SHORT COMMUNICATION

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The Physiological and Perceived Impact of Wearing a Face Mask During Maximal Exercise

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Abstract: The COVID-19 pandemic prompted the expectation of facemasks in fitness facilities during exercise. However, the physiological and perceptual responses of wearing a facemask during exercise has not been fully investigated. The purpose of this study was to determine the effect of facemasks on selected physiological and subjective variables during exercise. Using a crossover design, males (n =8) and females (n=7) and were randomly assigned to (1) a surgical facemask, (2) a cloth face mask, and (3) no mask and completed Bruce Protocol maximal graded treadmill tests 48 hrs apart. Collected data included heart rate (HR), oxyhemoglobin saturation (SpO_2), rating of perceived dyspnea (DYS), perceived rate of exertion (RPE) and time to exhaustion (TTE). No significant (p>0.05) differences were found for HR or SpO_2 at any of the treadmill stages. DYS was higher with both masks compared to no mask, but only significant (p < 0.05) between the cloth and no mask conditions in stages 2 and 3. RPE was greater in both mask conditions compared to no masks, but only significantly greater between the cloth mask and no mask conditions in stage 3. No significant differences were found for TTE among the conditions. Wearing face masks during exercise and has little effect on HR, SpO_2, or TTE. However, facemasks may negatively influence DYS and RPE contributing to feelings of exhaustion. Participants should be made aware that the discomfort of wearing a mask during exercise will not hamper performance.

Keywords: Face mask, Exercise, Heart rate, Treadmill.

1. Introduction

The use of face masks to slow the spread of respiratory infections has been documented during the Spanish flu, SARS, and COVID-19 (Liew and Flaherty, 2020). The Centers for Disease Control and Prevention (CDC) recommended the use of face masks in public when social distancing is impossible to help decrease the spread of COVID-19 (Liew and Flaherty, 2020). Concurrently, exercise and workout facilities adopted requirements or recommendations to wear face masks while exercising. However, it is believed that face masks may, not only negatively affect performance, but may also compromise ventilatory capacity (Liew and Flaherty, 2020) and increased dyspnea (Hopkins *et al.,* 2021). The two most commonly use face masks are surgical and cloth face masks. Surgical face masks contain three layers, with each layer serving to either resist fluid, filtrate particles, or absorb mucosalivary droplets (Haraf *et al.,* 2021). Face masks made from cloth may consist of a single or multiple layers typically made out of cotton, chiffon, or flannel (Haraf *et al.,* 2021).

The physiological effects of wearing face masks while exercising has met with mixed results. Similarly, the perceptual effects of wearing a face mask while exercising remains controversial (do Prado *et al.,* 2022). Epstein *et al.,* using healthy adults (mean age 28 yrs), compared no mask with surgical mask conditions (Epstein *et al.,* 2021). Participants were assessed using a cycle ergometer protocol to exhaustion and found that HR, systolic blood pressure, rating of perceived exertion (RPE), respiratory rate and time to exhaustion (TTE) did not reach significance (p>0.05) at any of the stages. Driver et al., concluded that, while completing a Bruce Treadmill graded exercise test (GXT), cloth face masks reduced exercise time, VO_2max, and SpO_2 and increased HR when compared to no mask (Driver *et al.,* 2021).

Additionally, Egger, *et al.,* using well-trained athletes (mean age 27 yrs) and stepwise exercise tests to exhaustion found that those wearing surgical masks had a significant (p<0.05) reduction in maximum performance, oxygen consumption and minute ventilation compared to the no mask condition (Egger *et al.,* 2022). HR was not significantly different between face mask and no face mask conditions at any of the increments. Additionally, most of the subjects reported acute dyspnea (DYS) with the face mask. Doherty et al., using 5 females with a mean age of 27 yrs, utilized a cycle protocol consisting of 70% of maximal HR compared no mask, surgical masks and cloth masks and found no differences in HR or oxyhemoglobin saturation (SpO_2) across all conditions (Doherty *et al.,* 2022). Furthermore, DYS was significantly (p<0.05) higher with cloth masks than with the surgical mask and no mask, and that the surgical mask was not different from no mask. The aforementioned previous studies were largely limited to older participants and single gender protocols Additional research is needed due to the continued ambiguity revolving around the physiological and perceptual effects face masks and exercise, therefore the aim of this study was to compare HR, SpO_2, DYS, RPE and TTE among younger adults while wearing surgical and cloth face masks and no face mask during a maximal Bruce GXT. The null hypothesis for each measured variable was assumed surrounding this investigation in that no significant differences among the groups were expected.

2. Materials and Methods

2.1 Participants

Following oral instruction and a question cum answer period 15 healthy, physically active and aerobically fit males (n = 8) and females (n= 7) with an age of 20.27 yrs, average weight of 77.54kg, and BMI of 24.15 kg/m^2 read and signed a University IRB approved consent document. Those with a history of asthma, pulmonary or heart disease, and or hypertension medications were excluded from the study. Participants were asked to complete a Health History Questionnaire, Health Risk Assessment, and the Physical Activity Readiness Questionnaire (PAR-Q & You) to evaluate their health status and eligibility to participate in the study.

2.2 Face Masks

The study was designed as a randomized, counterbalanced trial of healthy volunteers to compare the effects of wearing selected face masks (cloth or surgical) on physiological variables such as HR, SpO_2, TTE and perceptual variables of RPE and dyspnea (DYS) during a maximum Bruce Protocol Treadmill test (Figure 1). Participants were required to visit the lab three times separated by 48 hrs. During each visit, participants completed a maximal Bruce protocol graded exercise treadmill stress test (GXT) wearing either a (1) disposable three-layered surgical face mask (Hunan EEXI Technology & Service Co., Liuyang Hunan, China), (2) a cloth face mask made from 96% viscose fiber, and 4% spandex (Shantou Meijiatong Clothing Co, Shantou City, China), (3) or no mask.

2.3 Assessments

Heart rate, SpO_2, DYS and RPE was recorded during the final minute of each stage. HR was measured using a Polar Heart Monitor (Polar USA, Bethpage, NY USA) and SpO_2 was obtained by placing a pulse oximeter (Pulse Ox 500C, Einstein Associates LLC, Stafford TX USA) on the participant's index finger. The Modified Borg Dyspnea 1-10 scale was utilized to assess breathlessness and the Borg Rating of Perceived Exertion (RPE) 1-20 scale was used to assess each participants' perceived exertion, and time to exhaustion (TTE) was recorded in seconds from the beginning of Stage 1 to volitional fatigue.

2.4 Statistical Analysis

All results are expressed as means, ± standard deviation (SD), and statistical significance was set a p<0.05. Using SPSS statistical software (Version 27.0, IBM Corp, Chicago, IL, USA), two-factor repeated-measures ANOVAs were utilized to detect any differences in HR, SpO_2, DYS, RPE and TTE and a one-factor repeated measures ANOVA was used for TTE.

3. Results

An initial fifteen adults participated in the study and were assessed on the Bruce Protocol maximal treadmill test (Table 1). As expected, HR increased significantly (p<0.05) with each treadmill stage, however, no significant differences (p>0.05) were detected in HR among the conditions at rest or at any of the treadmill stages. Slightly lower SpO_2 values were found for both mask conditions compared to no mask at stages 3-5, but these differences did not reach significance.

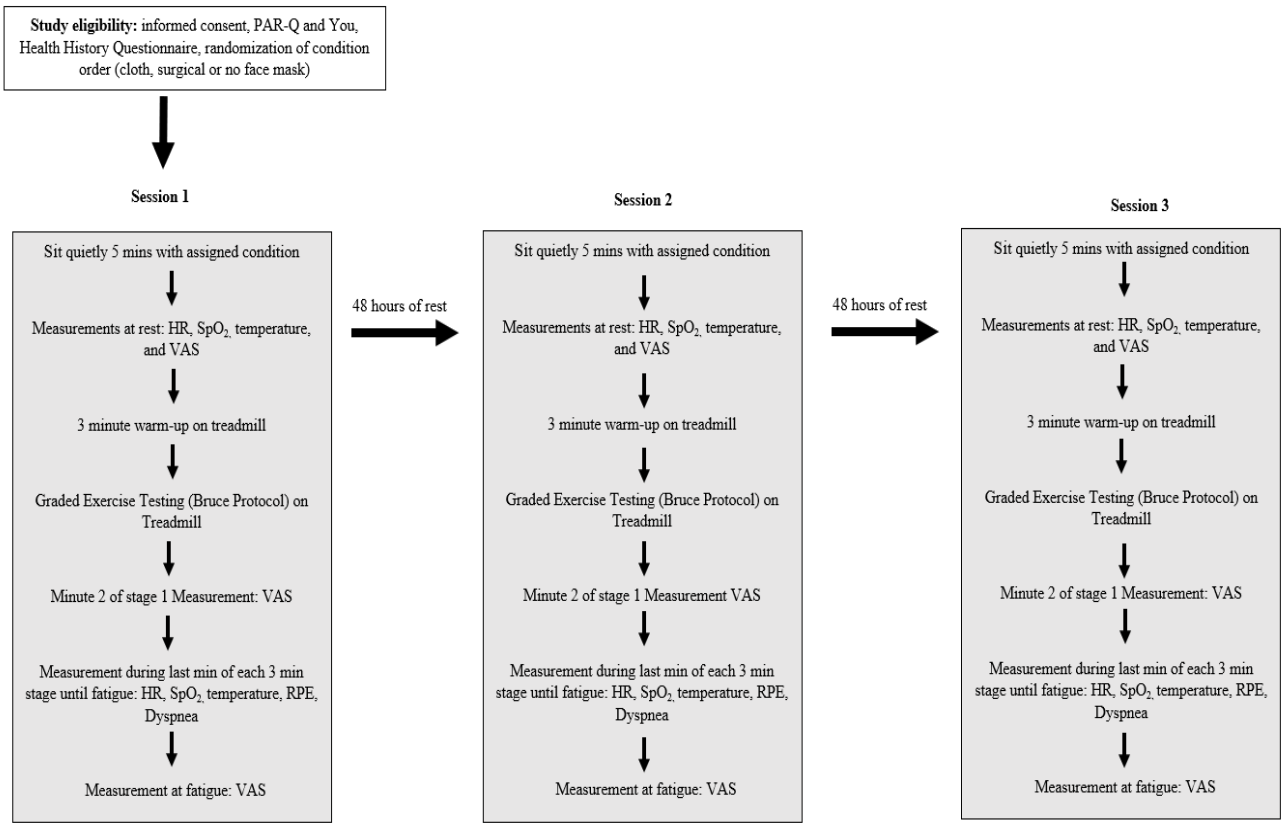

Figure 1 Study Design. HR, heart rate; SPO_2, oxygen saturation; VAS, visual analog scale; RPE, rating of perceived exertion.

Table 1. Physiological and Perceptual Results by Condition and Bruce Treadmill Stages

STAGE & VARIABLE	NONE	SURGICAL	CLOTH	
Stage 1 HR (*n*=15	114.5 ± 17.42	114.2 ± 13.52	112.5± 16.33	*p*=0.89
Stage 2 HR (*n*=15)	143.27 ± 20.62	145.13 ± 18.07	143.00 ± 20.53	*p*=0.76
Stage 3 HR (*n*= 15)	172.93 ± 20.26	163.73 ± 27.87	172.8 ± 16.25	*p*=0.66
Stage 4 HR (*n*= 11)	184.32 ± 10.88	178.54 ± 15.34	185.73 ± 9.84	*p*=0.30
Stage 5 HR (*n*= 7)	193.01 ± 6.14	187.00 ±13.61	191.71 ± 7.13	*p*=0.41
Stage 1 SpO^2	97.64 ± 1.55	97.64 ± 1.21	97.29 ± 1.64	*p*=0.43
Stage 2 SpO^2	96.86 ± 4.00	97.07 ± 1.44	97.64 ± 1.74	*p*=0.82
Stage 3 SpO^2	97.36 ± 1.45	96.07 ± 2.43	96.07 ± 2.43	*p*=0.37
Stage 4 SpO^2	95.80 ± 2.94	94.70 ± 4.08	93.10 ± 7.62	*p*=0.51
Stage 5 SpO^2	97.00 ± 2.31	95.17 ± 2.19	92.29 ± 5.67	*p*=0.10
Stage 1 Dyspnea	0.66 ± 0.52	1.26 ± 1.29	1.41 ± 0.87	*p*<0.09
Stage 2 Dyspnea	1.80 ± 0.80	2.54 ± 1.06	2.77 ± 1.05	*p*<0.04[b]
Stage 3 Dyspnea	3.86 ± 1.81	4.60 ± 3.79	5.61 ± 2.13	*p*<0.04[b]
Stage 4 Dyspnea	6.60 ± 1.74	7.42 ± 2.14	7.81 ± 2.00	*p*<0.56
Stage 5 Dyspnea	8.00± 1.38	8.62 ± 0.95	9.14 ± 0.69	*p*<0.13
Stage 1 RPE	6.93± 0.99	8.00± 2.53	8.54 ± 1.25	*p*<0.05
Stage 2 RPE	9.44 ± 1.47	10.00 ± 1.57	10.73 ± 1.79	*p*<0.09
Stage 3 RPE	11.78 ± 2.14	12.75 ± 2.87	13.29 ± 2.13	*p*<0.03[b]
Stage 4 RPE	16.20 ± 1.63	16.55 ± 2.16	16.67 ± 1.92	*p*<0.41
Stage 5 RPE	17.89 ± 1.15	17.94 ± 1.09	18.89 ± 1.21	*p*<0.17
TTE (sec)	718.26 ± 114.91	702.38 ± 690.13	670.80 ±133.57	*p*=0.53

[a] Significant: no mask vs. surgical mask
[b] Significant: no mask vs. cloth mask

DYS was greater with both masks compared to the no mask condition at all stages of the GXT, but only significantly (p>0.05) greater between the cloth and no mask conditions at the GXT stage 2 and 3. Regarding RPE, the only significance was found between the cloth mask and no mask at stage 3. In debriefing the participants, it was noted that both DYS and RPE was greater while wearing masks and that as the exercise intensity increased the masks became much more uncomfortable. While no significant differences were found for TTE among the groups, both the surgical mask and cloth mask conditions resulted in a reduced time of 2.2% and 6.7% respectively.

4. Discussion

These results suggest that wearing either a cloth or a surgical face mask has minimal influence on physiological variables such as HR or SpO_2 during maximal exercise. Heart rate and SpO_2 saturation at all time frames during the graded exercise test were similar when wearing either type of mask compared or not wearing a mask. These results regarding HR are consistent with several previous researchers (Epstein *et al.,* 2021; Egger *et al.,* 2021; Doherty *et al.,* 2021; Shaw *et al.,* 2020). However, our results are also in contrast with others (Driver *et al.,* 2021; Lässing *et al.,* 2020; Darnell *et al.,* 2022; Dubé *et al.,* 2022)

Regarding exercise endurance the present date for TTE was lower for both mask conditions compared to no mask, which was particularly evident for the cloth mask (no mask: 708.26 sec; surgical mask: 702.38 sec; cloth mask 670.80 sec), however, these values did not reach significant differences among the groups. These results are in agreement with others (Epstein *et al.,* 2021; Shaw *et al.,* 2020; Fikenzer *et al.,* 2020), who concluded that endurance performance is not influenced by wearing a face mask. Contrary, Driver *et al.,* observed a cloth mask resulted in a 14% reduction in exercise time (Driver *et al.,* 2021). However, the participants also wore a metabolic system mask over the cloth mask which potentially interfered with respiration, thus decreasing performance. Darnell *et al.,* using well trained Division I athletes further found that exercise performance is impacted at high intensities by wearing face masks, and Dube *et al.,* working with healthy adults found that face masks significantly decrease exercise capacity (Darnell *et al.,* 2022; Dubé *et al.,* 2022).

Regarding perceptual variables, the current investigation suggests that wearing a face mask, specifically a cloth face mask, influences perceived DYS. Similarly, Egger *et al.,* noted that nearly 70% of their subjects reported acute dyspnea from the suction of the wet deformed mask (Egger *et al.,* 2021). Liew and Flaherty speculated an intolerance of wearing a face mask might be due to psychological effects such as discomfort instead of an increased physiological burden (Liew and Flaherty, 2020). In addition, heat, high humidity and a general feeling of discomfort may contribute to the perception of DYS. Watts noted that wearing a mask can lead to an abnormal breathing pattern presumably due to neurological feedback (Watts, 2023). For instance, increased sensory impulses from the highly thermosensitive area covered by the mask and/or psychological manifestations such as anxiety, claustrophobia or sensory responses caused by mask moisture and deformation may lead to perceived difficulty in breathing (do Prado *et al.,* 2022).

RPE was subjectively greater for both mask conditions at all stages when compared to the no mask condition. However, only the cloth mask condition was significantly higher than the no mask condition at stage 3. No other significant differences were observed for RPE. These results contrast those of Hoffman who concluded that exercising with a mask resulted in a significantly higher Borg score than without a mask (Hoffman, 2021). Results of RPE is in contrast with others (Egger *et al.,* 2021; Shaw *et al.,* 2020; Amput and Wongphon, 2022) who concluded that face masks cause an increase in RPE during exercise. In the current study, the RPE differences in stage 3 may have been solely by chance since no other significant differences were found for RPE. Additionally, surgical masks have been associated increased respiratory muscle effort, which can contribute to both perceived DYS and RPE (Cheng *et al.,* 2022).

5. Conclusion

The predominance of evidence suggest that wearing a face mask during both light and intense exercise does not affect physiological variables such as HR, temperature SpO_2, pulmonary function or TTE. It can be concluded that wearing a surgical or cloth face mask during exercise and has little effect on HR, SpO_2 or performance. However, the discomfort of wearing a face mask does seem to exacerbate perceptual variables such as RPE and DYS ratings during exercise which makes the participant feel less comfortable as

the activity progresses. It is suggested that supervising personnel should prepare the patrons for what to expect when wearing a face mask and that the perception does not influence their performance.

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Ethics Approval
The approval was sought from the institutional Review Board.

Author Contribution Statement
Brandie C. Cheshier - Methodology, Data collection, Analysis, Writing—original draft, **Bert H. Jacobson** - Conceptualization, Supervision, Validation, Writing—review & editing, **Qincy R. Johnson** - Data collection, Analysis, Writing—review & editing, **Antonio Perez** - Writing—original draft, review & editing. All authors read and approved the final manuscript.

Data availability
The datasets generated and analyzed during the current study are available from the corresponding author upon approval of the request.

Informed Consent
Written consent was obtained from the participants.

Conflict of interest
The author declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Does this article pass screening for similarity?
Yes