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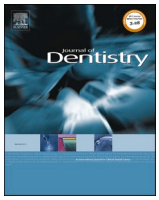

General and orofacial symptoms associated with acute and long COVID in 80- and 90-year-old Swedish COVID-19 survivors

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ABSTRACT

Objectives: To describe acute and long COVID-19 symptoms among older elderly Swedes and to find predictive factors for the development symptoms associated with acute and long COVID.
Material and methods: A questionnaire about general and oral health was mailed to all 80-year-olds (born 1942, $n = 6299$) and 90-year-olds (born 1932, $n = 1904$) in two Swedish counties. Participants reporting COVID-19 were asked to complete an additional questionnaire.
Results: Overall response rate was 66 % ($n = 5375$). Affirmative responses to having been sick/tested positive for COVID-19 were reported by 577 persons. Response rate to the COVID-19 questionnaire was 49 %. The majority (88 %) reported some general symptoms during the acute stage while 44 % reported orofacial symptom/s. Reporting of any form of long-COVID general symptoms was 37 and 35 % for orofacial symptoms. Predictive factors for contracting COVID-19 (based on self-report from 2017) were living in elderly housing/senior care facility (OR 1.6, CI 1.0–2.3), large number (>10) of weekly social contacts (OR 1.5, CI 1.3–1.9), being married (OR 1.4, CI 1.1–1.7) and high school/university education (OR 1.3 CI 1.1–1–6). The highest odds ratio for general symptoms of long-COVID were a single complete denture (OR 5.0, CI 2.0–12.3), reporting bad breath (OR 3.7, CI 1.9–7.2) and daytime dry mouth (OR 2.2, CI 1.1–4.2). Regarding long-COVID orofacial symptoms, the highest risk factors were bad breath (OR 3.8, CI 1.9–7.5) and a single complete denture in one jaw (OR 3.4, CI 1.2–9.8).
Conclusion: Long-COVID general and orofacial symptoms are common among older elderly COVID-19 survivors
Clinical significance: Oral microorganisms may be responsible for development of long-COVID symptoms. Health personnel managing COVID-19 patients should carefully examine dental status, especially in those having acrylic-based removable dentures, for oral signs and symptoms. If found, rigorous oral hygiene procedures should be carried out including cleaning/disinfection of the denture.

1. Introduction

The COVID-19 pandemic that started at the turn of the new decade in years 2019/2020 has seen more than 765 million confirmed cases worldwide and has caused close to 7 million deaths [1]. It has been reported that approximately 93 % of all COVID-19 related deaths in the US are in adults over 50 years of age [2]. Among those total deaths, 27 % are adults over 85 years of age even though this age group makes up only 2 % of the US population [3]. The same pattern was seen in Sweden where people aged over 70 years accounted for 88 % of all COVID-19 related deaths (14,703 out of the total 16,645 deaths) as reported by August 2022 [4].

A wide array of general symptoms may occur in the acute stage of the COVID-19 infection, the most common being fever, dry cough and

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fatigue [5]. In addition to general symptoms from the COVID-19 infection, oral signs and symptoms are common and include smell/taste changes, dry mouth and swallowing difficulties, amongst others [6,7]. Most patients recover from COVID-19 but some do not, and exhibit persistent signs and symptoms long after the onset of the disease. This is referred to as long -COVID or post-COVID-19 and is defined by WHO as a condition that "occurs in individuals with a history of probable or confirmed SARS CoV-2 infection, usually 3 months from the onset of COVID-19 with symptoms and that last for at least 2 months and cannot be explained by an alternative diagnosis" [8].

Commonly found general symptoms of long-COVID include fatigue, headache, attention deficit disorder, hair loss, and dyspnea [9]. Older people have not only a higher risk of dying from COVID-19 but are also more prone to develop long-COVID, although contradictory findings are reported regarding the latter [10,11]. In relation to the foregoing, it has been reported that there is a sharp decline of long- COVID symptoms after the age of 70 years. This decrease might not be real and can be explained by "selective competing risk of mortality, non-response bias, lower symptom reporting in older adults, misattribution of long-COVID to other illness, or a combination of these factors" [12]. While reports on oral symptoms related to the acute phase of COVID-19 are commonly found in the literature [13–17], only scarce data is available about oral symptoms related to long-COVID, although diverse intraoral problems like taste and smell alterations, salivary gland ectasia, and temporomandibular disorder (TMD) have been reported [18,19].

The aim of the present study was to report on general and oral symptoms of acute and long-COVID in 80- and 90-year-old Swedish COVID-19 survivors. An additional aim was to try to find predictive and/or protective factors for suffering from long-COVID based on earlier serial reports in the same two cohorts [20].

2. Material and methods

2.1. Participants

In April 2022, a questionnaire was mailed to all 80-year-olds (born 1942) and 90-year-olds (born 1932) living in the two Swedish counties of Örebro and Östergötland. An almost identical questionnaire had previously been sent at 5-yearly intervals to both the 1942 and 1932 cohorts, starting in 1992 and 2007, respectively. Consequently, the 1942 cohort had been followed from age 50 to 80 years (30-year follow-up) and the 1932 cohort from age 75 to 90 years (15-year follow-up).

2.2. Questionnaire

The 2022 questionnaire comprised 59 questions related to perceived general and oral health and dental care utilization. Participants also answered a question on whether they had been sick with, or tested positive, for COVID-19. If affirmative, they were asked if they agreed to complete an additional questionnaire about COVID-19. The COVID-19 questionnaire comprised questions related to vaccination status against COVID-19, time/s of contracting the disease, general and oral symptoms in the acute stage and persistent symptoms. In addition, participants were asked to describe the type/s of treatment received.

This paper reports only on the participants who had COVID-19 disease (COVID-19 survivors) whereas the results from the remaining data collection will be published elsewhere.

2.3. Ethical considerations

The ethical committee in Lund approved the study (Dnr. 2021–03,154).

2.4. Statistical methods

Descriptive analyses were applied using IBM SPSS Statistics (ver. 28). Gender differences were examined by Pearson Chi-Square test. Long-COVID general and orofacial symptoms were investigated in those who had been sick in 2020 and 2021.

Unadjusted regression analyses were performed with three different dependent variables based on self-report in the 2022 survey, viz. 1: reported COVID-19 disease vs. controls; 2: long-COVID general symptoms vs. controls and 3: long-COVID orofacial symptoms vs. controls. Controls were all those who had not reported COVID or long-COVID symptoms.

Independent variables were selected from the responses regarding demographic, social, and the general and oral health domains in the 2017 survey. Variables that were found to be significantly different between the COVID groups and controls in the unadjusted bivariate logistic regression analyses ($p \leq 0.05$) were included in the adjusted logistic regression analysis (Forward conditional method).

3. Results

3.1. Demographics

The total population of 80- and 90-year-olds living in the two counties was 8203 people, comprising 4541 women (55 %) and 3662 men (45 %). The overall response rate was 66 % (5375/8203). The total population of 90-year-olds (1932 cohort) was 1904 (64 % women, 36 % men) giving a response rate of 54 % ($n = 1032/1904$, 60.5 % women, 39.5 % men). The corresponding figures for the 80-year-olds (1942 cohort) was 6299 (53 % women, 47 % men) and the response rate was 69 % ($n = 4343/6299$, 52 % women, 48 % men). Of those who responded in 2022, 85 % and 87 % of the 90-year-olds and 80-year-olds, respectively, had responded in 2017.

Affirmative responses to having been sick with or tested positive to COVID-19 were given by 577 persons (54 % women, 46 % men) corresponding to a prevalence of 10.7 % out of the total sample of responders ($n = 5375$). Out of those 577 with sickness/positive tests for COVID-19 disease, 366 consented to complete the additional questionnaire about COVID-19.

The response rate to the COVID-19 questionnaire was 49 % (283/577) and 49 % were women ($n = 138$) and 51 % were men ($n = 145$). Most responders were from the 1942 cohort, now 80 years old ($n = 254$) and the remaining ones were from the 1932 cohort, now 90 years old ($n = 29$).

A total of 85 % of those who reported COVID-19 illness had a positive test for COVID-19 and vaccine had been given to 98.6 % of the responders with more than 96 % having gotten 3 or more vaccine shots. During the five months prior to the start of the investigation in April 2022, 144 patients reported being sick with COVID-19. During 2020 or 2021, 132 patients (60 women and 72 men) had been sick and among those the mean period since being sick was 16 months (range 5–28 months). This latter group constituted the data sample used for assessing symptoms of long-COVID. Seven patients did not report the time of contracting the disease (missing data) but responded to the other questions. Only a few respondents reported having been sick more than once ($n = 15$). Self-perceived severity of disease symptoms was in general mild or moderate while 17 % reported severe or very severe symptoms. Very severe symptoms were more common among men. Among the men, no symptoms were more commonly reported compared to women (Fig. 1).

3.2. General and orofacial symptoms

The overall majority (88 %, $n = 249$) reported some form of general symptoms during the acute stage of the disease (during the 1st month of contracting the disease), and significantly more commonly in women (92 %, $n = 127$) than men (84 %, $n = 122$). The corresponding figure for any acute orofacial symptom was 44 % ($n = 124$), and again more commonly in women (48 %, $n = 66$) than men (40 %, $n = 58$) but not significantly so.

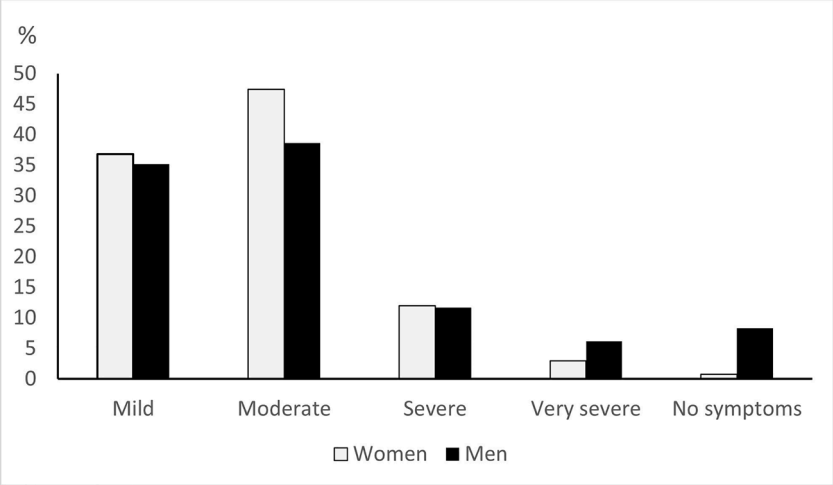

Fig. 1. Self-perceived severity of symptoms of COVID-19 disease in women and men.

Any form of long-COVID general symptoms in those who had been sick in 2020/2021 ($n = 132$) was reported by 37 % ($n = 49$), and more commonly in women (42 %, $n = 25$) than in men (33 %, $n = 24$), but the difference being not significant. The corresponding figure for any long-COVID orofacial symptoms was 35 % ($n = 46$), and again more commonly in women (38 %, $n = 23$) compared to men (32 %, $n = 23$), but the difference being not significant.

Table 1
Percentage distribution of reported acute general symptoms (during 1st month after contracting the disease) and general symptoms of long-COVID-19* (mean 16 months with a range of 5–28 months after last episode of COVID-19 disease). P denotes gender differences (Pearson Chi-Square).

General symptom	COVID-19 acute symptoms $n = 283$			Long-COVID-19 symptoms $n = 132$		
	Women $n = 138$	Men $n = 145$	p	Women $n = 60$	Men $n = 72$	p
Brain tiredness	10.1	4.8	NS	3.3	4.2	NS
Concentration difficulties	8.0	6.9	NS	6.7	6.9	NS
Confusion	3.6	3.4	NS	3.3	1.4	NS
Congestion or runny nose	37.0	29.7	NS	13.3	8.3	NS
Cough	46.4	32.4	.02	6.7	5.6	NS
Decreased muscle force	18.1	20.7	NS	6.7	18.1	NS
Depression/anxiety	4.3	3.4	NS	1.7	5.6	NS
Dizziness	13.8	5.5	.02	6.7	8.3	NS
Fatigue	48.6	51,7	NS	20.0	15.3	NS
Fever	58.7	45.5	.03	5.0	2.8	NS
Headache	13.0	8.3	NS	3.3	6.9	NS
Loss of sensation in legs/feet or arms/hands	3.6	1.4	NS	11.7	8.3	NS
Memory problems	1.4	4.8	NS	6.7	12.5	NS
Muscle/joint pain	30.4	17.9	.01	11.7	13.9	NS
Nausea/diarrhea	14.5	7.6	NS	3.3	0.0	NS
Pain or pressure in the chest, heart palpitations	4.3	7.6	NS	3.3	6.9	NS
Shortness of breath or difficulty breathing	10.9	20.0	.03	10.0	6.9	NS
Skin rash	2.2	3.4	NS	5.0	1.4	NS
Sleep problems	5.8	9.0	NS	3.3	11.1	NS
Sore throat	28.3	20.0	NS	3.3	1.4	NS
Sound hypersensitivity	5.1	2.1	NS	3.3	4.2	NS
Walking, balancing problems	8.0	6.9	NS	8.3	12.5	NS

* Those who contracted COVID-19 during 2022 (the examination year) are excluded.

Distribution of reported acute general symptoms (during the 1st month of contracting the disease) is shown in Table 1. The most commonly reported symptoms were fever, fatigue, cough and congestion or runny nose in both women and men, ranging from about 30 to 60 %. Fever, cough, and muscle and/or joint pain were significantly more common in women ($p < 0.05$) while shortness of breath/difficulty breathing was more common among men ($p < 0.05$).

In women, the most commonly reported long-COVID general symptom was fatigue, congestion or runny nose, muscle and/or joint pain, loss of sensation in legs/feet or arms/hands and shortness of breath or difficulty breathing, ranging from 10 to 20 %. In men, the most common symptoms were fatigue, decreased muscle force, muscle and/or joint pain, memory problems and walking and/or balancing problems, ranging from 12.5 to 20 %. None of the reported long-COVID symptoms showed any statistically significant gender differences (Table 1).

Distribution of reported acute orofacial symptoms (during the 1st month of contracting the disease) are shown in Table 2. The most commonly reported orofacial symptoms in both women and men were loss of appetite/not hungry, taste and smell change, and dry mouth with

Table 2
Percentage distribution of reported acute orofacial symptoms (during 1st month after contracting the disease) and orofacial symptoms of long-COVID-19* (5–28 months after last episode of COVID-19 disease). P denotes gender differences (Pearson Chi-Square).

	COVID-19 acute symptoms $n = 283$			Long-COVID-19 symptoms $n = 132$		
	Women $n = 138$	Men $n = 145$	p	Women $n = 60$	Men $n = 72$	p
Chewing difficulties	0	3.4	.03	1.7	2.8	NS
Cracked teeth	0.7	2.1	NS	1.7	4.2	NS
Dry eyes	10.1	6.9	NS	8.3	9.7	NS
Dry mouth	12.3	10.3	NS	15.0	8.3	NS
Eating difficulties	2.2	4.8	NS	1.7	1.4	NS
Gum bleeding	1.4	2.8	NS	3.3	0	NS
Loss of appetite/not hungry	21.7	21.4	NS	6.7	5.6	NS
Pain in the face/jaws	2.2	3.4	NS	1.7	0	NS
Smell change	15.2	10.3	NS	15.0	12.5	NS
Speaking difficulties	1.4	2.8	NS	0	4.2	NS
Swallowing difficulties	3.6	6.9	NS	1.7	1.4	NS
Taste change	21.0	11.7	.03	11.7	11.1	NS
Tinnitus	2.9	4.1	NS	11.7	11.1	NS
Ulcer/blisters in the mouth	1.4	4.1	NS	5.0	0	NS
Ulcer/blisters on the lips	1.4	4.8	NS	3.3	0	NS

a reported occurrence of 8 to 22 %. No gender differences in acute orofacial symptoms were found except for taste change which was significantly more common in women ($p < 0.05$).

Smell and taste change, tinnitus and dry mouth or dry eyes were the most commonly reported long-COVID orofacial symptoms, ranging from 8 % to 15 %. None of the long-COVID orofacial symptoms showed any statistically significant gender difference (Table 2).

Frequency distributions of reported number of long-COVID general symptoms ($n = 49$ individuals) and long-COVID oral symptoms ($n = 43$ individuals) are shown in Table 3. As regards long-COVID general symptoms, over 41 % reported more than five different symptoms while 49 % reported 2–4 long-COVID orofacial symptoms.

3.3. Regression analyses

Based on the self-reported information gleaned from the pre-COVID-19 2017 survey, a relatively large number of associations between contracting COVID-19/long-COVID and several diverse tentative related factors were found in the unadjusted regression analyses (Table 4). Based on the statistically significant correlation in the adjusted regression analysis, predictive factors for contracting COVID-19 were living in elderly housing/senior care facility (OR 1.6, CI 1.0–2.3), followed in descending order, by large number (>10) of weekly social contacts (OR 1.5, CI 1.3–1.9), being married (OR 1.4, CI 1.1–1.7) and high school/university education (OR 1.3 CI 1.1–1–6) (Table 5). The highest odds ratio for having general symptoms of long-COVID after being sick in 2020/2021 was wearing a complete denture in one jaw (OR 5.0, CI 2.0–12.3), followed by reporting bad breath (OR 3.7, CI 1.9–7.2) and dry mouth during daytime (OR 2.2, CI 1.1–4.2) (Table 6). As regards long-COVID orofacial symptoms, the highest risks were bad breath (OR 3.8, CI 1.9–7.5) and having complete denture in one jaw (OR 3.4, CI 1.2–9.8) (Table 7).

4. Discussion

The response rate of 66 % could reasonably be considered very good considering the old age of the participants. Many elderly people have problems with responding to questionnaire surveys because of, for example, physical handicap, or reduced mental or intellectual abilities. Also, these groups of elderly frequently reside in special housing which means that they may require greater assistance. Available statistics from 2021 show that among individuals aged 80+ years-old in Sweden, 17.6 % of women and 11.2 % of men, lived in this way [21]. As we have included 90-year-old persons, one can suspect that these figures would be even higher in our study which in turn might decrease the response rate.

The gender distribution of the participants was equal to that recorded by Statistics Sweden in 2022 for the total population of 80- and 90-year-olds, i.e., 55 % women and 45 % men. Those who were born outside Sweden comprised 6.0 % of our sample compared to 11.3 % in the Swedish population [22]. Those with high school/university education consisted of 22.1 % in our sample compared to 21.0 % for the whole country [23]. In addition, 57.2 % of our sample were married compared to 46.1 % in the Swedish population [24]. As regards residency, 84.4 % lived in urban areas and 15.6 % in the countryside, while in Sweden as a whole, the corresponding figures for 2020 were 87.6 % and 12.4 %, respectively [25]. These data are not presently reported. In summary, our sample of 80- and 90-year-olds was relatively representative of the total Swedish population as regards gender, level of education and residency, while foreign-born individuals were slightly under-represented and married individuals slightly over-represented.

This study aimed principally to provide information about the general and orofacial symptoms of acute and long COVID-19 in 80- and 90-year-old Swedish COVID-19 survivors. Secondly, we aimed to identify predictive and/or protective factors for suffering from long-COVID-19 drawing on earlier findings in serial surveys conducted in the same cohorts over 30-year and 15-year periods, respectively.

It was found that any form of acute general symptom was significantly more common among women than men, which concurs with other studies where both acute and psychological symptoms were more

Table 3
Frequency distribution of reported number of long-COVID general symptoms ($n = 49$ individuals) and long-COVID oral symptoms ($n = 43$ individuals).

	Long-COVID general symptoms Range 1–15	Long-COVID oral symptoms Range 1–8
	% (n)	% (n)
1 symptom	24 (12)	37 (16)
2–4 symptoms	35 (17)s	49 (21)
≥5 symptoms	41 (20)	14 (6)

Table 4
Unadjusted logistic regression between those who reported COVID-19 ($n = 504$), long- COVID general symptoms ($n = 43$), long-COVID oral symptoms ($n = 38$) in 2022 (dependent) vs. the remaining participants (controls: $n = 4134$; $n = 4595$ and $n = 4600$, respectively) based on self-reported variables in the 2017 survey (independent). As regards the COVID-19/long-COVID groups, only those who responded in both 2022 and 2017 are included in the analysis.

Variable	COVID-19 vs. controls	Long-COVID general vs. controls	Long-COVID oral vs. controls
Birth year	N.S.	N.S.	N.S.
Gender	N.S.	N.S.	N.S.
Birthplace	N.S.	N.S.	N.S.
Residency	N.S.	N.S.	N.S.
Weekly social contacts	$P < 0.001$	N.S.	N.S.
Household	$P = 0.04$	N.S.	N.S.
Education	$P = 0.001$	$P = 0.01$	N.S.
Marital status	$P = 0.002$	N.S.	N.S.
Self-perceived health	N.S.	N.S.	N.S.
Self-perceived health compared to peers	$P = 0.007$	N.S.	N.S.
Medicine prescribed last two weeks	N.S.	N.S.	N.S.
Doctor visit last 3 months	$P = 0.03$	N.S.	N.S.
Body mass index	N.S.	N.S.	N.S.
Smoking	N.S.	N.S.	N.S.
Smokeless tobacco	N.S.	N.S.	N.S.
Alcohol intake	$P = 0.01$	N.S.	N.S.
Chewing problems	N.S.	N.S.	N.S.
Dry mouth daytime	N.S.	$P = 0.002$	$P = 0.03$
Dry mouth nighttime	N.S.	N.S.	N.S.
Number of own teeth	N.S.	N.S.	N.S.
Burning mouth	N.S.	N.S.	N.S.
Mouth ulcer	N.S.	N.S.	N.S.
Taste changes	N.S.	N.S.	$P = 0.05$
TMJ pain	N.S.	N.S.	N.S.
TMJ sound	N.S.	N.S.	N.S.
Mouth opening problems	N.S.	N.S.	N.S.
Bruxism	N.S.	N.S.	N.S.
Gingival bleeding	N.S.	N.S.	N.S.
Bad breath	N.S.	$P < 0.001$	$P < 0.001$
Dental material problems	N.S.	N.S.	$P = 0.03$
Tooth sensitivity	N.S.	N.S.	N.S.
Satisfaction with teeth	N.S.	$P < 0.05$	N.S.
OIDP	N.S.	N.S.	N.S.
Dentist visits	N.S.	N.S.	N.S.
Partial denture	N.S.	N.S.	N.S.
Complete denture in one jaw	N.S.	$P < 0.001$	$P = 0.05$
Complete denture in both jaws	N.S.	N.S.	N.S.
Any type of denture	N.S.	$P = 0.002$	N.S.
Caries problem last year	N.S.	N.S.	N.S.
Periodontal problems last	N.S.	N.S.	N.S.

Table 5
Adjusted logistic regression (Forward conditional analysis) between those who reported COVID-19 ($n = 504$) vs. the remaining participants (controls: $n = 4134$) (dependent variable). Independent variables were those found to be significant ($p \leq 0.05$) in the unadjusted analysis (Table 4).

Independent variables	Unadjusted	Adjusted P	OR	CI 95 %
Weekly social contacts Ref. >10 contacts/week	$P < 0.001$	<0.001	1.5	1.3–1.9
Household Ref. Elderly housing, senior care facility	$P = 0.043$	0.03	1.6	1.0–2.3
Education Ref. High school/university	$P = 0.001$	0.01	1.3	1.1–1.6
Marital status Ref. Married/cohabiting	$P = 0.002$	0.007	1.4	1.1–1.7
Self-perceived health compared to peers Ref. Much better/better	$P = 0.007$	N.S.	–	–
Doctor visit last 3 months Ref. Yes	$P = 0.03$	N.S.	–	–
Alcohol intake Ref. One or more times weekly	$P = 0.01$	N.S	–	–

Table 6
Adjusted logistic regression between those who reported long-COVID general symptoms ($n = 43$) vs. the remaining participants (controls: $n = 4595$) (dependent variable). Independent variables were those found to be significant ($p \leq 0.05$) in the unadjusted analysis (Table 4).

Independent variables	Unadjusted	Adjusted P	OR	CI 95 %
Education Ref. High school/university	$P = 0.01$	N.S.	–	–
Dry mouth daytime Ref. Often/sometimes	$P = 0.002$	0.02	2.2	1.1–4.2
Bad breath Ref. Yes	$P > 0.001$	<0.001	3.7	1.9–7.2
Satisfaction with teeth Ref. Not satisfied	$P < 0.05$	N.S.	–	–
Complete denture in one jaw Ref. Yes	$P < 0.001$	<=0.001	5.0	2.0–12.3
Any type of denture Ref. yes	$P = 0.002$	N.S.	–	–

Table 7
Adjusted logistic regression between those who reported long-COVID oral symptoms ($n = 38$) in 2022 (dependent) vs. the remaining participants (controls: $n = 4600$) (dependent variable). Independent variables were those found to be significant ($p \leq 0.05$) in the unadjusted analysis (Table 4).

Independent variables	Unadjusted	Adjusted P	OR	CI 95 %
Dry mouth daytime Ref. Often/sometimes	$P = 0.03$	N.S.	–	–
Taste changes Ref. Yes	$P = 0.05$	N.S.	–	–
Bad breath Ref. Yes	$P < 0.001$	<0.001	3.8	1.9 – 7.5
Dental material problems Ref. Yes	$P = 0.03$	N.S.	–	–
Complete denture in one jaw Ref. Yes	$P = 0.05$	0.03	3.4	1.2 – 9.8

common in women [26–28]. Some type of orofacial symptom was reported by 44 % in this study, which is lower than in a systematic review where almost two-thirds of COVID-19 patients reported oral manifestations [14]. In the same report, taste alterations, xerostomia and ulcerations were the most common findings which is similar to our results where taste/smell changes and dry mouth (xerostomia) were the most frequently reported symptoms.

Risk factors for contracting COVID-19, based on the responses in our 2017 report, were living in elderly housing/senior care facility, greater number of weekly social contacts, being married and high education, with ORs ranging from 1.6 to 1.3. This was not an unexpected finding as numerous reports have documented increased risk for COVID-19 in the frail and elderly living in different types of elderly housing and, by definition, increasing the socializing risk [27]. As regards education the finding is more confusing. Low education is strongly correlated with increased disease severity and mortality from COVID-19 [29]. In our study, higher education was correlated with increased risk for contracting the disease. However, considering a presumably high attrition rate among those with low education in this age group, the correlation with high education and COVID-19 (survivors) may be plausible.

Pulmonary infection is one of the main contributing factors related to increased severity and death in COVID-19 infection [30]. As regards denture wearing, there is a more than 9-fold increased risk for acquiring pneumonia compared to individuals not wearing removable dentures [31]. In comparing frail, elderly denture-wearing individuals without respiratory infection with hospitalized patients with pneumonia a statistically significant increase in putative respiratory pathogens was found in the pneumonia group. This finding could be explained by the role of denture acrylic biomaterials serving as a reservoir for respiratory pathogens and especially Streptococcus pneumoniae, which in turn may lead to an increased risk of pneumonia in the elderly [32]. Recently published data from Norway indicates that oral-type pleural infection is the most common type of community-acquired pleural infection. The mechanism by which seeding of bacteria from a dental focus occurs is probably via haematogenous spread, similar to brain abscess development. Streptococcus intermedius and Fusobacterium nucleatum are likely to be responsible for establishing the pleural infection [33].

Our finding of a 4- to 5-fold increased risk for long-COVID in individuals having a complete denture in one jaw deserves attention. Bad breath (halitosis) is most often caused by oral gram-negative anaerobic microorganisms producing volatile sulphur compounds [34]. Having a denture in one jaw only implies that some natural teeth are present in the opposing jaw. In this regard, it has been shown that dentate individuals have a greater amount of, and different oral microbiota, than completely edentulous individuals [35]. Self-reported dry mouth was also correlated with increased risk for having general long-COVID symptoms, while salivary gland hypofunction may lead to altered composition of oral microorganisms causing dysbacteriosis [36].

Candida albicans infection is commonly found in denture wearers and candidiasis may interact with COVID-19 and thus negatively affect disease severity and mortality [37]. Chronic obstructive pulmonary disease (COPD), a highly prevalent disease in the elderly, is a significant risk factor for a negative outcome of COVID-19 disease [38]. Inflammation in the oral cavity is associated with the development of COPD and denture wearing may serve as a reservoir for respiratory pathogens and thereby increase the risk for exacerbations of COPD [39].

Consequently, it seems quite likely that oral microbiota originating both from removable dentures and from plaque surrounding natural teeth may have a negative impact on lung health especially if combined with a COVID-19 infection. Other tentative explanations are, however, plausible. Considering that the overall majority of the responders had received three or more vaccine shots there could be a risk for “post vaccination syndrome” which in part is reported to have similar manifestations as those of long COVID symptoms reported in this study [40]. Risk for pneumonia in old age may also be associated with pre-existing lung disease from, for example, smoking or industrial exposure to lung irritants. Risks for wearing a denture may also relate to early life exposure to a poor diet, poor oral hygiene, and poor health behaviors, leading to early tooth loss and general poor health in later life. This may account for the correlation between presence of a denture and symptoms of long-COVID, and the microflora, bad breath and dry mouth might therefore not be directly or primarily associated with denture wearing nor with orofacial long-COVID symptoms or pneumonia.

In 2017, 4.1 % of the 1942 cohort (then 75 years old) wore a complete denture in one jaw [41]. The corresponding figure for the 1932 cohort (then 85 years old) was 8.3 %. Further, the global prevalence of edentulism is estimated to be 23 % [42], and because of the loss of all teeth, a large proportion of these people will be using complete dentures.

In conclusion, general and orofacial symptoms in long COVID are common among older elderly COVID-19 survivors and oral microorganisms are associated with and may at least in part be responsible for development of long-COVID symptoms. It follows that health personnel managing COVID-19 patients should carefully examine the dental status of those who are dentate and, in the edentulous, especially those having acrylic-based removable complete or partial dentures, for clinical signs of stomatitis or other intraoral problem such as dry mouth or halitosis. If so found, rigorous oral hygiene procedures should be carried out including cleaning and disinfection of the denture and reducing intraoral pathogens by prophylactic regimes, for example chlorhexidine rinsing [43].

CRediT authorship contribution statement

Ann-Katrin Johansson: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Ridwaan Omar:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Sverre Lehmann:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Josefin Sannevik:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Berit Mastrovito:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Anders Johansson:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

[1] WHO Coronavirus (COVID-19) Dashboard, WHO Coronavirus (COVID-19) Dashboard | WHO Coronavirus (COVID-19) Dashboard With Vaccination Data (Retrieved 25 October, 2023).
[2] Statista, Impact of the COVID-19 pandemic on older adults in the U.S. - Statistics & Facts. Impact of the COVID-19 pandemic on older adults in the U.S. - Statistics & Facts | Statista (Retrieved 25 October 2023).
[3] Statista, Distribution of total COVID-19 deaths in the United States as of April 26, 2023, by age group. Share of total COVID-19 deaths by age U.S. 2023 | Statista (Retrieved 25 October 2023).
[4] National Board of Health and Welfare, Statistics on COVID-19. Statistics on COVID-19 – Socialstyrelsen (Retrieved 25 October 2023).
[5] Coronavirus disease (COVID-19). Coronavirus disease (COVID-19) (who.int) (Retrieved 25 October 2023).
[6] J. Aragoneses, A. Suárez, J. Algar, C. Rodríguez, N. López-Valverde, J. M. Aragoneses, Oral manifestations of COVID-19: updated systematic review with meta-analysis, Front. Med. (Lausanne) 8 (2021), 726753, https://doi.org/10.3389/fmed.2021.726753.
[7] M.J.N. Al-Magsoosi, O.K.B. Al-Asadi, N.T. Al-Quraine, S.M. Sami, J. Haider, Oral manifestations associated with COVID-19 infection: a cross-sectional study of recovered Iraqi patients, Int. J. Dent. 2023 (2023), 4288182, https://doi.org/10.1155/2023/4288182.
[8] World Health Organization. A clinical case definition of post COVID-19 condition by a Delphi consensus, 6 October 2021. A clinical case definition of post COVID-19 condition by a Delphi consensus, 6 October 2021 (who.int) (Retrieved 25 October 2023).
[9] S. Lopez-Leon, T. Wegman-Ostrosky, C. Perelman, et al., More than 50 long-term effects of COVID-19: a systematic review and meta-analysis, Sci. Rep. 11 (2021) 16144, https://doi.org/10.1038/s41598-021-95565-8.
[10] N. Zeng, Y.M. Zhao, W. Yan, et al., A systematic review and meta-analysis of long term physical and mental sequelae of COVID-19 pandemic: call for research priority and action, Mol. Psychiatry. 28 (2023) 423–433, https://doi.org/10.1038/s41380-022-01614-7.
[11] K.I. Notarte, M.H.S. de Oliveira, P.J. Peligro, et al., Age, sex and previous comorbidities as risk factors not associated with SARS-CoV-2 infection for long COVID-19: a systematic review and meta-analysis, J. Clin. Med. 11 (2022) 7314, https://doi.org/10.3390/jcm11247314.
[12] E.J. Thompson, D.M. Williams, A.J. Walker, et al., Long COVID burden and risk factors in 10 UK longitudinal studies and electronic health records, Nat. Commun. 13 (2022) 3528, https://doi.org/10.1038/s41467-022-30836-0.
[13] K. Nasiri, S. Tehrani, M. Mohammadikhah, et al., Oral manifestations of COVID-19 and its management in pediatric patients: a systematic review and practical guideline, Clin. Exp. Dent. Res. 9 (2023) 922–934, https://doi.org/10.1002/cre2.776.
[14] K. Nijakowski, S. Wyzga, N. Singh, F. Podgórski, A. Surdacka, Oral manifestations in SARS-CoV-2 positive patients: a systematic review, J. Clin. Med. 11 (2022) 2202, https://doi.org/10.3390/jcm11082202.
[15] N.O. Binmadi, S. Aljohani, M.T. Alsharif, S.A. Almazrooa, A.M. Sindi, Oral manifestations of COVID-19: a cross-sectional study of their prevalence and association with disease severity, J. Clin. Med. 11 (2022) 4461, https://doi.org/10.3390/jcm11154461.
[16] A. Emodi-Perlman, I. Eli, J. Smardz, et al., Temporomandibular disorders and bruxism outbreak as a possible factor of orofacial pain worsening during the COVID-19 pandemic-concomitant research in two countries, J. Clin. Med. 9 (2020) 3250, https://doi.org/10.3390/jcm9103250.
[17] A.M. Paradowska-Stolarz, Oral manifestations of COVID-19: brief review, Dent. Med. Probl. 58 (2021) 123–126, https://doi.org/10.17219/dmp/131989.
[18] E.F. Gherlone, E. Polizzi, G. Tetè, et al., Frequent and persistent salivary gland ectasia and oral disease after COVID-19, J. Dent. Res. 100 (2021) 464–471, https://doi.org/10.1177/0022034521997112.
[19] B. Rafałowicz, L. Wagner, J. Rafałowicz, Long COVID oral cavity symptoms based on selected clinical cases, Eur. J. Dent. 16 (2022) 458–463, https://doi.org/10.1055/s-0041-1739445.
[20] A.K. Johansson, R. Omar, B. Mastrovito, J. Sannevik, G.E. Carlsson, A. Johansson, Prediction of xerostomia in a 75-year-old population: a 25-year longitudinal study, J. Dent. 118 (2022), 104056, https://doi.org/10.1016/j.jdent.2022.104056.
[21] Personer som har särskilt boende efter ålder. Andel (procent) av alla i gruppen efter ålder, kön och år. Personer som har särskilt boende efter ålder. Andel (procent) av alla i gruppen efter ålder, kön och år. PxWeb (scb.se) (Retrieved 25 October 2023).
[22] Statistics Sweden, Number of persons with foreign or Swedish background (detailed division) by region, age and sex. Year 2002 – 2022. Number of persons with foreign or Swedish background (detailed division) by region, age and sex. Year 2002 - 2022. PxWeb (scb.se) (Retrieved 25 October 2023).
[23] Statistics Sweden, Life tables by level of education, type of household, sex and age. Year 2012 – 2022. Mean population by level of education, type of household, sex, age and year. PxWeb (scb.se) (Retrieved 25 October 2023).
[24] Statistics Sweden, Population by region, marital status, age and sex. Year 1968 – 2022. Population by region, marital status, age and year. PxWeb (scb.se) (Retrieved 25 October 2023).
[25] Population and land area within and outside of localities, by region. Every fifth year 2005 –2020. Population and land area within and outside of localities, by region. Every fifth year 2005 - 2020. PxWeb (scb.se) (Retrieved 25 October 2023).
[26] Y. Jin, H.L. Sun, S.C. Lam, et al., Depressive symptoms and gender differences in older adults in Hong Kong during the COVID-19 pandemic: a network analysis approach, Int. J. Biol. Sci. 18 (2022) 3934–3941, https://doi.org/10.7150/ijbs.69460.
[27] D. Janiri, M. Tosato, A. Simonetti, et al., Post-COVID-19 psychiatric symptoms in the elderly: the role of gender and resilience, J. Pers. Med. 12 (2022) 2016, https://doi.org/10.3390/jpm12122016.
[28] G. Pelà, M. Goldoni, E. Solinas, et al., Sex-related differences in long-COVID-19 syndrome, J. Womens. Health (Larchmt). 31 (2022) 620–630, https://doi.org/10.1089/jwh.2021.0411.
[29] J. Zhuo, N. Harrigan, Low education predicts large increase in COVID-19 mortality: the role of collective culture and individual literacy, Public. Health 221 (2023) 201–207, https://doi.org/10.1016/j.puhe.2023.06.016.
[30] P. Oboza, N. Ogarek, M. Olszanecka-Glinianowicz, P. Kocelak, The main causes of death in patients with COVID-19, Eur. Rev. Med. Pharmacol. Sci. 27 (2023) 2165–2172, https://doi.org/10.26355/eurrev_202303_31589.
[31] H. Alzamil, T.T. Wu, E. van Wijngaarden, et al., Removable denture wearing as a risk predictor for pneumonia incidence and time to event in older adults, JDR. Clin. Trans. Res. 8 (2021), 23800844211049406, https://doi.org/10.1177/23800844211049406.
[32] J.A. Twigg, A. Smith, C. Haury, et al., Compositional shifts within the denture-associated bacteriome in pneumonia - an analytical cross-sectional study, J. Med. Microbiol. 72 (2021), https://doi.org/10.1099/jmm.0.001702.
[33] R. Dyrhovden, T.M. Eagan, Ø. Fløtten, et al., Pleural empyema caused by Streptococcus intermedius and Fusobacterium nucleatum - a distinct entity of pleural infections, Clin. Infect. Dis. (2023) ciad378, https://doi.org/10.1093/cid/ciad378.
[34] M.A. Memon, H.A. Memon, F.E. Muhammad, et al., Aetiology and associations of halitosis: a systematic review, Oral. Dis. 29 (2023) 1432–1438, https://doi.org/10.1111/odi.14172.

[35] R.K. Gazdeck, S.R. Fruscione, G.R. Adami, Y. Zhou, L.F. Cooper, J.L. Schwartz, Diversity of the oral microbiome between dentate and edentulous individuals, Oral. Dis. 25 (2019) 911–918, https://doi.org/10.1111/odi.13039.
[36] A.M. Lynge Pedersen, D. Belstrøm, The role of natural salivary defences in maintaining a healthy oral microbiota, J. Dent. 80 (Suppl 1) (2019) S3–S12, https://doi.org/10.1016/j.jdent.2018.08.010.
[37] L.S. Jerônimo, R.P. Esteves Lima, T.Y.U. Suzuki, J.A.C. Discacciati, C.L.B. Bhering CLB, Oral candidiasis and COVID-19 in users of removable dentures: is special oral care needed? Gerontology 68 (2022) 80–85, https://doi.org/10.1159/000515214.
[38] N.T. Awatade, P.A.B. Wark, A.S.L. Chan, et al., The complex association between COPD and COVID-19, J. Clin. Med. 12 (2023) 3791, https://doi.org/10.3390/jcm12113791.
[39] D. Przybyłowska, R. Rubinsztajn, R. Chazan, E. Swoboda-Kopeć, J. Kostrzewa-Janicka, E. Mierzwińska-Nastalska, The prevalence of oral inflammation among denture wearing patients with chronic obstructive pulmonary disease, Adv. Exp. Med. Biol. 858 (2015) 87–91, https://doi.org/10.1007/5584_2015_128.
[40] H.M. Krumholz, Y. Wu, M. Sawano M, et al., Post-vaccination syndrome: a descriptive analysis of reported symptoms and patient experiences after Covid-19 immunization. Preprint. medRxiv. 2023 (2023) 11.09.23298266. 10.1101/2023.11.09.23298266.
[41] A.K. Johansson, R. Omar, L. Unell, et al., Changes in conditions related to reported oral and general health over a ten-year period as reflected in two cohorts of 75-year-old subjects examined in 2007 and 2017, J. Oral. Rehabil. 47 (2020) 1382–1393, https://doi.org/10.1111/joor.13073.
[42] World Health Organization. Oral health oral health (who.int) (Retrieved 25 October 2023).
[43] T. Ebrahimi, A.R. Shamshiri, M. Alebouyeh, S.Z. Mohebbi, Effectiveness of mouthwashes on reducing SARS-CoV-2 viral load in oral cavity: a systematic review and meta-analysis, BMC Oral Health 23 (2023) 443, https://doi.org/10.1186/s12903-023-03126-4.