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Wearing a surgical mask: Effects on gas exchange and hemodynamic responses during maximal exercise

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Abstract

The importance of using masks during exercise has increased since the coronavirus disease-2019 (COVID-19). This study aimed to investigate the effects of using surgical masks on gas exchange and exercise responses in maximal exercise. Twenty-six participants were included. Participants performed the maximal exercise tests twice, masked, and unmasked. Gas exchange parameters (at maximal exercise and anaerobic threshold [AT]) and hemodynamic responses were measured. In the hemodynamic responses measured at rest, only the saturation of peripheral oxygen (SpO_2) was lower in the masked (mean: 97.23 ± 1.33%) measurement than in the unmasked (mean: 97.96 ± 1.07%) measurement ($p = 0.006$). Test duration was lower in the masked test (unmasked: 10.32 ± 1.36 min vs. masked: 10.03 ± 1.42 min, $p = 0.030$). Peak oxygen consumption (VO_{2peak}) (unmasked: 31.23 ± 5.37 vs. masked: 27.03 ± 6.46 ml/kg/min), minute ventilation (V_E) l/min, and energy expenditure (EE) kcal/hour were higher in unmasked tests ($p < 0.001$). There was no difference in the gas exchange parameters measured at the AT in the masked and unmasked tests ($p > 0.05$). Respiratory gas exchange parameters were affected in peak exercise due to increased respiratory workload, but not at the AT. There was no change in hemodynamic responses because vascular control may not be affected by mask usage.

KEYWORDS

COVID-19, exercise capacity, gas exchange, mask usage, oxygen consumption

1 | INTRODUCTION

Since the epidemic of coronavirus disease-2019 (COVID-19) in Wuhan, China, in December 2019, the virus has continued to spread in almost every country in the world (Lee, 2020). This results in a rapid increase in the usage of face masks becoming a kind of personal protective equipment against the spread of respiratory infections and effective at preventing transmission of respiratory viruses (Desai & Mehrotra, 2020). Commonly used face masks are the surgical disposable type. A surgical mask worn by a healthcare professional within 1 m from the patient protects against contamination by droplets and can reduce the risk by 80% (Azap & Erdinç, 2020; Cook, 2020). Therefore, wearing a surgical mask is one of the precautions that can limit the spread of some respiratory viral diseases, including COVID-19.

With the increase in the use of masks, wearing a mask during physical activity has become a topic of discussion and

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curiosity. One of the main problems with the usage of masks during exercise is that it prevents comfortable breathing and creates resistance to airflow due to humidity (Santos-Silva et al., 2020). Additionally, in the same setting, this may cause a hypercapnic and hypoxemic environment due to insufficient oxygen (O_2) and carbon dioxide (CO_2) exchange (Roberge et al., 2010). However, respiratory masks are used to evaluate cardiopulmonary capacity (Johnson, 2016). A type of mask called "gas masks" was used to increase lung capacity, where this hypoxic environment was consciously created in athletes. Thus, as wearing a mask during exercise may positively contribute to ventilation and lung capacity, training is often performed in hypoxic conditions to increase aerobic performance (Öncen & Salih, 2018). Conversely, these respiratory masks are not used by health professionals as they are not appropriate for them and the general population. Additionally, there is not enough information in the literature on how surgical masks affect cardiopulmonary capacity in healthy individuals (Fikenzer et al., 2020).

Changing a sedentary lifestyle and reversing its health-related effects are crucial during the COVID-19 pandemic (Chandrasekaran & Fernandes, 2020). To prevent the risk of contamination during physical activity, exercising with a mask has gained importance, but there is limited number of studies investigating the effect of mask usage during exercise on exercise capacity and hemodynamic responses in healthy individuals. Our study aimed to evaluate the effects of the widespread usage of surgical masks on gas exchange parameters and exercise responses (heart rate [HR], blood pressure [BP], saturation of peripheral oxygen [SpO_2], and perceived dyspnoea severity).

2 | MATERIALS AND METHODS

2.1 | Participants

Twenty-six healthy volunteers were included in the study. Active participants from the local university staff and students were included. Age, height, weight, sex, and demographic data were recorded. Participants with chronic cardiac (heart failure, unstable angina, myocardial infarction, arrhythmia, etc.), pulmonary (asthma, pneumonia, etc.), neurological, musculoskeletal, and orthopaedic diseases and the ones who had been diagnosed with COVID-19 before or had a history of contact with someone diagnosed with COVID-19 were excluded. Professional athletes were also not included in the study. Each participant was interviewed regarding any COVID-19 symptoms according to the European Respiratory Society recommendations (McGowan et al., 2020).

2.2 | Study design

Exercise tests were performed randomly with and without a mask. Written informed consent was obtained from all participants included in the study. The study protocol was authorized by the KTO Karatay University Ethics Committee (date of approval: 17/07/2020, approval number: 2020/004) in compliance with the ethical standards of the Helsinki Declaration.

At least 72-h break was allowed between two exercise tests. Both tests were performed at the same time of the day; masks were worn 15 min before starting the exercise. Having worn a surgical mask, it was checked whether there was any air leak during inspiration and expiration. The same type of disposable surgical mask (La Pante, PSM Co. Ltd.) had a Conformité Européene (CE) mark that was used for each participant in the study.

Cardiopulmonary Exercise Test (CPET) was performed taking into consideration all precautions of the European Respiratory Society (ERS) current exercise test guidelines published for the COVID-19 pandemic (McGowan et al., 2020). According to ERS recommendations, the test should always be performed with a high specification disposable bacterial and viral filter selected in our research (Antibacterial Filter Round Mouthpiece). To allow airborne droplets to settle on surfaces, the laboratory should be left for at least 20 min (Faghy et al., 2020) before sterilization. The sterilization of the device used was repeated after each exercise test according to the user guide. Before and after each test, the environment was ventilated. All tests were completed without any complications or discomfort. The participants were not informed about the results they obtained during the test to overcome the anticipation bias.

2.3 | CPET

CPET provides an assessment of integrative exercise responses involving the pulmonary, cardiovascular, and skeletal muscle systems that are not adequately reflected through measurement of individual organ system function (Albouaini et al., 2007). For this reason, exercises using large muscle groups, especially the lower limb muscles, are preferred during the test (Albouaini et al., 2007; Ferrazza et al., 2009). Walking is an activity closer to daily life compared to cycling. In our study, the Bruce protocol was preferred because more muscle groups are engaged compared to when using a bicycle ergometer, it is frequently used in the clinic, and it induces more oxygen consumption than the bicycle tests (Hanson et al., 2016). In the Bruce protocol, each test starts with a speed of 1.7 km/h, a 10% slope and an increase in speed; slope was increased every three minutes on the treadmill (Treadmill h/pcosmos 150/50). The test proceeded until the individual was unable to continue the test (Bruce et al., 1974).

CPET utilizes noninvasive exercise stress testing to generate multiple variables that are then extrapolated from this data, including anaerobic threshold (AT) and VO_{2max}, markers of aerobic capacity. AT is defined by the term as the point at which oxygen demand exceeds supply and anaerobic metabolism begins (Albouani et al., 2007). In our study, peak oxygen consumption (VO_{2peak}), minute ventilation (V_E), met (metabolic equivalent), and energy expenditure (EE) were measured and calculated directly with a gas analyser at maximal exercise and AT (Cosmed Fitmate Med). HR, BP, SpO_2, and perceived dyspnoea severity (Modified Borg Scale [MBS]) (Burdon et al., 1982) were recorded before and immediately after the tests and 5 min after rest.

2.4 | Statistical analysis

According to the study by Fikenzer et al. (2020), the VO_{2peak} masked and unmasked test results were investigated, and the number of participants planned to be included in the study was determined via G Power 3.1.9.2 (95% statistical power) programme as 24. An additional participant has been included in case of dropout, and a total of 25 participants were included in the study. The statistical analyses were performed using SPSS 25.0 for Windows. Kolmogorov–Smirnov test was used to analyse the normality of the data. In the measurement of the dependent variables, for normal distrubition *t* test, if the variable does not normally distributed Wilcoxon signed-rank test were used to compare the repeated measures of each group (Hayran & Hayran, 2011). The significance level was determined at a 95% confidence interval according to the value of $p < 0.05$.

3 | RESULTS

Twenty-six participants (15 females and 11 males; mean age: 24.88 ± 4.09) were included in the study. The baseline characteristics of participants are given in Table 1.

3.1 | Comparison of masked and unmasked CPET results

CPET results are given in Table 2. Test duration was significantly lower in masked than unmasked test (mean: 10.03 ± 1.42 vs. 10.32 ± 1.36 min; $p = 0.030$). The peak values were significantly higher in unmasked compared to masked test in view of met, VE and EE values ($p < 0.01$). Peak oxygen consumption (VO_{2peak}) was significantly higher in unmasked (mean: 31.23 ± 5.37 ml/kg/min) exercise test than masked test (mean: 27.03 ± 6.46 ml/kg/min). In the masked and unmasked exercise tests, there was no significant difference between the respiratory frequency and HR_{peak} values, but these values were higher in the unmasked group due to the longer exercise test time ($p > 0.05$). No difference was found between the two tests in all parameters measured at the AT ($p > 0.05$).

TABLE 1 Baseline characteristics of participants

	Mean ± *SD*	Min	Max
Age (years)	24.88 ± 4.09	19	34
Height (m)	1.72 ± 0.07	1.60	1.87
Weight (kg)	67.83 ± 13.41	46.00	97.40
BMI (kg/m^2)	22.58 ± 3.32	16.49	31.09
HR (bpm)	85.69 ± 12.71	61	116
SBP (mmHg)	107.88 ± 9.71	90	120
DBP (mmHg)	70.00 ± 8.60	50	85

Note: Values are mean ± *SD*.

Abbreviations: BMI, body mass index; HR, heart rate; DBP, diastolic blood pressure; MBS, Modified Borg Scale; SBP, systolic blood pressure; SpO_2, peripheral oxygen saturation.

TABLE 2 Comparison of masked and unmasked CPET results.*

	Unmasked Mean ± *SD*	Masked Mean ± *SD*	*p* Value
Test duration (min)	10.32 ± 1.36	10.03 ± 1.42	0.030*
MET	8.92 ± 1.53	7.72 ± 1.84	0.001*
Peak			
VO_2 (ml/kg/min)	31.23 ± 5.37	27.03 ± 6.46	0.001*
VO_2 (ml/dk)	2145.27 ± 647.70	1842.76 ± 622.06	0.001*
V_E (l/min)	79.16 ± 21.27	63.74 ± 19.91	<0.001†
Respiratory frequency	44.31 ± 7.66	42.38 ± 8.19	0.072
HR (bpm)	180.3 ± 13.46	173.65 ± 17.59	0.078
EE (kcal/h)	643.62 ± 194.38	552.76 ± 186.50	0.001*
Anaerobic threshold			
AT time (min)	3.72 ± 0.90	3.63 ± 0.79	0.648
VO_2 (ml/kg/min)	16.43 ± 2.91	14.91 ± 4.34	0.103
VO_2 (ml/dk)	1114.46 ± 299.88	1009.57 ± 355.42	0.117
V_E (l/min)	16.43 ± 2.91	25.24 ± 9.73	0.056
Respiratory frequency	24.81 ± 7.38	24.07 ± 8.49	0.489
Heart rate (bpm)	133.08 ± 33.48	131.34 ± 19.44	0.768
EE (kcal/h)	334.31 ± 89.98	302.88 ± 106.70	0.117
AT % VO_2	53.08 ± 10.18	55.11 ± 12.98	0.436
AT % HR	75.77 ± 15.14	75.15 ± 7.82	0.837

Note: Values are mean ± *SD*.

Abbreviations: AT, anaerobic threshold; CPET, cardiopulmonary exercise test; EE, energy expenditure; HR, heart rate; MET, metabolic equivalent; *SD*, standard deviation; VE, minute ventilation; VO_2, oxygen consumption.

*Paired Student *t* test

†Wilcoxon Signed-rank test, $p < 0.05$.

3.2 | Hemodynamic responses of masked and unmasked tests

Hemodynamic responses measured in masked and unmasked tests of the participants at rest, immediately after exercise tests, and recovery values are given in Table 3. Among the hemodynamic

TABLE 3 Comparison of hemodynamic responses in masked and unmasked exercise tests

	Unmasked Mean ± *SD*	Masked Mean ± *SD*	*p* Value
Rest			
SBP (mmHg)	107.88 ± 9.71	105.00 ± 9.69	0.113
DBP (mmHg)	70.00 ± 8.60	73.27 ± 21.11	0.683
HR (bpm)	85.69 ± 12.71	86.54 ± 14.83	0.651
$SpO_{2\%}$	97.96 ± 1.07	97.23 ± 1.33	0.006†
MBS	0.75 ± 1.08	0.69 ± 1.14	0.910
Immediately After Test			
SBP (mmHg)	135.19 ± 14.52	134.23 ± 14.53	0.737
DBP (mmHg)	67.50 ± 7.64	67.50 ± 7.51	0.927
HR (bpm)	161.88 ± 13.08	160.73 ± 14.27	0.573
$SpO_{2\%}$	97.15 ± 1.48	96.77 ± 2.16	0.190
MBS	5.61 ± 1.89	6.38 ± 1.67	0.066
Recovery			
SBP (mmHg)	108.08 ± 7.88	106.15 ± 8.75	0.210
DBP (mmHg)	69.62 ± 7.47	69.62 ± 6.91	0.918
HR (bpm)	108.08 ± 10.51	104.27 ± 12.82	0.023*
$SpO_{2\%}$	96.88 ± 1.14	97.23 ± 1.33	0.095
MBS	1.15 ± 1.20	1.38 ± 1.48	0.333
Delta			
ΔSBP (mmHg)	27.30 ± 15.95	29.23 ± 9.86	0.593
ΔDBP (mmHg)	−2.50 ± 7.77	−5.76 ± 22.16	0.812
ΔHR (bpm)	76.19 ± 12.04	74.19 ± 16.89	0.511
$\Delta SpO_{2\%}$	−0.80 ± 1.49	−0.46 ± 1.96	0.280
ΔMBS	4.86 ± 1.88	5.69 ± 1.84	0.077

Note: Values are mean ± *SD*.

Abbreviations: DBP, diastolic blood pressure; HR, heart rate; MBS, Modified Borg Scale; SBP, systolic blood pressure; *SD*, standard deviation; SpO_2, peripheral oxygen saturation.

*Paired Student *t* test.

†Wilcoxon signed-rank test, $p < 0.05$.

responses of masked and unmasked tests measured at rest, only the SpO_2 was lower during the use of a mask ($p = 0.006$). Although it was not statistically significant, the SpO_2 was lower after the test in masked tests than in the unmasked tests (mean: 96.77 ± 2.16% vs. 97.15 ± 1.48% $p > 0.05$). Likewise, MBS score was not statistically significant and was higher in the masked test (mean: 6.38 ± 1.67 vs. 5.61 ± 1.89 $p > 0.05$). The recovery HR was statistically higher in the masked test than in the unmasked test ($p = 0.023$). There was no difference between masked and unmasked exercise tests in other hemodynamic responses such as HR, BP, MBS, and delta values measured before and immediately after the tests ($p > 0.05$).

4 | DISCUSSION

The present study aimed to investigate effects of mask usage on the hemodynamic responses and the differences in gas exchange parameters in maximal exercise in healthy individuals. Our results showed that the usage of surgical masks had noticeable effects, especially on gas exchange parameters and hemodynamic responses were less affected during maximal exercise.

The decrease in oxygen consumption may be caused by the resistance of the airways due to the usage of masks (Lee & Wang, 2011). Because of stress induced by exercise, this airway resistance increases the respiratory workload and restricts ventilation (Fikenzer et al., 2020). These respiratory protective masks may reduce tidal volume, resulting in lower respiratory frequency and consequently lower ventilation (Melissant et al., 1998). Similarly, in our study, VO_{2peak} and V_E were lower in the masked tests than in the unmasked tests owing to airway resistance and humidity caused by the mask. Due to the decrease in ventilation, peak respiratory frequency in the masked test was not statistically significant, but it was lower. Despite a difference in gas exchange parameters during peak exercise, these values at the anaerobic threshold did not differ in masked and unmasked tests. Thus, the usage of masks did not affect the gas exchange parameters because of the shorter exercise time, the absence of fatigue, and the low workload at anaerobic threshold.

Current evidence and experimental studies have shown that the usage of a surgical mask does not negatively have an effect on peripheral oxygen saturation (Samannan et al., 2020). In this study, the peripheral oxygen saturation value decreased by 0.73% with the usage of a mask at rest. Although this finding is statistically significant, it is a relatively small decrease as it may have resulted from the adaptation of the oxygen use capacity of people who have used masks for a long time.

In the study by Fikenzer et al. (2020), it was stated that cardiac work tended to increase insignificantly with less power achieved in masked tests, and myocardial compensation developed against the pulmonary limitation caused by mask use. Our results are consistent with the literature: there is no difference in the HR and BP because the vascular control was not affected using masks. Only the recovery HR is higher in the unmasked group. This finding may have resulted from the longer test period and higher workload in the unmasked test.

The usage of masks during exercise can cause a hypercapnic hypoxia environment (Roberge et al., 2010). This acidic environment reduces peripheral vasodilation, coronary perfusion, and muscle metabolism but increases cardiac load; these changes contribute to the increase of fatigue (Chandrasekaran & Fernandes, 2020). Besides, the use of a mask was emphasized to be likely to cause dyspnoea because of the re-inhalation of CO_2 released during exercise (Banzett et al., 1990). In our study, MBS, which was used to determine perceived dyspnoea severity associated with fatigue during exercise, was not statistically significant, but a lower workload and a higher MBS score were noted in the masked group. Based on this finding, it is possible to say that the use of masks can slightly increase the perceived severity of dyspnoea at the maximum workload.

The use of masks during maximal exercise in young and healthy individuals had a noticeable effect on respiratory gas exchange parameters due to increased airway resistance and humidity but did not affect hemodynamic responses and dyspnoea severity.

Our study had some limitations. Because of the type of gas analyser device used, the CO_2 level could not be measured in the study. Since the population of our study consisted of young and healthy individuals, it is not possible to interpret the findings for different chronic diseases and different age groups. The resistance-related properties of surgical masks may vary from brand to brand. It is difficult to specify a certain level of resistance specific to the surgical mask used in our study. Comparing different types of masks (cloth mask, N95, etc.) in the study could have allowed more interesting results, but the COVID-19 pandemic conditions and especially the surgical type of mask used in daily life caused the use of a single type of mask in our study. The results of our study can only be interpreted for the walking exercise performed on the treadmill, where the workload increases progressively. For this reason, it is difficult to interpret the study outcomes for exercises such as long-term walking activity or cycling, which are often preferred in daily life. For this reason, we believe that studies investigating the effect of mask use on daily activities due to diseases with potential contamination risk will contribute to the literature.

5 | CONCLUSIONS

The present study showed that the usage of masks affected the respiratory gas exchange parameters during maximal exercise in healthy young adults. The use of masks may slightly reduce oxygen consumption, especially during peak exercise. No negative effects on hemodynamic parameters were reported in this study. In the future, we believe that further studies investigating the potential usage of surgical masks used in daily life in a controlled manner for also physical activities will contribute to the literature. Moreover, as this study focused on the effects of the mask for maximal exercise intensity, our results during maximal intensity exercise in young healthy individuals are stimulating for sports-exercise programmes for the same group of individuals. We also suggested conducting studies examining exercise responses of the mask for different age groups.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data are available on request from the authors.

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