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TANAFFOS

Physiological Responses to Facemask Use during a Graded Treadmill Test in Healthy Male Adolescents and Young

Nasibeh Kazemi [1], Bryanne N. Bellovary [2], Ali Shaker [1], Saeedeh Shadmehri [3], Mohammad Ali Azarbayjani [4], Mozhgan Ahmadi [3]

[1] Department of Sport Physiology, Marvdasht Branch, Islamic Azad University, Marvdasht, Iran, [2] Kinesiology Department, State University of New York – Cortland, Cortland, NY, USA, [3] Department of Physical Education and Sport Sciences, Yadegar-e-Imam Khomeini (RAH) Shahre-rey Branch, Islamic Azad University, Tehran, Iran, [4] Exercise Physiology Department, Islamic Azad University, Central Tehran Branch, Tehran, Iran

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Correspondence to: Kazemi N

Address: Department of Sport Physiology, Marvdasht Branch, Islamic Azad University, Marvdasht, Iran

Email address: nasibe.kazemi@yahoo.com

Background: we aimed to investigate the physiological impact of facemasks use during a graded treadmill exercise test in male adolescents and young adults.

Materials and Methods: Twenty-one males aged 15 to 28 volunteered. Participants completed four sessions with a 72-hour gap between each session. They completed four visits: 1 rest and 3 graded treadmill exercise test sessions no mask, surgical mask, and FFP2/N95 mask. Pre- and post-graded treadmill exercise test, heart rate, systolic blood pressure, diastolic blood pressure, and blood oxygen saturation were measured. Repeated measures analysis of variance determined statistical differences ($p<0.05$).

Results: There were no differences in exercise performance (e.g., time to termination, estimated VO2max) nor heart rate, systolic blood pressure, and diastolic blood pressure between conditions. FFP2/N95 mask resulted in lower blood oxygen saturation compared to no mask and surgical mask, and the surgical mask was lower than no mask at exhaustion.

Conclusion: Participants could safely complete the graded treadmill exercise test without detriment to exercise performance even though blood oxygen saturation decreased with facemask use.

Keywords: Athletes; COVID-19; Maximal exercise; Running; Safety

INTRODUCTION

On March 11th, 2020 the World Health Organization announced a new outbreak of Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-Cov-2). This causes an infectious disease called COVID-19 (1). This virus mainly affects the respiratory system and is highly contagious when sneezing or coughing through the exchange of respiratory droplets with other people. Since its initial outbreak, facemasks have been recommended as a potential tool to combat COVID-19 spread in public, at work, and during physical activity and exercise (2-5). However, the physiological impact of facemask use during strenuous exercise remains inconclusive.

Some studies report impairments to exercise performance (i.e., time to test termination, maximal oxygen consumption [VO_2max], and maximal power output) during a graded exercise test (2,4,6,7). Proposed reasons for reduced exercise performance include rebreathing of carbon dioxide (CO_2), hypoxia, hypercapnia, reduced ventilation, and subsequent reduction of tissue oxygenation (4,7,8). However, a meta-analysis demonstrated no effect from facemask use on exercise performance and a small effect on physiological responses (e.g., ratings of perceived exertion [RPE], heart rate [HR], dyspnea, respiratory rate, and end-tidal CO_2) during exercise (9). Further previous researchers have identified that more studies are needed on the physiological impact of facemask use during exercise and a lack of generalizability to adolescent populations (5,9).

To add to the body of evidence on the impact of facemask use on exercise performance and physiological responses to exercise, we aimed to compare no facemask use to surgical and FFP2/N95 mask use during a graded treadmill exercise test (GXT). The real-world application was considered, so expired gases were not collected during this study to prevent layering a gas collection mask over a surgical or FFP2/N95 mask. Therefore, the purpose of this was study was to determine the impact of facemask use on exercise performance and physiological responses during a GXT in adolescent and young adult males.

MATERIALS AND METHODS

Participants

Twenty-one male participants (aged 15 – 28 years old) voluntarily took part in this study (Table 1). The participants self-reported an average of three years of experience in mixed martial arts and kickboxing and regularly trained three days per week. All participants self-reported no history of coronavirus, smoking, diabetes, chronic respiratory or cardiovascular disease, or acute respiratory illness (e.g., pneumonia or upper respiratory tract disease). The purpose of the study was explained to the participants. All questions were addressed by the research team and written informed consent was obtained from the participant or their legal guardian for participants under 18 years old. The university's Marvdasht Institutional Review Board approved the study and complied with the Declaration of Helsinki (10).

Experimental Design

All participants completed four sessions at similar times in the morning between 7:30 and 11:30 with 72 hours separating each visit. All participants were advised to avoid sports and energy supplements, high-fat foods, alcohol, hookah, and cigarettes starting two weeks before their first visit through their completion of the study protocols. Participants also avoided strenuous exercise for 48 hours and sleeping at least 8 hours before each visit.

On the first visit, height and weight were measured by tape measure and digital scale, respectively, without shoes and used to calculate body mass index. Resting blood pressure ([BP], Glamor sphygmomanometer, Germany), HR (PM 200 Beurer Polar monitor, China), blood oxygen saturation via finger pulse oximeter ([SpO_2], PO 30 Beurer, Germany), and 10-lead electrocardiography ([EKG], Custo, Germany) were assessed without any facemask use while supine for participant characterization (Table 1). While seated, a 10 mL blood sample was collected from the antecubital vein in Vacutainer tubes (Fartest, made in Iran). On visits 2-4, participants performed the Bruce treadmill GXT to volitional fatigue. The facemask use during the GXT was randomized. Participants performed the GXT either without a mask (NM), with a surgical mask (SM, Disposable Protective Mask, China), or with a FFP/N95 mask (FFPM, Nano Fiber Mask, Honorary Industrialist Company, Shiraz University of Medical Science, approved by the Atomic Energy Organization of Iran). All visits were performed in a controlled laboratory environment at 25°C and 35% humidity. Blood pressure, HR, SpO_2, and 10-lead EKG were assessed pre- and immediately post-GXT. A 10 mL blood sample was collected immediately post-GXT similar to that during the first visit.

Procedures

Bruce Treadmill Graded Exercise Test

Before testing, participants were explained about the treadmill (GXT-8800, Germany) GXT protocol and instructed to run until volitional fatigue. Each stage lasted three minutes before speed and grade increased according to Table 2 and ratings of perceived exertion (Borg 0-10 scale) were collected upon completing each stage. All tests were performed under the supervision of an exercise specialist. Maximal oxygen consumption was estimated using Equation 1[11]. The time (minutes) to perform each trial was used to estimate VO_2max.

Equation 1. $VO_2max = 14.76 - 1.379*time + 0.451*time^2 - 0.012*time^3$

Table 1. Participant characteristics

	Age (yr.)	Height (m)	Weight (kg)	BMI (kg · m^{-2})	Resting SBP (mmHg)	Resting DBP (mmHg)	Resting HR (bpm)	Resting SpO_2 (%)
n=21	19.0 ± 3.5	1.8 ± 0.1	66.9 ± 11.4	21.9 ± 3.5	128 ± 15	75 ± 10	73 ± 10	98.0 ± 0.8

Note: Values are reported as mean ± standard deviation. Resting values were recorded during supine rest. BMI=body mass index. SBP=systolic blood pressure. DBP=diastolic blood pressure. HR=heart rate. SpO_2=blood oxygen saturation.

Table 2. Bruce treadmill graded exercise test protocol

Stage	Speed (mph)	Grade (%)	Duration (min)
1	1.7	10	3
2	2.5	12	3
3	3.4	14	3
4	4.2	16	3
5	5.0	18	3
6	5.5	20	3
7	6.0	22	3

Blood Marker Analysis

Blood samples were collected by venipuncture. Complete blood counts (CBC) for white blood cell analysis were obtained by standard methods from the clinical hematology laboratory. Tubes containing K2 EDTA (FARA TEST, 2 ml, Iran) were used to measure CBC (2 ml of total blood sample). CBC blood oxalate was measured using a calibrated cell counter device (SYSMEX K1000 model, Japan) and K2 anticoagulant.

The other blood samples were collected in test tubes containing granules + clot activator (FL medical company, Italy) to analyze cortisol, iron (FE), total iron-binding capacity (TIBC), and C-reactive protein (CRP). Blood samples were centrifuged (3000 RPMs, 5 min, 4-8°C) with the serum portion transferred to a microtube. The serum portion was stored in a -24°C freezer until ready for analysis. Cortisol concentrations were determined by enzyme-linked immunosorbent assay (ELISA) using a Statfax 4200 monobind kit. CRP concentrations were assessed by the quantitative biochemical method using the Biorexfars kit (made in Iran) and the classic alpha machine. Serum TIBC concentrations were analyzed using the calimetric method (straight) with an autoanalyzer and kit (BYREX Fars, made in Iran). The Ferrene method was used to assess serum FE concentrations using a Biorexfars kit (made in Iran) and autoanalyzer.

Statistical Analysis

Statistical analyses were performed using SPSS (IBM SPSS Statistical Version 26). All data were presented as mean±standard deviation. A mixed model repeated measures ANOVA determined differences between pre- to post-GXT (Time), between the no mask/masked conditions (Condition), and if an interaction existed between Time and Condition for the systolic and diastolic BP (SBP and DBP, respectively), HR, and SpO_2 data. Repeated measures ANOVA assessed differences in GXT termination time, estimated VO_2max between conditions, and blood marker percent change. Blood marker data was calculated as a percent change from rest during the first visit to immediately post GXT for each condition prior to statistical analysis. If sphericity was violated, the Greenhouse-Geisser correction was used. Bonferroni's post-hoc procedure was used for pairwise analyses. Statistical significance was set at $p<0.05$.

RESULTS

Cardiovascular Responses to the Graded Exercise Test

Differences in HR, SpO_2, GXT termination time, and estimated VO_2max can be observed in Table 3. Heart rate and SBP increased while SpO_2 decreased and DBP remained similar from pre- to post-GXT during all trials. Only SpO_2 significantly differed between NM, SM, and FFPM, with an observed interaction between Time and Condition. The FFPM yielded the greatest decrease in SpO_2 at the end of the GXT compared to the SM ($P=0.044$) and NM ($p<0.001$) trials. There was also a greater decrease in SpO_2 during the SM trial compared to the NM trial

(P=0.002). There was no difference in GXT termination time nor estimated VO_2max between NM, SM, and FFPM trials.

Blood Marker Changes from the Graded Exercise Test

Differences in percent change from seated rest to immediately post-GXT for all blood markers can be found in Table 4. The FFPM trial elevated PLT to a greater extent compared to the NM trial (P=0.003), but there was no difference compared to the SM trial (P=0.63) nor a difference between the SM and NM trials (P=0.14). Cortisol was elevated most during the FFPM trial compared to the SM and NM trials (P=0.007 & 0.031, respectively), but there was no difference between the SM and NM trials (P=0.19). The percent change in TIBC was significantly different during the NM trial compared to the SM (P=0.01) and FFPM (P=0.045) trials, but there was no difference in percent change between SM and FFPM trials (P=1.0). Changes in FE levels were significantly different between the FFPM trial and the SM (P=0.01) and NM (P=0.0001) trials, but there was no difference between the SM and NM trials (P=1.0). The HCT percent change elevated to a greater extent during the NM trial compared to the SM (P<0.001) and FFPM (P=0.0002) trials, but there was no difference between the SM and FFPM trials (P=0.70). There was a greater percent change during the NM trial for MCV compared to the SM and FFPM trials (both p<0.001), but there was no difference between the SM and FFPM trials (P=1.0). The SM and FFPM trials elevated MCH and MCHC to a greater extent compared to the NM trial (p<0.001 for all), but there was no difference between the SM and FFPM trials (P=1.0 for both). There were no differences between the three trials for WBC, CRP, RBC, and HGB.

Table 3. Exercise performance and cardiovascular responses from the three graded exercise tests

	No Mask		Surgical Mask		FFP/N95 Mask		*p* Within Cond.	*p* Within Time	*p* Interact.
	Pre	Post	Pre	Post	Pre	Post			
Heart Rate (bpm)	77 ± 10	194 ± 7	80 ± 10	193 ± 13	82 ± 8	194 ± 7	0.42	< 0.001	0.22
Systolic BP (mmHg)	128 ± 11	156 ± 19	127 ± 15	158 ± 12	129 ± 13	161 ± 17	0.49	< 0.001	0.87
Diastolic BP (mmHg)	72 ± 7	76 ± 27	71 ± 9	77 ± 10	73 ± 9	77 ± 11	0.93	0.06	0.90
Oxygen Saturation (%)	98 ± 1	92 ± 3	97 ± 2	88 ± 6	97 ± 1	85 ± 5	< 0.001	< 0.001	< 0.001
VO_2max (ml·kg^{-1}·min^{-1})	43.4 ± 6.4		44.2 ± 6.4		44.1 ± 7.0		0.57	__	__
Termination Time (min)	12.2 ± 1.5		12.4 ± 1.5		12.4 ± 1.7		0.56	__	__

Note: Data reported as mean ± standard deviation. BP = blood pressure. VO_2max = maximal oxygen consumption. RPE = rating of perceived exertion. Cond. = condition; difference between no mask/mask use. Time = difference pre- to post-test. Interact. = interaction between Condition and Time.

Table 4. Absolute and percent change in blood marker data from seated rest to immediately post-treadmill graded exercise test.

	Absolute Values				Percent Change (%)			
	Seated Rest	Post No Mask	Post Surgical Mask	Post FFP/N95 Mask	No Mask	Surgical Mask	FFP/N95 Mask	*p* Within Percent Change
PLT (*10^3/µl)	222.1 ± 43.5	278.5 ± 48.2	291.9 ± 55.9	297.6 ± 50.2	27.4 ± 21.4	32.9 ± 20.9	36.4 ± 24.6	0.004
WBC (*10^3/µl)	6.1 ± 0.8	9.6 ± 1.7	9.8 ± 2.1	10.0 ± 2.2	57.9 ± 30.6	60.3 ± 33.7	65.2 ± 36.0	0.46
RBC (*10^6/µl)	5.5 ± 0.5	5.8 ± 0.5	5.7 ± 0.5	5.7 ± 0.5	5.1 ± 2.9	3.2 ± 4.0	4.2 ± 3.7	0.106
HGB (g/dl)	15.5 ± 1.0	16.5 ± 1.0	16.5 ± 0.9	16.7 ± 1.0	6.3 ± 3.8	6.1 ± 3.2	7.5 ± 3.1	0.275
HCT (%)	46.2 ± 2.0	49.5 ± 1.9	47.4 ± 2.0	47.8 ± 2.4	7.2 ± 3.3	2.6 ± 3.5	3.5 ± 3.9	< 0.001
TIBC (mcg/dl)	313.1 ± 61.9	290.4 ± 75.4	317.2 ± 51.1	312.4 ± 50.1	-7.3 ± 11.8	2.3 ± 9.3	0.8 ± 11.1	0.003
FE (mcg/dl)	124.8 ± 42.4	135.2 ± 31.8	135.1 ± 54.0	100.1 ± 28.0	16.1 ± 30.4	12.9 ± 46.8	-13.5 ± 31.1	0.001
MCV (fl)	84.0 ± 6.2	85.3 ± 6.4	84.1 ± 6.3	83.9 ± 6.3	1.6 ± 1.1	0.07 ± 1.3	-0.1 ± 1.5	< 0.001
MCH (pg)	28.3 ± 2.7	28.4 ± 2.7	29.2 ± 2.7	29.2 ± 2.7	0.5 ± 2.5	3.4 ± 1.8	3.1 ± 2.7	< 0.001
MCHC (g/dl)	33.6 ± 1.4	33.2 ± 1.2	34.8 ± 1.2	34.8 ± 1.2	-1.2 ± 2.3	3.5 ± 2.3	3.7 ± 3.3	< 0.001
CRP (mg/l)	0.42 ± 0.55	0.16 ± 0.26	0.88 ± 1.73	0.57 ± 1.05	52.1 ± 262.3	284.3 ± 519.7	124.7 ± 214.1	0.12
Cortisol (µg/dl)	6.3 ± 2.6	15.4 ± 4.1	13.1 ± 3.1	19.7 ± 8.8	187.0 ± 144.5	144.9 ± 114.8	256.2 ± 182.0	0.001

Note: Data are reported as mean ± standard deviation. Percent change reflect change from seated rest to immediately post-graded exercise test for the respective no mask/masked trials. PLT=platelets. WBC=white blood cells. RBC=red blood cells. HGB=hemoglobin. HCT=hematocrit. TIBC=total iron binding capacity. FE=iron. MCV=mean corpuscular volume. MCH=mean corpuscular hemoglobin. MCHC=mean corpuscular hemoglobin. CRP=C-reactive protein.

DISCUSSION

The main finding of the present study was that all participants could complete the GXT safely and to a similar extent (e.g., similar times to termination and estimated VO_2maxes) regardless of wearing a facemask. Heart rate and SBP increased similarly and DBP remained relatively stable for all three masked conditions while SpO_2 lowered to a greater extent while wearing a facemask. A novel aspect of the current study was the assessment of blood marker changes immediately post-GXT. While blood marker percent changes were significantly different across the masked conditions, it is important to note that all absolute values were within normal levels, respectively. None of the elevated or reduced changes in blood marker concentrations due to facemask use compared with no facemask use were considered abnormal concentrations (Table 4).

This present study is similar to that by Driver et al. (2), but they found significant differences in time to termination comparing a cloth mask to no mask Bruce GXTs. Possible reasons for these contrasting findings include the differences in facemasks used and superimposing a silicone expired gas collection mask over the cloth mask. Driver et al. (2) suggested the additional discomfort while wearing a cloth mask cued participants to end the GXT early; however, Shaw et al. (5) suggested that a gas collection mask over a facemask negatively impacts external validity as individuals will not exercise using this two-mask system. Though important for understanding cardiorespiratory responses when exercising with a facemask, there may still be unknown impacts when superimposing a silicone gas collection mask over a facemask that result in greater perceived discomfort and early GXT termination.

There were no differences in HR at exhaustion between the three masked conditions and this supports the findings of Shaw et al. (5) and Epstein et al. (12). This supporting evidence results despite these researchers conducting a cycling GXT. However, other cycling GXT studies had lower peak HRs when facemasks were used (2,13). The present study's participants had a background in mixed martial arts and kickboxing and are typically accustomed to high-intensity exercise bouts (14); meaning these individuals could push themselves to higher HRs and higher intensities during the treadmill GXT. Similarly, our findings for SpO_2 at exhaustion support (15,16) and contrast (5,12) previous literature. Since hemoglobin content was not different between conditions, this is not believed to be a factor. As expired gases were not collected, the impact of facemask use on ventilation and CO_2 ventilatory equivalents cannot be discerned in the present study. The FFPM condition may have increased CO_2 rebreathing resulting in hypercapnic hypoxia leading to O_2 displaced from hemoglobin by CO_2 (8). However, despite the reduced SpO_2 at exhaustion, all participants were able to safely perform the GXT while wearing a SM or FFPM.

The present study only recruited healthy male adolescents and young adults. Therefore, the results of this study cannot be generalized to similarly aged females, older adults, or those with pulmonary illness (e.g., chronic obstructive pulmonary disorder). Therefore, facemask use in older populations and those with pulmonary disease should be investigated further. Additionally, blood draws were not performed pre- and post-GXT which could confound blood markers influenced by daily hydration-, dietary-, and stress-status changes.

CONCLUSION

In summary, the present study demonstrated that exercise using a SM or FFPM did not impact exercise performance nor HR, SBP, and DBP, compared to NM at exhaustion. There were differences between masked conditions for SpO2 and specific blood markers. However, blood markers were not out of normal ranges. According to this study, healthy adolescents and young adults could safely use a facemask during acute strenuous exercise.

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