Impact of surgical mask on performance and cardiorespiratory responses to submaximal exercise in COVID-19 patients near hospital discharge: A randomized crossover trial

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Abstract

Background: Wearing a surgical mask in hospitalized patients has become recommended during care, including rehabilitation, to mitigate coronavirus disease 2019 (COVID-19) transmission. However, the mask may increase dyspnoea and raise concerns in promoting rehabilitation activities in post-acute COVID-19 patients.

Objective: To evaluate the impact of the surgical mask on dyspnoea, exercise performance and cardiorespiratory response during a 1-min sit-to-stand test in hospitalized COVID-19 patients close to discharge.

Methods: COVID-19 patients whose hospital discharge has been planned the following day performed in randomized order two sit-to-stand tests with or without a surgical mask. Outcome measures were recorded before, at the end, and after two minutes of recovery of each test. Dyspnoea (modified Borg scale), cardiorespiratory parameters and sit-to-stand repetitions were measured.

Results: Twenty-eight patients aged 52 ± 10 years were recruited. Compared to unmasked condition, dyspnoea was significantly higher with the mask before and at the end of the sit-to-stand test (mean difference[95%CI]: 1.0 [0.6, 1.4] and 1.7 [0.8, 2.6], respectively). The difference was not significant after the recovery period. The mask had no impact on cardiorespiratory parameters nor the number of sit-to-stand repetitions.

Conclusion: In post-acute COVID-19 patients near hospital discharge, the surgical mask increased dyspnoea at rest and during a submaximal exercise test but had no impact on cardiorespiratory response or exercise performance. Patients recovering from COVID-19 should be reassured that wearing a surgical

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facemask during physical or rehabilitation activities is safe. These data may also mitigate fears to refer these patients in rehabilitation centres where mask-wearing has become mandatory.

Introduction

The severe acute respiratory syndrome coronavirus 2 causing the coronavirus disease 2019 (COVID-19) has been shown to spread rapidly from person to person. The use of personal protective equipment has then become mandatory for healthcare workers caring for patients with COVID-19. To maximize the reduction of virus spread during clinical procedures involving the presence of healthcare workers, hospitalized patients were also recommended to wear a facemask.[1,2]

Routine clinical procedures involve, among other things, cardio-pulmonary and strengthening exercises. During exercises, wearing a surgical mask may be difficult to tolerate by patients, especially those who already experience breathing difficulties due to their illness. Indeed, studies showed that the surgical mask was associated with discomfort and breathing difficulties.[3] In addition, the World Health Organization advises against the wearing of masks during vigorous physical activities because they may reduce the ability to breathe comfortably.[4] There are also concerns that the masks increase breathing resistance during exercises and reduce oxygen uptake while increasing carbon dioxide rebreathing.[5] In the COVID-19 recovery process, perceived breathing difficulty and potential health concerns associated with mask-wearing during exercises may reduce physical activity uptake or preclude the early use of rehabilitation strategies in places where universal mask use is required. However, timely promotion of physical activities or exercises is crucial to minimize the functional impact of hospitalized COVID-19 patients.[6]

Describing safe exercise methods that simultaneously mitigate the risk of viral transmission is thus paramount to promoting rapid physical recovery of COVID-19 patients. Therefore, we aimed to evaluate the impact of wearing the surgical facemask on dyspnoea, exercise performance and cardiorespiratory response in the course of a submaximal exercise test that reflects the physical level of daily life activities in hospitalized patients with COVID-19 close to hospital discharge.

Material and methods

Patients with laboratory-confirmed COVID-19 who were hospitalized in the dedicated COVID-19 wards between January and March 2021 at Cliniques universitaires Saint-Luc (Brussels, Belgium) and were scheduled to be discharged from the hospital in the following 24-h, were invited to participate in this study. Patients were eligible if they were aged between 18–65 years and had no need of supplemental oxygen therapy the day of the experiment. Exclusion criteria were chronic respiratory diseases, neurological or orthopaedic comorbidities, language barriers, altered consciousness, and use of high-flow nasal cannula or bilevel non-invasive ventilation during the hospital stay. All included patients provided written informed consent to participate in the study. The study was approved by the local ethics committee (B4032020000121) and was registered in ClinicalTrials.gov (NCT04689542).

We designed a randomized crossover trial. Patients were randomized to perform a 1-min sit-to-stand test while wearing a surgical mask followed by a 1-min sit-to-stand test without wearing a surgical mask, or vice versa. Allocation was concealed using sequentially numbered sealed opaque envelopes prepared beforehand by a clinician not involved in the study. The two sit-to-stand tests

were separated from each other by 1 h. The subjects were familiarized with the sit-to-stand procedure by performing a training test at least 12 h before the randomization to account for the learning effect.[7] The surgical mask model used was a standard 3-ply disposable facemask CE-marked (BruMed, Kontich, Belgium). The mask was tightly fitted around the face using an adjustable plastic mask strap extender.

The 1-min sit-to-stand test was performed with a standard chair without armrests (height: 46 cm). Hands on the hips, participants had to completely stand up and sit down as many times as possible for one minute. Standardized instructions were given before the procedure. No encouragements were provided during the test. Subjects were told that rest periods were permitted during the test, with no interruption of the countdown timer.

Medical files of included patients were reviewed to collect the following data at hospital admission: demographic characteristics, comorbidities, laboratory data (C-reactive protein, urea, neutrophil-to-lymphocyte ratio) and chest computed tomography scan results with the percent of lung involved by consolidations. At hospital discharge, the following data were also retrieved: maximal oxygen flow needed during the hospital stay, oxygen therapy duration, hospital stay duration, and laboratory data again.

The day of the 1-min sit-to-stand test familiarization (*i.e.* <24 h before hospital discharge), all participants filled out the Global Physical Activity Questionnaire and the Nijmegen questionnaire. The Global Physical Activity Questionnaire comprises 16 questions and collects information on physical activity participation in three domains (activity at work, travel to and from places, and recreational activities) as well as sedentary behaviour in a typical week.[8] The participants were asked to consider a typical week as the period preceding the onset of the first COVID-19 symptoms. The Nijmegen questionnaire comprises 16 questions scored each from 0 to 4. A total score ≥ 23 out of 64 suggests hyperventilation syndrome.[9]

During the 1-min sit-to-stand test, the parameters were recorded at several time points over a 4-min long period (Supplement, E-Figure 1).

These time points were defined as follows: immediately before the sit-to-stand test (T_0), at the end of test (T_1), at 60- and 120-s post test (T_2 and T_3, respectively). In the masked condition, participants were instructed to wear the surgical mask throughout the procedure (*i.e.* from T_0 to T_3). Subjects were asked to rate dyspnoea according to the Borg CR10 scale[10] at T_0, T_1 and T_3. The primary outcome was dyspnoea at T_1. The rate of perceived exertion for leg was also assessed at T_1.[10]

The number of sit-to-stand repetitions was recorded and expressed in absolute values and in percentiles according to published reference values.[11] Heart rate and peripheral oxygen saturation were recorded with a finger pulse oximeter (Somnolter, Nomics, Belgium) and reported at T_0, T_2 and T_3. Respiratory rate was registered continuously over 3 min using abdominal and thoracic respiratory inductive plethysmography belts (Somnolter). The respiratory rate was reported over 1-min before, 1-min during and 1-min after each test

Five domains of comfort/discomfort of wearing a mask were assessed by questionnaire published in another study.[12] The evaluated domains were humidity, heat, breathing resistance, fatigue, and overall discomfort. All participants were asked to rate each of these domains from 0 to 10 before and immediately after the 1-min sit-to-stand test with the surgical mask. A higher score indicates a greater discomfort.

The sample size was calculated based on an estimated difference ($\pm$ SD) of 1 ± 1.3 point in dyspnoea between the two conditions (with/without surgical mask).[13] We estimated that 14 patients had to be recruited in this crossover trial (power: 80%, α risk: 0.05). We anticipated that the potential impact of the surgical mask on dyspnoea would be different between patients presenting varying levels of disease severity. Because more severe cases require longer period of oxygen need, we discriminated the severity of our patients according to the median oxygen supplementation duration in our hospital (3 days). Thus, we planned to recruit a total of 28 patients, including 14 patients with oxygen therapy duration ≤ 3 days (low oxygen need) and 14 patients with oxygen therapy duration

> 3 days (high oxygen need). The effect of the surgical mask on dyspnoea and rating of perceived exertion for leg was tested independently in each subgroup. Statistical analyses realized on other secondary outcomes were tested in the whole cohort (n = 28).

Data were analysed using SPSS 27.0 (IBM software). Normality of data was verified with the Shapiro-Wilk test All data were presented as mean (± SD) or median [interquartile range] depending on their distribution. Comparisons of 1-min sit-to-stand variables between the masked and unmasked conditions were tested with paired T-test or Wilcoxon test as appropriate. Comparisons between subgroups (low and high oxygen needs) were performed using unpaired T-test or Mann-Whitney test. Proportions between subgroups were compared using chi-square test or Fisher's exact test when the expected number was lower than five. To assess how each condition affected the evolution of cardiorespiratory parameters (respiratory rate, heart rate, peripheral oxygen saturation) over the different time points, we performed 2-way repeated measures ANOVA with time (T_0, T_2 and T_3) and condition (with/without mask) as within-subject factors. The Bonferroni correction was applied for any post-hoc comparisons. Correlations were tested using Pearson's correlation coefficient. A p-value ≤ 0.05 was considered statistically significant.

Results

Thirty-five eligible participants were consecutively screened and proposed to participate in this study. Seven declined to participate. The remaining 28 participants fulfilled the entire study protocol and were analysed (Figure 1). Their demographic data and baseline characteristics are outlined in Table 1. Compared to patients who required oxygen therapy
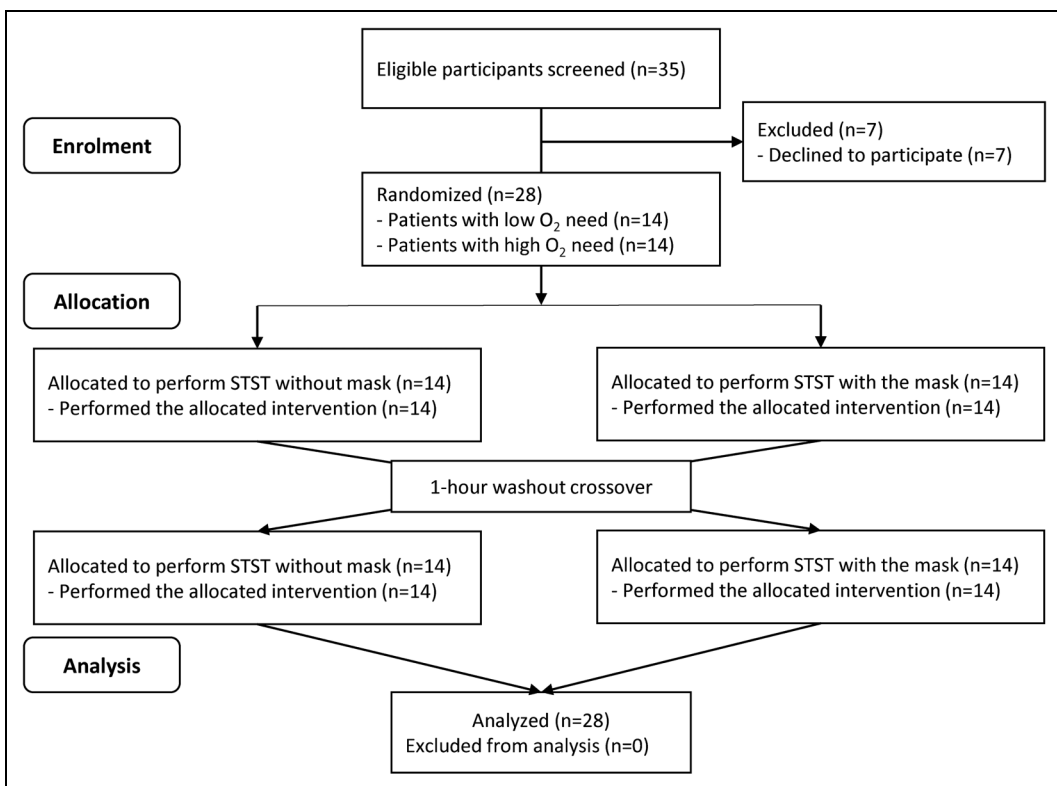

Figure 1. Consort flow chart of the study.

Table 1. Demographics and baseline characteristics.

	All patients n = 28	Patients with low O_2 need n = 14	Patients with high O_2 need n = 14	Low vs High O_2 need P value
Demographic data				
Age, years	55 [47–59]	54 [47–59]	56 [49–60]	0.629
Female sex, n (%)	9 (32)	5 (36)	4 (29)	>0.99
BMI, kg/m^2	28.8 ± 5.2	27.2 ± 3.0	30.3 ± 6.5	0.122
Comorbidities, n (%)				
Diabetes	6 (21)	1 (7)	5 (36)	0.165
Hypertension	5 (18)	2 (14)	3 (21)	>0.99
Cardiovascular disease	4 (14)	1 (7)	3 (21)	0.596
Immunocompromised	4 (14)	2 (14)	2 (14)	>0.99
Malignancy	2 (7)	1 (7)	1 (7)	>0.99
Clinical characteristics				
GPAQ, MET-min/week	3330 [1020–9300]	3840 [950–8010]	3330 [1290–9630]	0.927
Active behaviour, n (%)	24 (86)	12 (86)	12 (86)	>0.99
Nijmegen score	12.4 ± 9.1	14.9 ± 10.9	9.9 ± 6.2	0.149
Max O_2 flow need (L/min)	3.0 [2.0–5.5]	2.0 [1.8–3.0]	5.0 [3.0–15.0]	<0.001
O_2 therapy duration, days	4.0 [2.3–8.5]	2.5 [2.0–3.0]	8.0 [5.8–14.5]	<0.001
Hospitalization time, days	9.5 ± 6.3	5.2 ± 1.2	13.7 ± 6.4	<0.001
Biological findings				
At hospital admission				
CRP (mg/L)	73.0 [38.3–124.4]	82.2 [37.2–142.7]	60.3 [36.1–98.9]	0.491
Urea (mg/dL)	29.0 [23.0–37.3]	29.0 [21.2–34.5]	28.5 [23.8–39.0]	0.696
NLR (%)	5.3 [2.6–9.7]	3.0 [1.9–5.8]	9.1 [4.3–10.0]	0.004
At hospital discharge				
CRP (mg/L)	15.3 [7.0–36.5]	16.6 [8.7–45.9]	12.2 [6.6–29.9]	0.476
Urea (mg/dL)	33.5 [27.3–38.0]	33.5 [26.8–37.3]	32.0 [25.3–38.0]	0.854
NLR (%)	2.8 [1.6–4.7]	3.3 [1.4–6.1]	2.7 [1.6–4.5]	0.679
Lung CT scan				
CT at diagnosis, n (%)	14 (50)	6 (43)	8 (57)	0.450
Lesion stratification, n (%)				
< 10%	2 (14)	1 (7)	1 (7)	n/a
10–25%	3 (21)	2 (14)	1 (7)	n/a
25–50%	6 (43)	3 (21)	3 (21)	n/a
>50%	3 (21)	0 (0)	3 (21)	n/a
STST practise performance				
Repetitions	19.1 ± 7.4	17.5 ± 7.0	20.6 ± 7.6	0.266
% predicted value	38.9 ± 15.4	35.7 ± 14.4	42.1 ± 16.1	0.283

Abbreviations: BMI, body mass index; CRP, C-reactive protein; CT, computed tomography; GPAQ, Global physical activity questionnaire; n/a, not applicable; NLR, neutrophil to lymphocyte ratio; STST, 1-min sit-to-stand test
Continuous variables are reported as mean ± SD for normally distributed variables, median [interquartile range] for non-normally distributed variables. Categorical variables are presented as numbers (%). GPAQ level of activity was calculated according to World Health Organization recommendations.

for 3 days or less, patients from the high oxygen needs subgroup required a longer length of hospital stay, a higher maximal oxygen output, and had a higher neutrophil-to-lymphocyte ratio at hospital admission. All other outcomes did not significantly differ between subgroups.

The dyspnoea score in each subgroup and at different time points is given in Table 2 and Figure 2.

The effects of surgical mask had a similar impact in both subgroups of patients. The surgical mask had an immediate effect on dyspnoea as the Borg CR10 score was rated higher compared to the unmasked condition before the 1-min sit-to-stand test. This difference persisted and even increased at the end of the sit-to-stand test but disappeared after the recovery period.

In the whole cohort, the surgical mask generated a significant and clinically relevant increase (>1 unit change) in leg rating of perceived exertion post-effort compared to no mask (mean difference: 1 ± 1.9; 95%CI: [0.3, 1.7], $P = 0.007$). The effect of the surgical mask on rating of perceived exertion for leg was similar in both subgroups, although the difference was only statistically significant in the subgroup of patients with lower oxygen needs (Table 2).

Table 2. Effects of each condition on measured outcomes.

	Without surgical mask	With surgical mask	Mean difference [95% CI]	P value
Patients with low O_2 need (n = 14)				
Dyspnoea				
T_0	0.6 ± 0.9	1.6 ± 1.3	1.1 [0.4 to 1.8]	0.006
T_1	2.7 ± 2.0	4.4 ± 2.3	1.7 [0.7 to 2.7]	0.003
T_3	1.9 ± 1.4	2.4 ± 1.5	0.5 [−0.2 to 1.2]	0.169
Leg RPE	2.7 ± 1.4	3.6 ± 1.8	0.9 [0.1 to 1.6]	0.022
Patients with high O_2 need (n = 14)				
Dyspnoea				
T_0	0.1 ± 0.4	1.1 ± 1.1	0.9 [0.3 to 1.6]	0.006
T_1	2.4 ± 1.5	4.1 ± 3.0	1.6 [−0.0 to 3.3]	0.052
T_3	1.6 ± 1.4	2.0 ± 1.1	0.4 [−0.6 to 1.5]	0.407
Leg RPE	2.8 ± 1.6	3.9 ± 2.3	1.1 [−0.3 to 2.5]	0.100

Data are presented as mean $\pm$ SD.
Abbreviations: RPE, rate of perceived exertion; STST, 1-min sit-to-stand test; T_0: before the STST; T_1: at the end of the STST; T_3: 120-s post-STST

Compared to the unmasked condition, the surgical mask had no impact on the number of sit-to-stand repetitions (19.8 ± 7.6 vs 19.2 ± 7.8, respectively; mean difference: 0.6 ± 1.8; 95%CI: [-0.1, 1.3], $P = 0.088$).

The influence of time and conditions on cardio-respiratory parameters (heart rate, respiratory rate, peripheral oxygen saturation), along with their interaction, are summarized in Table 3. Only time influenced the cardio-respiratory parameters. The surgical facemask had no effect on any of these parameters and did not interact with them over time.

The effect of the surgical mask on the different subjective domains are depicted in Table 4. All discomfort sensations statistically increased after the 1-min sit-to-stand test. No correlation was observed between the increase of discomfort in each domain and the change in other outcomes recorded.

Discussion

This study showed that the surgical facemask increases dyspnoea in patients recovering from COVID-19. The dyspnogenic effect of the surgical mask was discernible at rest, was further heightened during a submaximal effort, but vanished after a 2-min recovery period. The surgical facemask also increased the rating of perceived exertion for leg during the 1-min sit-to-stand test. However, the mask did not alter performance or the cardio-respiratory response to exercise.

This is the first study performed in COVID-19 patients that evaluated the effect of a facemask during an exercise that reflects the physical level of daily life activities. Most of available trials investigating the effects of masks (surgical, cloth, or FFP2-N95 masks) during effort have been conducted in healthy participants.[14] Overall, the data suggest that masks slightly increase dyspnoea and alter perceived effort during exercise or physical activities, with no impact on exercise performance or other physiological parameters. However, the protection masks are associated with a significant worsening of spirometry measurements due to an increase in airflow resistance.[15] Therefore, it is important to ensure their safe use during
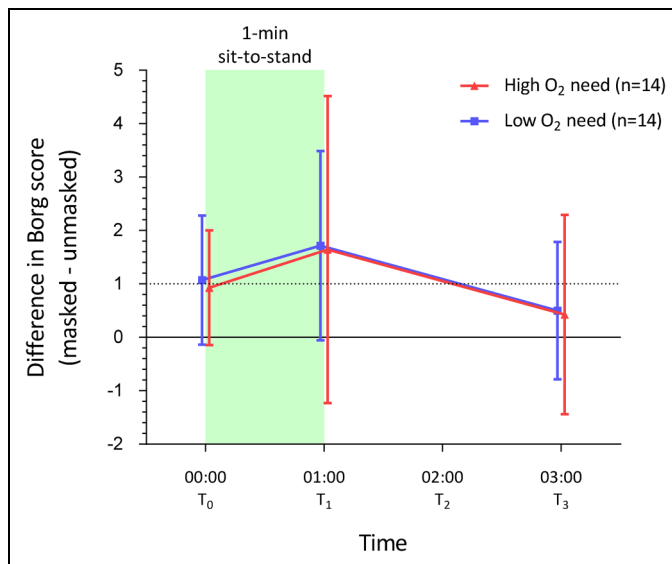
Figure 2. Difference in dyspnoea between the masked and unmasked condition at different time points of the experiment. Symbols and error bars indicate mean and standard deviation, respectively. A positive change in the Borg score indicate a greater dyspnoea rated with the surgical mask compared to no mask. The labels "High O_2 need" and "Low O_2 need" designate patients who required oxygen therapy for more than 3 hospital days or less/equal than 3 days, respectively. The dotted line highlights the minimal clinically important difference in the Borg score. The shaded area represents the duration of the 1-min sit-to-stand test (STST). T_0: Before the STST; T_1: At the end of the STST; T_2: 60-s post-STST; T_3: 120-s post-STST.

Table 3. Change in cardiorespiratory parameters among each condition.

Cardiorespiratory parameters	Without surgical mask	With surgical mask	Time	p-value Mask	Time × Mask
RR (bpm)	n = 28	n = 28			
1 min Pre STST	25.9 ± 5.1	25.7 ± 5.3	<0.001	0.779	0.894
1 min STST	34.1 ± 6.8	34.0 ± 6.8			
1 min Post STST	29.9 ± 6.1	30.8 ± 6.5			
SpO_2 (%)	n = 25*	n = 24*			
T_0	92.4 ± 3.0	92.7 ± 2.2	<0.001	0.781	0.948
T_2	91.3 ± 3.4	91.5 ± 3.8			
T_3	93.7 ± 2.5	93.9 ± 2.2			
HR (bpm)	n = 25*	n = 25*			
T_0	81.0 ± 16.1	82.3 ± 15.8	<0.001	0.822	0.934
T_2	95.4 ± 17.4	96.2 ± 17.8			
T_3	84.2 ± 17.6	85.3 ± 16.6			

Data are presented as mean ± SD.
*Missing datapoint(s) due to pulse oximeter with heart rate monitoring malfunction.
Abbreviations: bpm; breathes or beats per minute; HR, hearth rate; RR, respiratory rate; SpO_2, pulse oxygen saturation; STST, 1-min sit-to-stand test; T_0: before the STST; T_2: 60-s post-STST; T_3: 120-s post-STST

Table 4. Subjective perceptions with the surgical facemask before (pre) and after (post) the 1-min sit-to-stand test.

Subjective sensations	Pre n = 28	Post n = 28	P value
Humidity	3.0 ± 2.3	4.7 ± 2.8	0.001
Heat	4.0 ± 2.7	5.4 ± 2.9	0.007
Resistance	3.6 ± 2.3	4.6 ± 2.5	0.001
Fatigue	3.8 ± 2.4	5.2 ± 2.8	0.006
Overall discomfort	3.6 ± 2.9	5.1 ± 2.9	0.001

rehabilitation in patients with respiratory diseases. Two studies have recently demonstrated that, in patients with chronic obstructive pulmonary disease, the surgical mask slightly increased dyspnoea but had no impact on cardio-respiratory parameters or on the distance covered during a 6-min walking test.[16,17] Similarly, exercise performance and cardio-respiratory variables were not impacted by the surgical mask in our post-acute COVID-19 patients. These results are reassuring in promoting regular exercise routine at hospital discharge in a long-term pandemic as our data showed that the discomfort associated with mask does not lead to safety concerns. Our data may also mitigate fears to refer these patients in rehabilitation centres where universal mask use is required. This is especially relevant since patients hospitalized for COVID-19 have a low functional exercise capacity at discharge, and that the spontaneous recovery after three months is poor.[18]

It is only at high intensity exercise that the masks reduce exercise performance.[15,19,20] A recent study found that the intensity of the 1-min sit-to-stand test was not sufficiently high to elicit an increase in dyspnoea sensation with the surgical mask in young healthy adults.[21] A clinically relevant increase in dyspnoea was only noted at the end of the sit-to-stand test with the cloth mask, probably because this mask opposed more resistance to airflow than the surgical mask.[21] In contrast, this study found that acute COVID-19 patients near hospital discharge experienced a significant and clinically relevant dyspnoea sensation at rest, as soon as the surgical mask was worn.

Although our patients were recovering from COVID-19, they still presented impaired cardio-respiratory fitness as shown by the abnormally elevated respiratory rate and low oxygen saturation values at ambient air before the sit-to-stand test (Table 3). The addition of a slight resistance to airflow with a possible source of carbon dioxide rebreathing may then have been sufficiently high enough to reach a point susceptible to makes breathing oppressive.

The dyspnoea sensation with the surgical mask was heightened during the effort, which is likely the reflect of a greater airflow resistance associated to higher ventilation demand while exercising.[15] Surprisingly, although dyspnoea at recovery was higher than dyspnoea before the test, the difference between the masked and unmasked conditions was no longer significant. Dyspnoea is a complex sensation involving sensory and affective dimensions which are closely intertwined.[22] In patients without significant dyspnoea at baseline such as in our cohort, wearing a facemask make patients suddenly aware of their own respiration, which can be unsettling.[23] However, post-effort, the blunting of multiple inconvenient sensations (mask humidity, hotness, etc) as well as the feeling of relief from effort cessation may have prevailed over dyspnoea sensation by distracting the patient's attention from their own respiration. Of note, the kinetic of change in dyspnoea and rate of perceived leg exercise was roughly similar between subgroups of participants discriminated by the levels of oxygen requirements during their hospitalization. Therefore, the findings and clinical messages of this study may apply to a broad spectrum of post-acute COVID-19 patients. However, as defined per our eligibility criteria, we are unable to infer these findings in patients who recovered from critical COVID-19 pneumonia.

Our study had several limitations. First, bodily movements associated with the sit-to-stand test made the evaluation of heart rate and peripheral oxygen saturation unreliable immediately after the test. We therefore only collected these data once they had stabilised, *i.e.* 60 s post-effort. Second, the masks were tightly attached to the patient's face and may have collapsed during the effort, potentially increasing dyspnoea.

To conclude, in COVID-19 patients close to hospital discharge, the surgical facemask increased dyspnoea at rest as well as during a short submaximal exercise test but had no impact on the cardio-respiratory response or on exercise performance during the test. Since perceived breathlessness is not related to physiological measures, these data offer insights for rehabilitation as they suggest that masking should not discourage people who recover from post-acute COVID-19 to engage in physical or pulmonary rehabilitation activities in places where mask-wearing has become mandatory. These findings are particularly relevant since early referral from the acute care setting to rehabilitation services is critical to minimize the functional impact of post-acute COVID-19 patients.

Clinical messages

- In COVID-19 patients near hospital discharge, the surgical mask increased dyspnoea at rest or during a submaximal exercise test but this perception is uncoupled to physiological measures.
- These findings support timely referral to rehabilitation activities for post-acute COVID-19 patients even if mask-wearing has become mandatory during these activities.

Author contribution statement

W. Poncin and G Reychler had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. *Concept and design:* W. Poncin, G. Reychler. *Acquisition, analysis, or interpretation of data:* All authors. *Drafting of the manuscript:* W. Poncin. *Critical revision of the manuscript for important intellectual content*: All authors. *Statistical analysis*: W. Poncin, G. Reychler. *Supervision*: W. Poncin, G. Reychler.

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Supplemental material

Supplemental material for this article is available online.

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