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Post-COVID syndrome: analysis of the prevalence of chemosensory dysfunction and predictive factors of recovery in COVID-19 long-haulers in Jordan

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Abstract. – OBJECTIVE: One of the major concerns of the post-COVID-19 era is elucidating and addressing the long-term complications of COVID-19.

SUBJECTS AND METHODS: A web-based questionnaire was distributed in Jordan to assess the prevalence and recovery from chemosensory dysfunction among COVID-19 long-haulers in Jordan.

RESULTS: A total of 611 respondents complained of chemosensory dysfunction (age range = 18-68 years), and the majority of the respondents were female (88.4%). Parosmia was the most prevalent olfactory dysfunction reported (n = 337, 33.3%), and parageusia was the most frequently reported gustatory dysfunction (n = 239, 36.4%). Medications were not reported to be associated with a better perception of smell or taste by nearly half of those who had been treated (n = 146, 46.1%). Among participants who had received olfactory rehabilitation/training (n = 215, 35.2%), 43.7% (n = 94) reported modest improvement, with the most frequently helpful scents being coffee (n = 80, 24.8%), aromatic oils (n = 74, 23%), and perfumes/colognes (n = 73, 22.7%). Age was found to have a significant negative correlation with complete recovery. In addition, age ($p < .05$), anosmia ($p < .001$), hyperosmia ($p < .001$), ageusia ($p < .05$), and duration of olfactory dysfunction ($p < .001$) were all independent predictors of complete recovery.

CONCLUSIONS: Chemosensory dysfunctions are largely subjective; therefore, more objective examinations are required to draw more definite conclusions.

Key Words:
Chemosensory dysfunction, Long COVID, Post-COVID, Parosmia, Phantosmia.

Abbreviations

COVID-19: Coronavirus disease of 2019; ACE2: Angiotensin-converting enzyme 2; SARS CoV 2: Severe acute respiratory syndrome coronavirus 2; IRB: Institutional Review Board; PCR: Polymerase chain reaction; CI: confidence interval.

Introduction

Most people afflicted with COVID-19 experience chemosensory dysfunction during the acute phase of the infection. Olfactory dysfunction has been proposed[1] as the best predictor of COVID-19 diagnosis and the most common symptom of COVID-19. A large-scale study[2] assessed 514,459 records from more than 10 million respondents to three digital COVID-19 survey platforms and found that the likelihood of testing positive for COVID-19 increases by up to 17 times in people reporting a loss of smell or taste. However, about 30% of COVID-19 cases continue to experience some olfactory dysfunction long after the infection has subsided[3]. Although healthy individuals may not perceive it as highly crucial, the sense of smell functions as an alerting device for fires, leaking gas, spoiled food, and even the need to shower. In addition, olfaction is pivotal to building the flavor of food dishes and beverages to make eating and cooking enjoyable. Consequently, olfactory dysfunction casts a shadow on many aspects of the affected individual's daily life, including nutrition, safety awareness, and physical and psychological wellness.

Chemosensory dysfunction linked to COVID-19 infection can manifest as olfactory dysfunction

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and/or gustatory dysfunction[4]. Chemosensory disorders can be described either quantitatively (i.e., anosmia, hyposmia, or hyperosmia) or qualitatively (i.e., parosmia, a distortion of the sense of smell in the presence of a stimulus; phantosmia, which is smell hallucination in the absence of an existing stimulus; and cacosmia, an inability to recognize smells)[5]. Patients with qualitative smell disorders usually suffer from a quantitative smell disorder as well[6]. Analogous to olfactory dysfunction, gustatory disorders can manifest either quantitatively (i.e., ageusia, hypogeusia, or hypergeusia) or qualitatively (i.e., parageusia, also known as dysgeusia, a distortion of the sense of smell in the presence of an existing stimulus; phantogeusia, a taste hallucination characterized by the perception of a metallic or salty taste without external stimulus)[7].

Post-viral olfactory disorder is the most common cause of long-lasting or permanent acquired olfactory dysfunction[8]. Although the exact mechanism of COVID-19-induced olfactory dysfunction has not been fully elucidated, several theories have been proposed in literature[9], including local airway obstruction – blocking the odorant pathway to olfactory epithelium – due to inflammation of nasal mucosa or olfactory cleft edema, injury to the olfactory neuroepithelium (primarily through damage to ACE2 expressing sustentacular cells), direct damage to the olfactory nerve, downregulation of olfactory receptors, and disruption of signals in the olfactory receptor cells.

Notwithstanding that gustatory dysfunction is often confused with olfactory dysfunction (because the lay public often mistakenly associates flavor with taste) and might be caused by the same pathomechanism as olfactory dysfunction[10], compelling evidence from many studies in literature conducted after the pandemic indicates otherwise: olfactory and gustatory dysfunctions develop along different pathways. Furthermore, gustatory dysfunction has been reported[11] in other viral infections besides COVID-19.

These long-lasting or persistent symptoms fall under the umbrella of long COVID or post-COVID conditions, which describe people with physical and/or mental health consequences experienced more than 12 weeks after a COVID-19 infection; these patients are referred to as COVID-19 long-haulers[12,13].

Several studies[14-16] have assessed recovery from chemosensory dysfunction linked to COVID-19 infection and the impact of age, gender, smoking, and severity of COVID-19 infection on recovery. However, as noted subsequently in the discussion section, there is a wide range of prevalence rates of chemosensory dysfunction between studies. These studies have predominantly been conducted on Caucasian populations and, therefore, cannot be generalized without considering the effects of ethnicity, genetics, lifestyle, disease phase, SARS-CoV-2 strains, and environmental and cultural factors. This study explores the associated factors and predictors of recovery from COVID-19-induced olfactory dysfunction in COVID-19 long-haulers in Jordan.

Subjects and Methods

Questionnaire and Study Design

After reviewing related studies on the prevalence and recovery from COVID-19-induced chemosensory dysfunction, a self-administered online survey was developed using Google Forms in both Arabic and English and a link to the form was distributed on social media. The questionnaire was divided into four sections. The first section included demographic information (i.e., age, gender, smoking habits, COVID-19 history, and severity of COVID-19 symptoms) and was developed by the authors based on the literature, while the subsequent sections were derived from research by Teaima et al[17], Raad et al[18], and Rashid et al[19]. The second section assessed the following: type of olfactory dysfunction (if present); severity, duration, and onset of symptoms; triggering smells; smells perceived by patients with qualitative olfactory disorders; type of gustatory dysfunction (if present); and distorted tastes. The third section explored various treatments used by patients to alleviate their symptoms, and the fourth section collected vaccination information. From the second to fourth sections, participants were asked to select all answers that applied.

Upon reaching an agreement on the final version of the questionnaire – having achieved the desired level of content and face validity, confirmed through evaluation by experts in relevant fields (i.e., otorhinolaryngology, pathophysiology, medicine, and pharmacology) – the questionnaire was piloted among 10 individuals with chemosensory dysfunction to test the clarity and readability of the questions, and the questionnaire was modified accordingly. Data from the pilot were not included in the data analysis.

Patient Eligibility (Inclusion/Exclusion Criteria)

Data collection for this cross-sectional retrospective study was conducted over three months,

from March to May 2022. The inclusion criteria for the study cohort were as follows: the age at data collection was 18 or higher, had a history of COVID-19 infection, and had experienced chemosensory dysfunction after COVID-19 infection or vaccination. Exclusion criteria excluded patients with any of the following: epilepsy, brain tumor, head injury, mental illness, or memory disorder, and patients who were using psychiatric drugs or had undergone head surgery.

Ethics Approval

This study was approved by the Ethics Committee for Scientific Research of Zarqa University, with an institutional review board reference number (1/2022) provided on January 10, 2022. Every participant completed and signed an informed consent form.

Sample Size Calculation

The minimum sample size (n = 385) was determined using the Raosoft online sample size calculator[20], using the Jordanian population size and assuming a 50% response distribution and a 95% confidence level (i.e., a 5% margin of error).

Statistical Analysis

The data were analyzed using the Statistical Package for Social Sciences (SPSS Version 26.0, IBM Corp., Armonk, NY, USA). Descriptive statistics (i.e., frequency, percentage, mean, standard deviation, and range) were obtained to describe the relationship between demographics, olfactory or gustatory function, and olfactory or gustatory function recovery. A Pearson's correlation analysis, Chi-squared test for independence, Fisher's exact test, and likelihood ratio Chi-squared analysis were performed to assess the strength and direction of the relationships between the studied variables. In addition, a binary logistic regression test was performed to predict the factors associated with recovery from olfactory dysfunction. A p-value < .05 was considered significant, and all the tests were two-tailed.

Results

Demographics and Clinical Characteristics of the Participants

In total, 864 participants completed the questionnaire (Table I). The age of the participants ranged between 18-68 years, with a mean of 27.7 [standard deviation (SD) = 8.2] years. The majority of participants were females (n = 764, 88.4%), 581 participants (67.2%) were nonsmokers, and 218 were current smokers (25.2%). Most of the participants were infected with SARS-CoV-2 (n = 767, 88.8%); however, only 67% (n = 579) had a COVID-19 diagnosis confirmed via a polymerase chain reaction (PCR) test or a rapid test. Regarding the severity of the COVID-19 symptoms, most participants had mild symptoms (n = 580, 75.6%), with only 1.6% (n = 12) experiencing serious symptoms. More than half of the participants

Table I. Demographics and clinical characteristics of the study participants.

Characteristics	N (%)
Age [N = 864, mean [SD] 27.7 [8.2] years, range [18-68]]	
Gender (N = 864)	
Male	100 (11.6%)
Female	764 (88.4%)
Smoking history (N = 864)	
Nonsmoker	581 (67.2%)
Current smoker	218 (25.2%)
Former smoker	43 (5.0%)
Passive smoker	22 (2.5%)
Duration of smoking (N = 283)	
1-5 years	163 (57.6%)
6-10 years	86 (30.4%)
11-15 years	27 (9.5%)
16-20 years	7 (2.5%)
COVID-19 history (N = 864)	
Yes	767 (88.8%)
No	97 (11.2%)
PCR laboratory test or a rapid COVID-19 test (N = 864)	
Yes	579 (67.0%)
No	285 (33.0%)
Severity of COVID-19 symptoms (N = 767)	
Mild	580 (75.6%)
Moderate	175 (22.8%)
Serious	12 (1.6%)
Received COVID-19 vaccine (N = 864)	
Yes	632 (73.1%)
No	232 (26.9%)
No. of COVID-19 vaccine doses (N = 632)	
One Dose	72 (11.4%)
Two Doses	483 (76.4%)
Three Doses	77 (12.2%)
Type of COVID-19 vaccines (N = 632)	
Sinopharm	125 (27.7%)
Pfizer-BioNTech	262 (58.1%)
AstraZeneca-Oxford	43 (9.5%)
Johnson & Johnson	3 (0.7%)
Moderna	14 (3.1%)
Sputnik V	4 (0.9%)

N = number, % = percentage, SD = standard deviation.

reported that they had been vaccinated (n = 632, 73.1%); 483 participants (55.9%) had received two doses of the COVID-19 vaccine, and the most indicated vaccine was Pfizer (n = 397, 59.3%).

Characteristics of Chemosensory Dysfunction in the Study Participants

Among the participants who complained of chemosensory dysfunction (611 out of 864 participants, 70.7%), 93.5% (n = 571) reported the dysfunction post-COVID-19 infection, while 6.5% (n = 40) reported the dysfunction after receiving the COVID-19 vaccine (Table II). Most of the participants complained of mixed chemosensory dysfunction (n = 504, 82.5%). Among those with olfactory dysfunction, anosmia was present in 21.4% (n = 217), hyposmia in 13.8% (n = 140), parosmia in 33.3% (n = 337), phantosmia in 14.4% (n = 146), cacosmia in 13.0% (n = 132), and hyperosmia in 4.0% (n = 40). Olfactory dysfunction lasted less than one month in less than a third of the study participants (n = 200, 32.7%), one to three months in 107 participants (17.5%), and more than one year in 124 participants (20.3%).

Regarding the severity of the parosmia symptoms, more than half of the participants (62%, n = 209) had severe symptoms. Just over half of the participants who reported parosmia (57%,

Table II. Characteristics of chemosensory dysfunction in the study participants.

Variable	N (%)
Cause of chemosensory dysfunction (N = 611)	
Post-COVID-19 infection	571 (93.5%)
Post-COVID-19 vaccination	40 (6.5%)
Type of chemosensory dysfunction (N = 611)	
Mixed chemosensory dysfunction	504 (82.5%)
Olfactory dysfunction only	107 (17.5%)
Gustatory dysfunction only	0 (0%)
Pattern of olfactory dysfunction (N = 611)	
Anosmia	217 (21.4%)
Hyposmia	140 (13.8%)
Parosmia	337 (33.3%)
Phantosmia	146 (14.4%)
Cacosmia	132 (13.0%)
Hyperosmia	40 (4.0%)
Duration of olfactory dysfunction (N = 611)	
Less than a month	200 (32.7%)
1-3 months	107 (17.5%)
4-6 months	76 (12.4%)
7 months-1 year	104 (17.0%)
More than 1 year	124 (20.3%)
Severity of parosmia symptoms (N = 337)	
Mild	31 (9.2%)
Moderate	97 (28.8%)
Severe	209 (62.0%)
Onset of parosmia (N = 337)	
Sudden	192 (57.0%)
Gradual	145 (43.0%)
Occurrence of parosmia (N = 337)	
During the first week of COVID-19 symptoms or after vaccination	88 (26.1%)
During the first month of COVID-19 symptoms or after vaccination	52 (15.4%)
Within 2-3 months of COVID-19 symptoms or after vaccination	79 (23.4%)
Within 4-6 months of COVID-19 symptoms or after vaccination	26 (7.7%)
More than 6 months to 1 year of COVID-19 symptoms or after vaccination	8 (2.4%)
More than 1 year of COVID-19 symptoms or after vaccination	1 (0.3%)
Disturbances surfaced after full/partial restoration of the sense of smell	66 (19.6%)
Strange disturbances surfaced after another viral infection (e.g., cold or flu)	17 (5.1%)
Type of parosmia (N = 337)	
Troposmia	336 (99.7%)
Euosmia	1 (0.3%)

(Table continued)

Table II *(Continued).* Characteristics of chemosensory dysfunction in the study participants.

Variable	N (%)
Recovery from olfactory dysfunction (N = 611)	
Recovered completely	213 (32.1%)
Recovered partially	433 (65.2%)
Not recovered	18 (2.7%)
Pattern of gustatory dysfunction (N = 504)	
Ageusia	116 (17.7%)
Hypogeusia	194 (29.6%)
Parageusia	239 (36.4%)
Normogeusia	107 (16.3%)
Distortion of the main tastes (N = 504)	
Sweet	314 (23.5%)
Bitter	295 (22.0%)
Salty	391 (29.2%)
Sour	338 (25.3%)
Treatment received for olfactory dysfunction	
Yes	317 (51.9%)
No	294 (48.1%)
Improvement after treatment	
Modestly improved	117 (36.9%)
Greatly improved	54 (17.0%)
No improvement	146 (46.1%)
Received olfactory rehabilitation/training	
Yes	215 (35.2%)
No	396 (64.8%)
Improvement after olfactory rehabilitation/training	
Modestly improved	94 (43.7%)
Greatly improved	31 (14.4%)
No improvement	90 (41.9%)

N = number, % = percentage.

n = 192) stated that the parosmia had a sudden onset. The parosmia symptoms began during the first week of COVID-19 infection or vaccination in 88 (26.1%) participants, and within two to three months of COVID-19 infection or vaccination in 79 participants (23.4%). Euosmia (i.e., perception of a pleasant smell, a rare form of parosmia) was reported by only one respondent. With respect to parosmia-triggering odors (Figure 1), the most frequently reported odors were onions (7.6%), eggs (6.9%), meat and chicken (6.4%), and garlic (6.4%). However, a large number of the participants described the odor they perceived as "a bad smell that I cannot describe", and this was the most frequently selected answer (19.7%) (Figure 2). Regarding phantosmia, the most frequently reported perceived odor was sewage or garbage odor (21.2%), and the least frequently reported perceived odor was fish (0.6%) (Figure 3). Concerning recovery, complete recovery from olfactory dysfunction post-COVID-19 infection or post-vaccination was reported by less than a third of the participants (32.1%, n = 213), while partial recovery from olfactory dysfunction was reported by two-thirds of the participants (65.2%, n = 433).

Among the participants with gustatory dysfunction, parageusia was the most frequently reported taste dysfunction (n = 239, 36.4%), followed by hypogeusia in 194 participants (29.6%) and ageusia in 116 participants (17.7%). With respect to distorted tastes, the most frequently reported distorted taste was salty (n = 391, 29.2%), followed by sour (n = 338, 25.3%).

Regarding the treatment received by the study participants who complained of olfactory dysfunction, just over half of the participants had been treated (n = 317, 51.9%), with zinc therapy being the most frequently administered treatment (n = 215, 26.2%), followed equally by antibiotics and vitamin B (n = 107, 13%). Nearly half of the participants who were treated (n = 146, 46.1%) reported that the treatments did not alter their smell or taste perception, while 54 participants (17%) reported that their sense of smell or taste greatly improved after treatment. Among the participants who complained of chemosensory dysfunction (n = 611 participants), 215 (35.2%) reported that they had

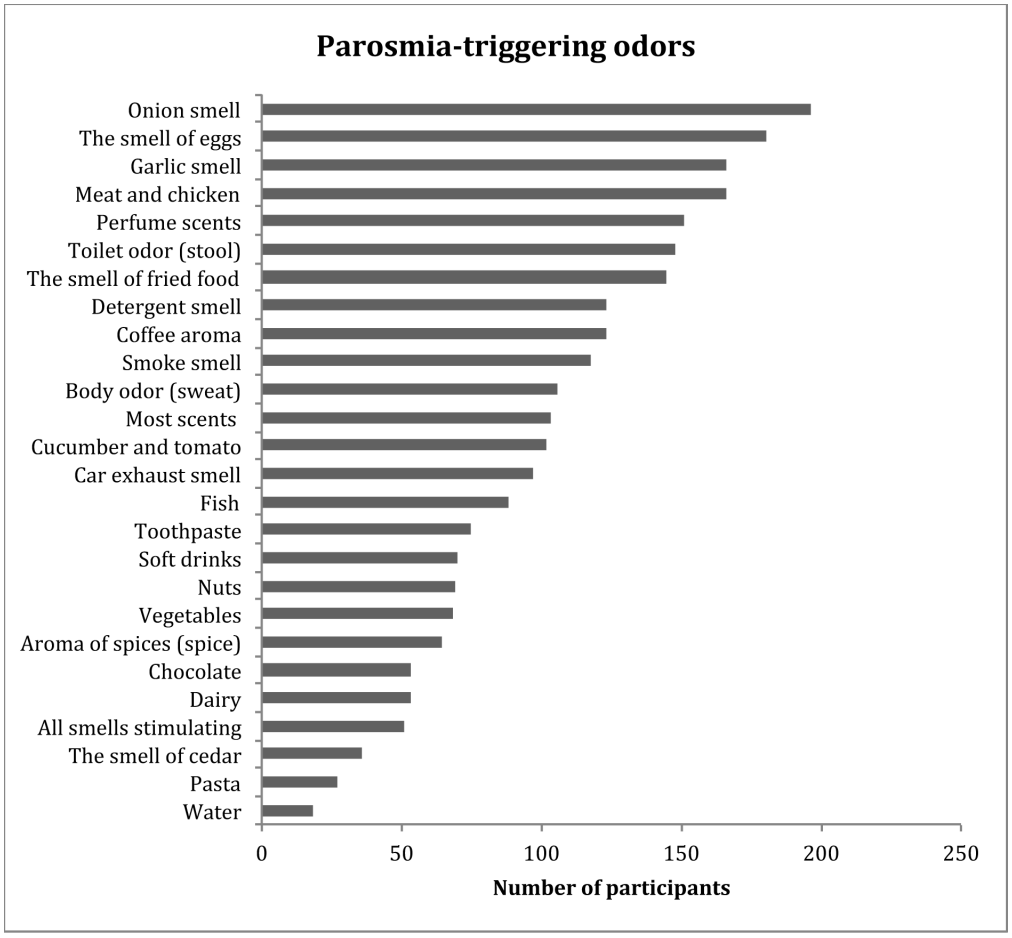

Figure 1. Types of parosmia-triggering odors.

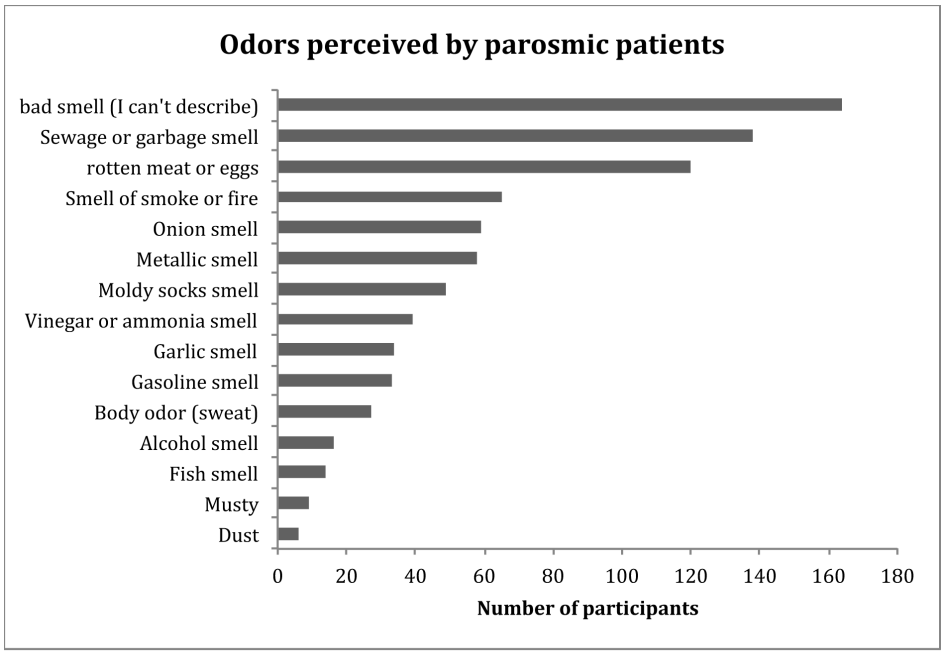

Figure 2. Odors perceived by parosmic patients.

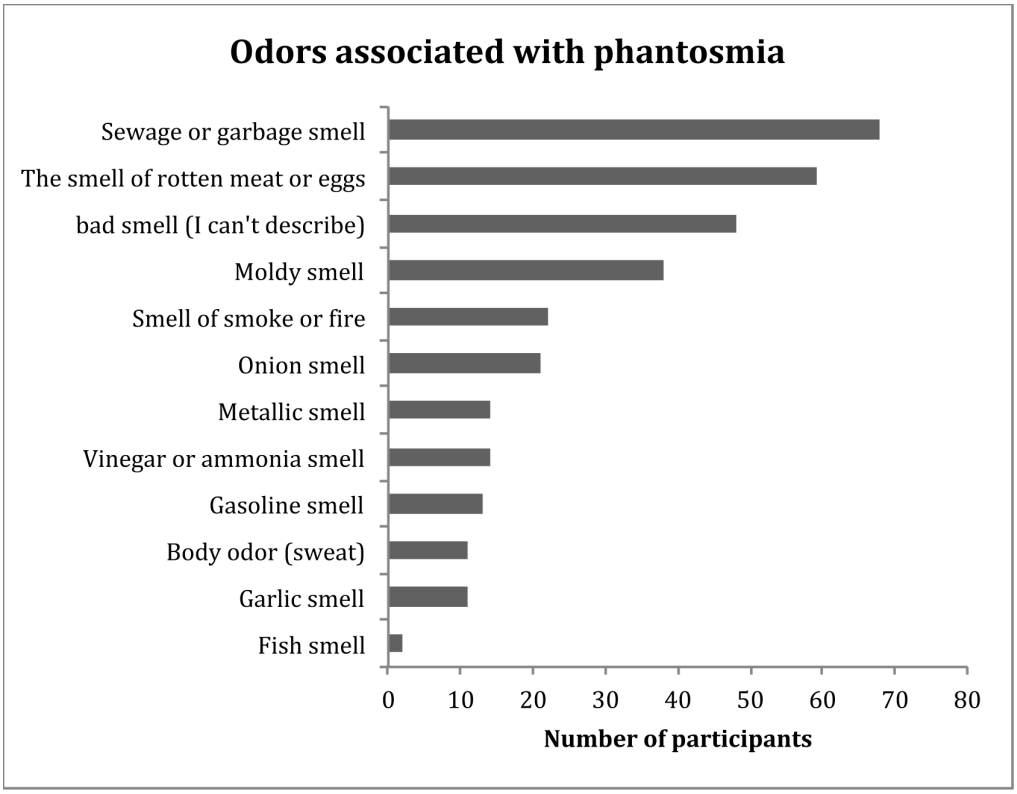

Figure 3. Odors associated with phantosmia.

received olfactory rehabilitation/training; in this subset, 43.7% (n = 94) reported that their sense of smell had improved modestly. Among the study participants who had received olfactory rehabilitation/training, the most frequently reported scents that enhanced olfactory function were coffee (n = 80, 24.8%), aromatic oils such as clove oil (n = 74, 23%), and perfumes/colognes (n = 73, 22.7%).

Factors Associated with Recovery from Olfactory Dysfunction

A Pearson correlation analysis, Chi-squared test for independence, Fisher's exact test, and likelihood ratio chi-squared analysis were performed to assess the relationship between recovery from olfactory dysfunction and the demographics and clinical characteristics of the study participants (**Supplementary Table I**). Broadly, there was a significant negative correlation between the age of the participants and complete recovery. In addition, complete recovery was found to be correlated with anosmia, parosmia, phantosmia, cacosmia ($p < .001$), and hyperosmia ($p < .5$). Furthermore, complete recovery was correlated with the duration of olfactory dysfunction. Parosmia, in terms of its severity, onset, and emergence (i.e., sudden or gradual), was also found to be associated with complete recovery ($p < .01$).

Partial recovery was associated with the severity, onset, and emergence of parosmia ($p < .01$). There was a high prevalence of complete recovery and partial recovery from olfactory dysfunction among participants who complained of gustatory dysfunction (i.e., ageusia and parageusia). In addition, complete recovery and partial recovery were found to be associated with the treatment received for olfactory dysfunction ($p < .5$), and the respondents who had received treatment for olfactory dysfunction reported significant improvement, irrespective of whether it was partial or complete recovery ($p < .01$). Among the participants who had received olfactory rehabilitation/training, there was a significant correlation between improvement in olfactory function and complete recovery and partial recovery from olfactory dysfunction. In contrast, there was a high prevalence of complete recovery among participants who had not received olfactory rehabilitation/training ($p < .5$).

Predictors of Recovery from Olfactory Dysfunction

Binary logistic regression was performed to explore the predictors of recovery from olfactory

dysfunction. As seen in **Supplementary Table II**, after testing the fitness of the model with respect to participants who experienced complete recovery, the following were found to be independent predictors of complete recovery from olfactory dysfunction: age [odds ratio = 0.967, 95% CI (confidence interval) = 0.936-0.998, $p < .05$]; anosmia (odds ratio = 2.908, 95% CI = 1.740-4.860, $p < .001$); hyperosmia (odds ratio = 5.601, 95% CI = 2.360-13.294, $p < .001$); duration of olfactory dysfunction ($p < .001$); and ageusia (odds ratio = 2.120, 95% CI = 1.144-3.929, $p < .05$). In contrast, the predictors of partial recovery from olfactory dysfunction were anosmia (odds ratio = 0.186, 95% CI = 0.094-0.368, $p < .001$) and hyperosmia (odds ratio = 0.174, 95% CI = 0.042-0.730, $p < .05$).

Discussion

A total of 864 participants completed the questionnaire, and although the majority of the respondents were infected with SARS-CoV-2 (n = 767, 88.8%), only 67% (n = 579) had confirmed their COVID-19 diagnosis via a PCR test or a rapid test. Two-thirds of the respondents (70.7%) complained of chemosensory dysfunction, and 6.5% (n = 40) reported that they developed the dysfunction post-COVID-19 vaccination. Several studies[21,22] have reported chemosensory dysfunction following COVID-19 vaccination. In a survey conducted across Europe to investigate the most prevalent symptoms after complete vaccination, chemosensory dysfunction was the second most common symptom (63.4%) reported by patients (n = 153) in the study[22].

One study[23] attempted to explore post-COVID-19 syndrome in Jordan and found that among 657 patients, 71.9% experienced at least one post-COVID-19 symptom. The most common symptoms reported in the study included dyspnea, fatigue, chemosensory dysfunction, cough, and depression. The factors found to be significantly associated with a high prevalence of post-COVID-19 syndrome were female gender, ≥ 30 years of age, and the presence of comorbidity.

Most of the participants complained of mixed chemosensory dysfunction (n = 504, 82.5%). There are numerous reports of COVID-19-induced mixed chemosensory dysfunction in the literature, and it has been attributed to the close correlation between the senses of smell and taste. For example, anosmia and dysgeusia are frequently reported together. According to a large-scale study[24] including 69,841 participants from the United States and the United Kingdom – 68% of whom reported anosmia and dysgeusia – a genetic predisposition explains the concurrent occurrence of these two neurological symptoms.

Regarding the prevalence of different types of chemosensory dysfunction, the reported percentages in the literature vary widely due to many confounding factors, including the following: vaccination; method of dysfunction or recovery assessment (objective vs. subjective or self-reported); age, gender, and ethnicity of participants; phase of the infection; and implicated SARS-CoV-2 strains. For example, several studies[25,26] have found that COVID-19 from the more recent SARS-CoV-2 variants cause relatively less olfactory dysfunction than COVID-19 from the earlier variants or the wild SARS-CoV-2 virus.

Among the respondents who complained of olfactory dysfunction, parosmia was the most prevalent form of the dysfunction indicated (n = 337, 33.3%). Parosmia is triggered by a variety of stimuli, including garlic, onions, tobacco, coffee, perfume, bell peppers, citrus fruits, and chicken and meat; even water and air have been reported in the literature as triggers of parosmia. These previously familiar odors are perceived by patients with parosmia as a rotten, burned, garbage, or sewage smell and may even be perceived as an "obnoxious odor that I cannot describe"[27]. In addition to COVID-19-induced parosmia, parosmia dysfunction was also reported[21] post COVID-19 vaccination.

Most of the respondents in this study perceived odors in their surroundings as awful and unfavorable. Only one respondent perceived odors in their surroundings as pleasant, described by the respondent as "the smell of roses," which has scarcely been reported[28] among patients with COVID-19-induced parosmia. It should be noted that in a large proportion of COVID-19 patients, parosmia was reported after the patients recovered from smell loss. For example, a study by Ohla et al[29] reported that in 620 out of 1,468 COVID-19 parosmia patients, parosmia began after the patients recovered from smell loss. The same study suggests that olfactory dysfunction is a key indicator for forecasting long COVID, as it is associated with a significant number of relevant symptoms.

Sewage, garbage, burned odor, smoke or cigarette, and ammonia or vinegar are the most frequently reported[30] odors perceived by phantosmia patients. The prevalence of qualitative olfactory dysfunction seems to increase with time after COVID-19 infection. In a 200-day follow-up survey[29]

of 1,468 patients suffering from olfactory dysfunction, -10% of the participants reported parosmia and phantosmia at baseline, and the percentage increased after 200 days to -47% and -25% for parosmia and phantosmia, respectively. Although rarely reported to have been induced by COVID-19[31, 40] respondents in our study reported hyperosmia.

Evaluation of concurrent gustatory dysfunction was done based on dysfunction type and affected taste. In this study, parageusia was the most frequently reported taste dysfunction (n = 239, 36.4%), and the most frequently affected taste was salty (n = 391, 29.2%). Different types of taste are sensed by different taste bud cells. Type II cells detect bitter, sweet, and umami stimuli, while type III cells detect sour stimuli. Although it has been proposed[32] that salt stimuli are perceived by type I cells, salt perception is still somewhat of an enigma. Therefore, direct damage to different taste bud cells may be responsible for the different alterations in the various types of tastes among patients.

Regarding the treatments received by participants in this study, over half of the participants had received treatment (n = 317, 51.9%), primarily over-the-counter dietary supplements (i.e., zinc and vitamin B), which attracted lots of attention in Jordan during the pandemic[33]. Nearly half of the participants reported that they saw no improvement after treatment (n = 146, 46.1%). Following the COVID-19 pandemic, olfactory training has gained significant popularity (separately or in combination with nasal corticosteroids), and many studies[34,35] have reported significant improvement in patients following olfactory training. In this study, 215 respondents (35.2%) received olfactory rehabilitation/training, and 43.7% (n = 94) reported that their sense of smell improved modestly. The scents most frequently reported as having helped enhance olfactory function were coffee (n = 80, 24.8%), aromatic oils such as clove oil (n = 74, 23%), and perfumes/colognes (n = 73, 22.7%).

In this study, we show that age has a significant negative correlation with complete recovery. Our data confirm the findings of previously published studies conducted among Spanish[16] and British populations[36]; however, a study conducted in Singapore[37] reports that age is not linked to smell recovery. Further studies with a direct comparison between races could resolve this discrepancy.

In addition, treatments have been found to be significantly associated with complete and partial recovery, and different COVID-19 treatments have been reported in literature. Oral and nasal corticosteroids were reported as treatments in our study. We found only nasal corticosteroids to be associated with both complete recovery and partial recovery ($p < .05$). In parallel with our data, a recently published randomized, double-blind clinical trial[38] observed that oral corticosteroids (prednisolone) did not improve olfactory function after COVID-19.

Our data show that age, anosmia, hyperosmia, ageusia, and duration of olfactory dysfunction were independent predictors of complete recovery. Another study[39] found that anosmia and ageusia are associated with younger age, which could explain their correlation with complete recovery. A direct effect of the SARS-CoV-2 virus on sustentacular cells, which tend to regenerate at a faster rate after damage, could explain in part their being predictors of complete recovery in our study population[9]. Furthermore, the probability of complete recovery and partial recovery from olfactory dysfunction increases with rehabilitation/training, and this has been made evident by previously published studies[34,35]. To the best of our knowledge, this is the first study evaluating the prevalence of chemosensory dysfunction in COVID-19 long-haulers in Jordan and the first study investigating the predictive factors of recovery from olfactory dysfunction among COVID-19 long-haulers in Jordan.

Limitations

Finally, several caveats need to be noted regarding this study. First is the retrospective nature of the study, as participants were asked to recollect symptoms they experienced while infected, which may have introduced some recall bias. In addition, self-evaluation of symptoms of chemosensory dysfunction and recovery by the respondents may have resulted in underestimation[40] or overestimation[41] of their symptoms or rate of recovery, as self-evaluation is subjective. Furthermore, the use of convenient sampling and data collection through online platforms may have introduced selection bias, as the questionnaire would not have been displayed to individuals who were not frequently available on social media to recruit them for data collection.

Conclusions

Chemosensory dysfunctions are largely subjective, as many confounding factors may contribute to

both the perception of chemosensory dysfunction and the patient's perception of recovery. For example, hospitalized COVID-19 patients with severe symptoms (i.e., dyspnea) are less likely to be aware of or perceive chemosensory dysfunction. Therefore, more objective examinations are required to draw more definite conclusions.

Conflict of Interest
The authors declare that they have no conflicts of interest.

Ethics Approval
This study was approved by the Ethics Committee for Scientific Research of Zarqa University, with Institutional Review Board reference number 1/1/2022. All methods were carried out in accordance with the Declaration of Helsinki.

Infomed Consent
Written informed consent was obtained from all participants involved in the study before entry into the study.

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Authors' Contributions
Hana M. Sawan: Conception and design of the study, analysis, and interpretation of the data, and writing and review of the manuscript. Anas H. Khalifeh: Conception and design of the study, analysis, and interpretation of the data, and writing and review of the manuscript. Mohammed Ahmed: Writing, reviewing, and editing of the manuscript. Malek M. Khalil: Conception and design of the study and data collection. Shatha M. Al Omari: Conception and design of the study. Reem Binsuwaidan: Review and edit the manuscript.

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Availability of Data and Materials
All data generated or analyzed during this study are included in this published article and its supplementary information files.

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