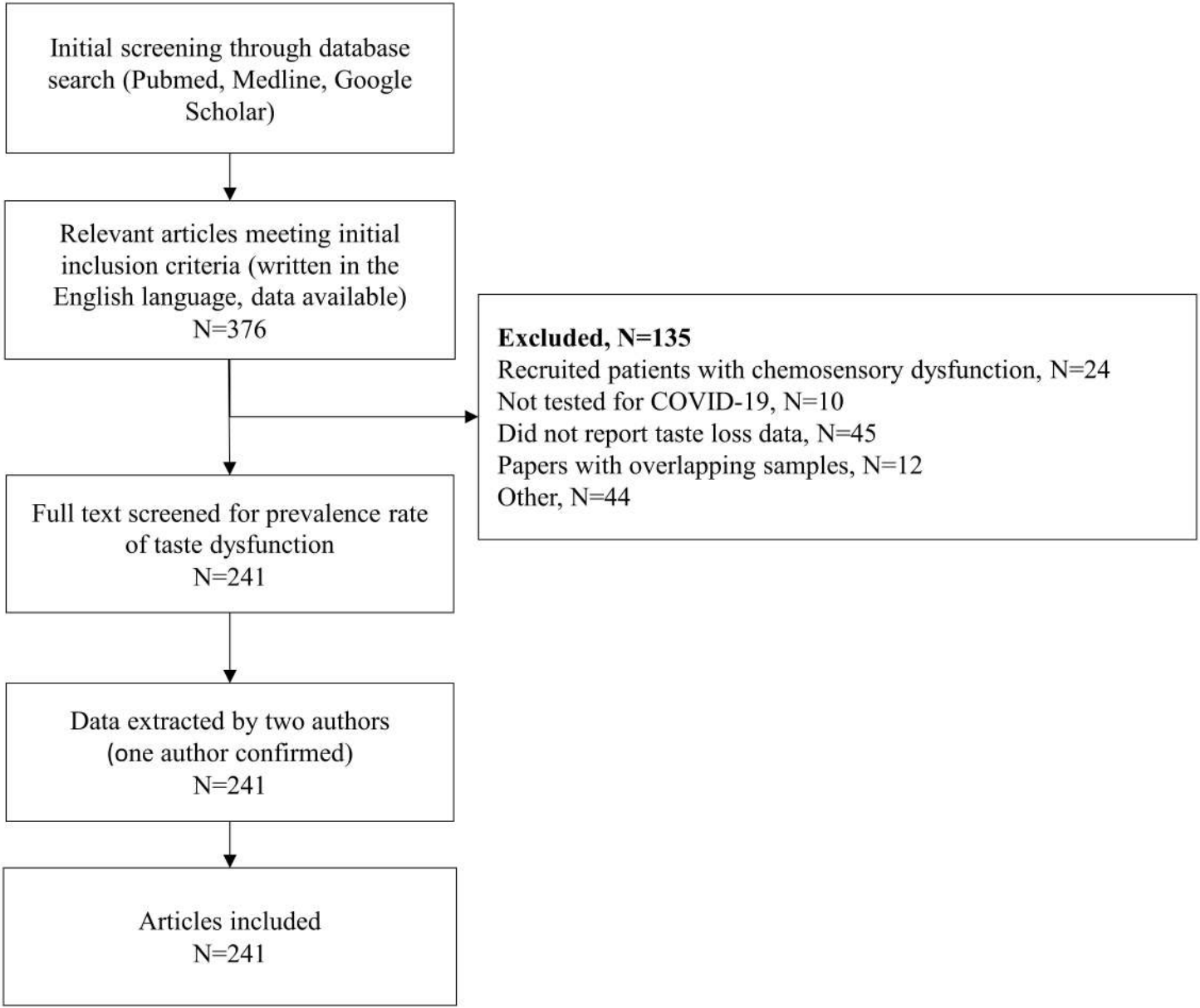
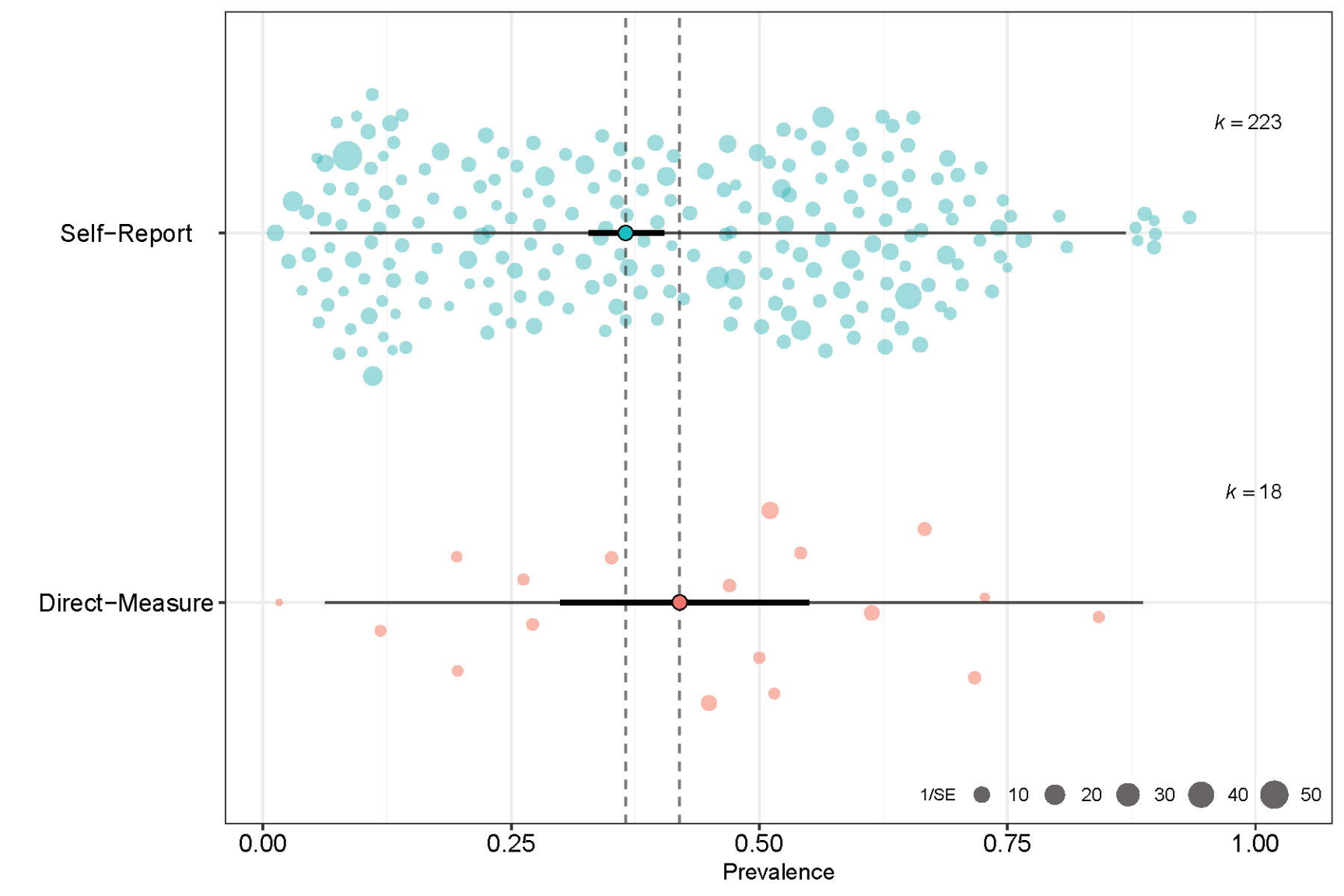

Initial screening through database search (Pubmed, Medline, Google Scholar)
Relevant articles meeting initial inclusion criteria (written in the English language, data available) N=376
Excluded, N=135
Recruited patients with chemosensory dysfunction, N=24
Not tested for COVID-19, N=10
Did not report taste loss data, N=45
Papers with overlapping samples, N=12
Other, N=44
Full text screened for prevalence rate of taste dysfunction N=241
Data extracted by two authors (one author confirmed) N=241
Articles included N=241


Self−Report
Direct−Measure
k = 223
k = 18
1/SE
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Prevalence