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Original Article

Exercise Capacity and Perceived Exertion on Treadmill Stress Test Performed While Wearing vs Without a Surgical Mask: A Randomized Clinical Trial in Healthy Adults

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Background: The graded exercise treadmill stress test (GXT) is among the most frequently performed tests in cardiology. The COVID-19 pandemic led many healthcare facilities to require patients to wear a mask during the test. This study evaluated the effect of wearing a surgical face mask on exercise capacity and perceived exertion.

Methods: In this prospective, randomized crossover trial, 35 healthy adults performed a GXT using the Bruce protocol while wearing a surgical mask, and without a mask. The primary outcome was exercise capacity in metabolic equivalents (MET), and the secondary outcome was exercise perception on the modified Borg scale (from 0 to 10). Effort duration, heart rate, oxygen saturation, and blood pressure were also analyzed.

Results: Exercise capacity was reduced by 0.4 MET (95% confidence interval [CI] -0.7 to -0.2) during the GXT with a mask (11.8 ± 2.7 vs

RÉSUMÉ

Introduction : L'épreuve d'effort gradué sur tapis roulant (GXT, de l'anglais *graded exercise test*) compte parmi les épreuves les plus fréquemment réalisées en cardiologie. La pandémie de COVID-19 a poussé de nombreux établissements de soins de santé à exiger aux patients le port du masque durant l'épreuve. La présente étude portait sur l'évaluation des effets du port du masque chirurgical sur la capacité à l'effort et l'effort perçu.

Méthodes : Dans cet essai croisé prospectif, 35 adultes en bonne santé ont réalisé une GXT selon le protocole de Bruce, avec le port du masque chirurgical et sans le port du masque. Le principal critère d'évaluation était la capacité à l'effort exprimée en équivalents métaboliques (MET, de l'anglais *Metabolic Equivalent of Task*), et le critère secondaire était la perception de l'effort selon l'échelle de Borg modifiée (de 0 à 10). La durée de l'effort, la fréquence cardiaque, la

Exercise testing is a convenient and valuable tool frequently used to assess patients with known or suspected cardiovascular disease. The most acknowledged indication for a graded exercise stress test remains the diagnosis of coronary artery disease. However, exercise testing is also frequently used for prognostic evaluation of different cardiopathies and risk stratification in cardiac rehabilitation.¹

Since March 2020 and the declaration of a global pandemic caused by COVID-19, many healthcare facilities request that patients always wear a mask while on the premises, to prevent the potential spreading of the virus to other patients or workers. In 2020, the American Society of Echocardiography published a statement on the reintroduction of echocardiographic services during the pandemic, recommending that, due to the potential for aerosol production during stress testing, patients and providers should consider wearing, at minimum, a surgical face mask, and an N95 in particular circumstances.² In our university-affiliated hospital, patients who need a graded exercise treadmill stress test (GXT) must wear a surgical face mask during the test. Many of them reported that the test was more difficult with a mask and believed they would achieve a better result without it. As exercise capacity is an important predictor of mortality,^{3,4} and a useful parameter in the follow-up of many patients with cardiovascular diseases, determining whether wearing a mask affects the results of a GXT, and if adjustments to the test interpretation are warranted, is essential.

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Ethics Statement: The study protocol was approved by the University Research Ethics Board of the Sherbrooke University Hospital Centre (CHUS). Informed consent was signed by all participants before beginning the study, in accordance with the Declaration of Helsinki.

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12.3 ± 2.5 MET, $P = 0.001$), and the final perceived effort increased by 0.5 points (95% CI 0.2 to 0.8; 8.4 ± 1.3 vs 7.9 ± 1.6, $P = 0.004$). Effort duration was cut down by 24 seconds (CI -0:39 to -0:09; 10:03 ± 2:30 vs 10:27 ± 2:16 [minutes:seconds], $P = 0.003$). Oxygen saturation was slightly lower at the end of the test when participants wore a mask. No significant differences occurred in heart rate or blood pressure during the test.

Conclusion: Wearing a surgical mask causes a statistically significant decrease in exercise capacity and increase in perceived exertion. This small effect is not clinically significant for the interpretation of test results.

Before the COVID-19 pandemic, a few studies evaluated the effect of wearing a surgical mask on exercise testing results. One study included 20 healthy adults undergoing a 1-hour treadmill walk (5.6 km/h) and found no clinically significant physiological change.⁵ However, another study of 44 healthy participants found that wearing a surgical face mask increased dyspnea during a 6-minute walk test, without changing the distance performed or other physiological parameters.⁶ Many more studies on this subject have been performed since 2020, investigating the impact of cloth, surgical, and N95 face masks during vigorous ergocycle effort. The results are variable, but globally, they suggest a mild effect or no effect at all on exercise capacity, despite a small deterioration of the pulmonary function parameters.⁷⁻⁹

When the current study was designed, no data had been published assessing the effect of wearing a face mask during a GXT using the Bruce protocol. Because this protocol is the one most commonly used for treadmill testing in cardiology, assessment of the effects of the mask and how they should impact the interpretation of results appeared to be important.¹⁰ More recently, Driver et al. demonstrated a 14% reduction in exercise duration and a 29% decrease in maximal oxygen consumption among participants during a GXT using the Bruce protocol performed while wearing a cloth face mask.¹¹

The purpose of the present study was to evaluate whether wearing a surgical face mask affects exercise capacity and perceived exertion during a GXT using the Bruce protocol in healthy participants. The mask type and the protocol were chosen to reflect the most common “real-life” setting in our cardiology laboratory. Based on the literature about surgical face masks and exercise testing, we hypothesized that the effect would not be clinically significant.

Materials and Methods

Population

Thirty-five healthy adults between ages 18 and 65 years who had received at least one dose of COVID-19 vaccine, at least 4 weeks before their first visit, were recruited. Exclusion criteria included the following: proven or suspected cardiac or

respiratory disease or other medical condition; requiring medication for the treatment of cardiovascular, respiratory, or neuromuscular conditions; walking difficulties limiting the capacity to perform a GXT; contraindications to GXT; abnormal resting electrocardiogram (ECG) limiting the interpretation of the stress test; and incapacity to wear a face mask or to understand and follow instructions. To reduce the risk of COVID-19 spread, participants who had symptoms related to COVID-19, had an unprotected exposure to a COVID-19-positive person, or had traveled outside the country in the 14 days before their research appointment had to cancel or postpone their participation.

The recruitment was done via e-mails sent to our organization’s employees, and posters placed in hospitals.

Résultats : La capacité à l’effort était réduite de 0,4 MET (intervalle de confiance [IC] à 95 % de -0,7 à -0,2) durant la GXT réalisée avec le port du masque (11,8 ± 2,7 vs 12,3 ± 2,5 MET, $P = 0,001$), et l’effort perçu final avait augmenté de 0,5 point (IC à 95 % de 0,2 à 0,8; 8,4 ± 1,3 vs 7,9 ± 1,6, $P = 0,004$). La durée de l’effort était réduite de 24 secondes (IC à 95 % de -0:39 à -0:09; 10:03 ± 2:30 vs 10:27 ± 2:16 [minutes:secondes], $P = 0,003$). La saturation en oxygène était légèrement plus faible à la fin de l’épreuve lorsque les participants portaient le masque. Aucune différence significative de la fréquence cardiaque et de la pression artérielle n’est apparue durant l’épreuve.

Conclusion : Le port du masque chirurgical entraîne une diminution statistiquement significative de la capacité à l’effort et une augmentation de l’effort perçu. Cet effet minime n’est pas cliniquement significatif pour l’interprétation des résultats de l’épreuve.

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Study design

The study protocol was approved by the University Research Ethics Board of the Sherbrooke University Hospital Centre (CHUS). It was registered on [ClinicalTrials.gov](https://clinicaltrials.gov) (NCT04891120). The study design was a randomized counter-balanced crossover trial. The participants were randomized into 2 groups. The participants in group A performed their first GXT while wearing a surgical face mask, and those in group B started the study without wearing a mask. On the second visit, all the participants crossed over to the other intervention. The second visit was scheduled to occur at least 48 hours after the first one. If possible, both GXT tests were scheduled for the same time of the day. Participants were instructed to reproduce the same hydration, nutrition, and resting conditions during the 2 visits. They were asked to refrain from strenuous activity for 48 hours before each test.

Outcomes

The primary outcome was change in exercise capacity (measured in metabolic equivalents [MET]) for participants undergoing the GXT with vs without a surgical face mask. The secondary outcome was the difference in perceived exertion on the modified Borg scale. We also compared the following exercise parameters as measured for participants wearing vs not wearing a surgical mask: heart rate, blood pressure, oxygen saturation, the time before reaching 85% of

maximal predicted heart rate, and the main reason why the participant had to stop the test.

Interventions

All participants provided informed written consent before beginning the study, in accordance with the Declaration of Helsinki. On the first visit, the eligibility criteria were confirmed. The following characteristics of each participant were collected: age, sex, weight, height, body mass index, and self-reported mean duration of physical activity per week. A physical examination was performed to rule out any contraindication for a GXT, followed by a resting ECG.¹²

The GXT was supervised by an electrophysiology technician and a 5th-year cardiology resident. Standardized instructions were given to the participants, and no physical or verbal encouragement was allowed. The modified Borg scale was explained to the participants (0 was described as sitting and doing nothing, and 10 was described as the most difficult exercise they could do), and they could refer to a visual chart placed in front of the treadmill. Participants were not allowed to use the handrails of the treadmill to help with their effort. The standard Bruce protocol was used for all participants. This protocol is composed of 7 stages, with increasing inclination and speed at each stage. The stages last 3 minutes, except for the last one, which continues with the same parameters until the participant reaches a state of exhaustion.¹² Blood pressure was obtained at rest and during exercise with a manual sphygmomanometer (Hillrom, Welch Allyn FlexiPort Reusable Blood Pressure Cuff, adult size; Welch Allyn, Mississauga, ON); heart rate was measured with the treadmill ECG; and saturation was obtained with a portable signal extraction pulse oximeter (Masimo Rad-5; Massimo Canada ULC, Vancouver, BC) before starting the test and during the effort. We used a T2100 treadmill from General Electric Healthcare (Wauwatosa, WI). After 1 minute of each stage and at the end of the GXT, blood pressure, heart rate, oxygen saturation, and perceived exertion (modified Borg scale from 0 to 10) measurements were collected.¹³ The participants were instructed that the speed and incline would increase 10 seconds before the beginning of each stage. They were instructed to perform their maximal possible effort and let the technician know when they could no longer continue, so the test could be stopped. The GXT could also be stopped if, for any reason, the supervisors deemed that pursuing the test was dangerous. The reason for termination of the GXT, and the time (minutes: seconds) at which participants reached 85% of their maximal predicted heart rate (85% of $220 - \text{age}$; an important target during stress testing in clinical cardiology¹⁴), were collected, as well as the effort duration (minutes: seconds), the maximal heart rate, and the MET achieved. The MET were estimated with the American College of Sports Medicine equation: $\text{VO}_2 = 3.5 + (0.2 \times \text{speed}) + (0.9 \times \text{speed} \times \% \text{grade})$, where VO_2 is the maximum rate of oxygen consumption.¹⁵ A monitored sitting rest period of 3 minutes was completed. The treadmill's screen displaying information about the test was hidden from the participants, to prevent them from getting access to any information that could affect the results of the tests.

The masks used were blue surgical masks with ear loops, with a splash resistance of > 16 kPa, and a bacterial filtration

power of 98% (PRI-MED Medical Products, Alberta, Canada). A strict disinfection procedure was applied after each GXT, and the supervisors wore a gown, a protective visor, and gloves during each test.

The resting and stress ECGs were analyzed by a cardiologist. If an anomaly was observed, the participant was referred to the appropriate resource for further investigation.

Sample size

For the sample size calculation, a difference of 1 MET was chosen as clinically significant according to the results of prior studies demonstrating a difference in mortality risk with a change of 1 MET in exercise capacity.^{3,4,16} The standard deviation from the reference population used was 2.1, following the normal values for healthy adults available in the American Heart Association guidelines.¹⁷ The correlation between results for participants wearing vs not wearing a mask was presumed to be more than 75%. The sample size calculated for an alpha value of 0.05 and a power of 80% to detect a 1 MET difference was 20, based on a paired Student's *t*-test. We recruited 35 participants to account for possible losses to follow-up and incomplete data related to COVID-19 restrictions.

Randomization and blinding

A randomized sequence in blocks of 4 was generated. Participants were assigned to group A or B at their first visit, following this sequence. Participants, supervisors, and the authors were not blinded to the intervention due to the nature of the study, but the statistician was blinded during data analysis.

Statistical method

Demographic quantitative data are presented as mean with standard deviation if normally distributed or as median with interquartile range if non-normally distributed. Demographic categorical variables are presented in frequency and percentage. For the primary and secondary outcomes, a paired Student's *t*-test was chosen for normally distributed variables, and a Wilcoxon's signed-rank test was used for non-normally distributed variables. Normality was determined based on visual assessment of the histograms. McNemar's test was used for dichotomic variables. Equivalence testing using the paired "two one-sided *t*-tests" (TOST) was also performed to assess whether the exercise capacity (measured in MET) was equivalent for participants undergoing the GXT while wearing vs not wearing a surgical face mask (margin of equivalence of ± 1 MET^{3,4}). TOST tests the null hypothesis of statistical difference, meaning that if the null hypothesis is rejected, we can conclude that the observed difference is included in the equivalence limits (± 1 MET). The results with a *P* value < 0.05 were considered statistically significant. IBM (Armonk, NY) SPSS Statistics 27 statistical software and R version 4.1.3 were used.

Results

A total of 35 participants were randomized in the study, of which 33 completed the 2 GXTs and were included in the analysis (Fig. 1). The recruitment period was May of 2021, and the GXT took place in May and June, 2021. The trial was stopped when the predetermined maximal number of participants was reached.

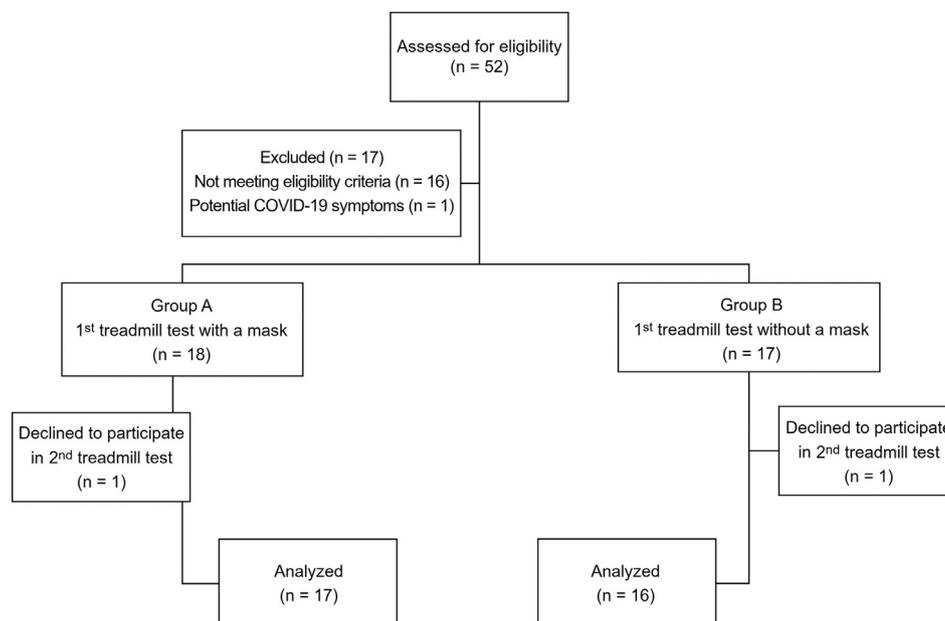


Figure 1. Flow chart of the study. Groups A and B were randomized.

The characteristics of the participants are shown in Table 1. Participants were mostly women (66%) and were aged between 21 and 65 years.

Table 2 shows the exercise parameters as measured for participants wearing vs not wearing a mask. Figure 2 shows the difference in exercise capacity and perceived exertion. The mean MET achieved during the GXT were 12.3 ± 2.5 for participants not wearing a mask, and 11.8 ± 2.7 for participants wearing a mask, for a mean difference of -0.4 MET (95% confidence interval [CI] -0.7 to -0.2 , $P = 0.001$; TOST P value < 0.001). The exercise duration in minutes:seconds was $10:03 \pm 2:30$ vs $10:27 \pm 2:16$ ($-0:24$, 95% CI $-0:39$ to $-0:09$, $P = 0.003$). At the end of the GXT, the perceived exertion on the Borg scale was 8.4 ± 1.3 vs 7.9 ± 1.6 , respectively ($+0.5$, 95% CI 0.2 to 0.8 , $P = 0.004$). The reason for ending the test was more frequently dyspnea when participants were wearing vs not wearing a mask (64% vs 36%). Oxygen saturation was slightly lower at the end of the test but remained within expected values ($96.2\% \pm 2.0\%$ with mask vs $97.3\% \pm 1.6\%$ without mask, $P = 0.002$) and is not considered clinically relevant. No significant difference occurred in heart rate, blood pressure, or the time elapsed before reaching 85% of the predicted maximal heart rate.

Discussion

This study is relevant to the current reality of exercise testing in cardiology during the COVID-19 pandemic. The results help to answer important questions about the effect of wearing surgical face masks on exercise capacity and perceived exertion. They also inform health professionals about possible changes regarding the interpretation of test results.

The design of the study is consistent with real-life exercise testing in our cardiology laboratory, and many other laboratories throughout the world, using the well-known Bruce protocol and a common type of face mask. Consequently, the

results apply to GXTs performed with participants wearing similar surgical face masks but should not be extrapolated to other mask types, such as cloth or N95.

The difference of -0.4 MET reaches statistical significance but is below the threshold of 1 MET considered significant for prognostic value^{3,4} (TOST P value < 0.001). Similarly, a difference in perceived exertion of less than 1 point on the Borg scale is not deemed clinically meaningful according to studies in patients with chronic pulmonary conditions.^{18,19}

Our results are partly discordant with those obtained by Driver et al. using the same graded treadmill protocol, and a similar crossover design.¹¹ They observed a 14% reduction in exercise duration when 31 healthy adults performed a GXT using the Bruce protocol while wearing a cloth face mask, vs without wearing a mask, whereas we observed a difference in exercise duration of less than 4% for participants wearing vs not wearing a surgical face mask.

Many factors could explain this difference, notably, the type and fit of the masks. Driver et al. studied cloth masks, which are generally thicker and fit more closely to the mouth than surgical masks. Moreover, they used a metabolic testing (or spirometry) mask on top of the face mask, which blocks air

Table 1. Participant characteristics

Characteristic	N = 35
Sex (male)	12 (34)
Age, y	41.8 (\pm 13.3)
Height, m	1.69 (\pm 0.09)
Weight, kg	66 (59–83)
BMI, kg/m ²	23 (21–29)
Weekly self-reported exercise, h	4 (3–8)

Data presented are mean (\pm standard deviation) if normally distributed, median (interquartile range) if not normally distributed, and frequency (percentage) for categorical variables.

BMI, body mass index.

Table 2. Comparison of exercise parameters with participants wearing vs not wearing a surgical mask

Parameter	Wearing mask (n = 33)	Not wearing mask (n = 33)	Mean difference	95% CI	P value
Functional capacity, MET	11.8 ± 2.7	12.3 ± 2.5	-0.4	(-0.7 to -0.2)	0.001
Effort duration, min:sec	10:03 ± 2:30	10:27 ± 2:16	-0:24	(-0:39 to -0:09)	0.003
Perceived exertion at the end of the test	8.4 ± 1.3	7.9 ± 1.6	0.5	(0.2 to 0.8)	0.004
Resting HR, bpm	72.6 ± 12.0	73.1 ± 12.6	-0.6	(-3.8 to 2.7)	0.719
Maximal HR, bpm	175.0 ± 14.4	177.3 ± 15.9	-2.3	(-5.3 to 0.8)	0.136
Time to reach 85% of maximal predicted HR, min:sec	7:25 ± 1:59	7:21 ± 2:04	0:04	(-0:17 to 0 :25)	0.683
Resting oxygen saturation, %	98.7 ± 1.1	98.6 ± 1.3	0.2	(-0.5 to 0.8)	0.623
Oxygen saturation at the end of the test, %	96.2 ± 2.0	97.3 ± 1.6	-1.2	(-1.8 to -0.5)	0.002
Resting BP, mm Hg	110/76 (105/68–121/80)	120/77 (110/70–129/80)	-4/-3	—	0.079/ 0.029
BP at the end of the test, mm Hg	161/70 (150/60–180/80)	160/72 (150/69–177/80)	2/-2	—	0.612/ 0.173
Dyspnea as reason for stopping the test, n, %	21 (64)	12 (36)	-9 (27)	—	0.022

Data presented are mean ± standard deviation (if normally distributed) or median and interquartile range (if not normally distributed) or frequency (percentage) for categorical variables. Perceived exertion was measured on the modified Borg scale (from 0 to 10).

CI, confidence interval; MET, metabolic equivalents; HR, heart rate; bpm, beats per minute; BP, blood pressure.

circulation on the sides of the cloth mask. Similarly, Fikenzler et al. tested the effect of surgical and N95 face masks during an ergocycle progressive stress test in 12 healthy men,⁹ also using a metabolic testing mask on top of the face mask. They observed a reduction of the VO_2 max of 13% with the more fitted N95 mask, and a reduction of only 4% with the surgical mask. This latter difference did not reach statistical significance ($P = 0.063$). These results suggest that thicker and more fitted masks have a greater impact on exercise testing results. However, other studies, such as those of Epstein et al.⁸ and Shaw et al.,⁷ found no significant impact of either surgical, cloth, or N95 masks during cycle ergometry in healthy individuals. Therefore, we expect that factors other than mask type or the use of a metabolic testing mask affect the performance of participants.

All the previously cited studies on surgical face masks are concordant and support our findings about the minimal impact of these masks on exercise testing results. Therefore, we conclude that, in most cases, treadmill stress testing for diagnostic and prognostic indications can be interpreted similarly if performed while wearing a surgical face mask vs without a mask. In other words, clinicians are encouraged to err on the side of caution and consider that decreased exercise capacity is attributable to physiological changes and not the wearing of a surgical mask. Further studies are required to investigate the effect of masks in populations with a significant disease burden. Moreover, the significant decrease in exercise capacity and increase in perceived exertion may have an impact in other exercise settings.

In our study, even if the difference in perceived exertion was small, dyspnea was evoked as the principal reason to stop the test in a greater proportion of participants who were wearing a surgical face mask (64% with mask vs 36% without mask). In Driver's study, the reported dyspnea was significantly increased during exercise with the cloth face mask compared to that without a mask, and minute ventilation was significantly reduced.¹¹ In Fikenzler's study, dyspnea was not directly assessed, but discomfort during the effort was more important with both the N95 and surgical face masks, compared to that without a mask.⁹ Finally, in Epstein's study, wearing an N95 face mask, compared to no mask, during the stress test was associated with a small but statistically significant increase in

end-tidal CO_2 during most of the test, whereas wearing a surgical face mask increased end-tidal CO_2 only when participants reached a state of exhaustion.⁸ This end-tidal CO_2 increase may exacerbate the sensation of dyspnea. The current data do not allow us to fully elucidate the mechanisms and anticipate the clinical repercussions of the increased dyspnea associated with wearing different types of masks. Even if this dyspnea does not significantly impair exercise capacity during a GXT performed while wearing a surgical mask, it could potentially have an impact on exercise performed in other

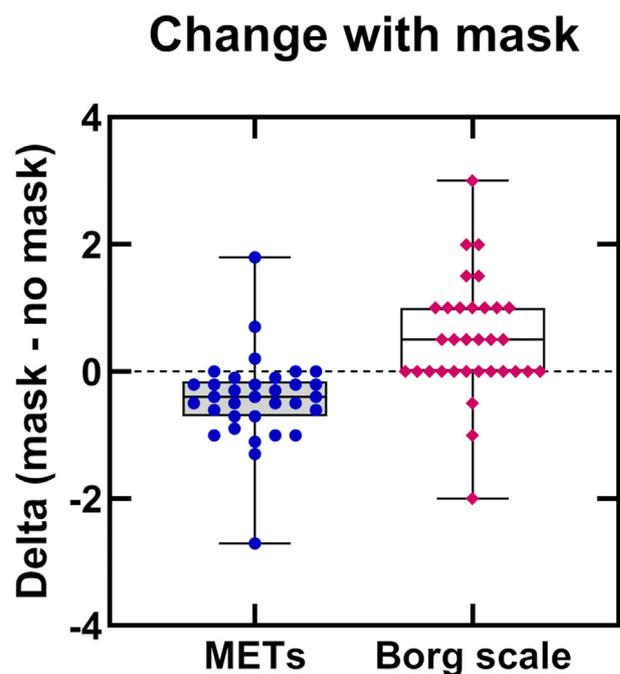


Figure 2. Changes in exercise capacity (metabolic equivalents [MET]) and perceived exertion (modified Borg scale; from 0 to 10) for participants at the end of the graded treadmill stress test performed while wearing a surgical face mask vs without wearing a mask. For most participants, exercise capacity decreased, and perceived exertion remained the same or increased. Data are shown as minimum and maximum with median and interquartile range.

conditions, such as cardiopulmonary rehabilitation, or by patients with a severe cardiac or pulmonary disease.

Study limitations

The number of participants recruited was small, but our sample had sufficient statistical power to detect clinically relevant changes. However, the recruitment methods may have induced a bias in the population because an important proportion of participants were healthcare workers used to wearing surgical face masks for prolonged periods. This choice was made to protect the study personnel by including only participants vaccinated against COVID-19. Additionally, this study population included only healthy volunteers. Therefore, further investigation is needed to validate the applicability of our results to patients with cardiovascular or pulmonary conditions. However, as shown in the studies with pulmonary testing during exercise, the principal effects of the mask are on ventilation and the respiratory rate.²⁰ We could hypothesize that most patients with cardiovascular diseases are limited during stress testing by the cardiac output component of their global fitness before the respiratory component, and consequently, the impact of the mask on their exercise capacity would be like that observed in our study. However, exercise physiology can be altered in different ways by cardiovascular or respiratory diseases, and to our knowledge, no randomized study assessed the effect of wearing a mask during a GXT in these populations.

The maximal VO_2 values (expressed in MET) reported in this study were estimated rather than measured. This approach reflects our clinical practice, in which stress testing by cardiologists does not include ventilation or respiratory gas parameters. However, potential errors caused by this approach should be the same during testing with vs without a mask and therefore do not impact our conclusions.

Conclusion

The 0.4 MET decrease in effort capacity and the 0.5-point increase on the Borg scale of perceived exertion found in this study for healthy participants undergoing GXT while wearing a surgical face mask are statistically significant but not clinically significant. However, dyspnea is more frequently reported as the reason to stop the test in participants wearing masks. Based on these findings, GXT results should be interpreted in the same manner regardless of whether participants were wearing or were not wearing a surgical face mask. However, for people with cardiovascular or pulmonary disease presenting with dyspnea, the differences may be more pronounced, and this requires further investigation.

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Disclosures

The authors have no conflicts of interest to disclose.

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