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The effect of surgical and N95 mask use during maximal exercise on physiological, perceptual, and performance responses in healthy men

Reza Banimehdi Dehkordi[1], Akram Jafari[1]*, Laleh Bagheri[2]

1. Department of Physical Education and Sport Sciences, Shahrekord Branch, Islamic Azad University, Shahrekord, Iran. (*Corresponding author: Jafari.akm@gmail.com, https://orcid.org/0000-0002-7771-3661)
2. Department of Exercise Physiology, Shahrekord University; Physical Education Teacher of Chaharmahal and Bakhtiari Province, Shahrekord, Iran.

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Abstract

Background: The effects of wearing common masks during maximal exercise activities on individuals remain unclear.

Aim: This study aimed to examine the effect of wearing surgical and N-95 masks on physiological, perceptual, and performance responses in healthy men performing a maximal shuttle run test.

Materials and Methods: Fifteen healthy men (age 23.78 ± 2.0) participated in three sessions: without a mask, with a surgical mask, and with an N-95 mask, with a one-week interval between each session. After each test, physiological variables (heart rate, blood lactate concentration, and oxygen saturation), perceptual variables (comfort/discomfort and perceived exertion), and performance variables (maximum oxygen consumption and shuttle run test duration) were measured. Data were analyzed using repeated measures ANOVA to compare differences between the conditions.

Results: Significant differences were observed between the conditions with and without a mask in terms of oxygen saturation (*P*= 0.043), blood lactate concentration (*P*= 0.026), and perceived exertion, maximum oxygen consumption, and shuttle run test duration (*P*= 0.001), with the no-mask condition demonstrating superior outcomes in all variables. The type of mask (surgical or N-95) did not significantly affect the measured variables. Wearing both masks led to an increased sensation of moisture, heat, shortness of breath, and fatigue.

Conclusion: Wearing masks, especially during intense physical activities, may impair physiological and performance metrics, recommending mask-free outdoor settings when feasible.

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1. Introduction

The global outbreak of COVID-19 has profoundly impacted public health systems, prompting widespread recommendations for mask-wearing as a crucial measure to mitigate virus transmission. As reported by the World Health Organization, over 770 million confirmed cases of COVID-19 had been documented by September 1, 2023, resulting in approximately 7 million deaths worldwide. Concurrently, more than 13.5 billion vaccine doses have been administered globally [1]. Emerging evidence indicates that a significant proportion of COVID-19 patients may develop long COVID syndrome, characterized by persistent and diverse symptoms that can last for months or years, including cardiovascular, thrombotic, and neurological complications [2, 3, 4, 5].

In this context, the use of face masks has been identified as a pivotal strategy for reducing virus transmission and safeguarding public health. Studies have demonstrated that masks can effectively diminish the spread of respiratory infections such as influenza and severe acute respiratory syndrome, thus controlling infectious disease outbreaks [6, 7]. Specifically, surgical masks and N-95 respirators have proven to be particularly effective in limiting viral transmission, with their use continuing to be recommended during pandemics and other public health emergencies [8]. Engagement in regular physical activity has been associated with a lower risk of various chronic diseases and is crucial in reducing mortality risk from COVID-19 [9]. Previous research has highlighted the positive effects of exercise on immune function [10], noting its significant role in enhancing the immune response to SARS-CoV-2 antigens [11]. Moreover, physical activity is known to elevate levels of endorphins, dopamine, and serotonin, providing a counterbalance to the psychological and metabolic challenges posed by quarantine and the pandemic [12]. Consequently, it is recommended that individuals integrate physical exercise into their daily routines to enhance overall well-being [13].

However, recent studies have raised concerns regarding the implications of mask-wearing during exercise, particularly its potential to increase respiratory resistance and the rebreathing of carbon dioxide. This could lead to hypercapnic hypoxia and reduced oxygen delivery to tissues [14]. For instance, Shurlock et al. (2021) suggested that mask use during physical activity could result in an accumulation of carbon dioxide due to hypercapnia and hypoxemia, subsequently leading to decreased oxygen availability, increased carbon dioxide levels, elevated heart rate, and heightened blood pressure, even during low-intensity activities [15]. Yet, these findings have not been universally corroborated across studies [8].

Discrepancies in existing research may stem from variations in exercise intensity and the types of masks employed. High-intensity activities are particularly prone to increasing respiratory rates, which can exacerbate the risk of hypercapnic hypoxia [15]. Given that many sports involve high-intensity efforts that are vital for individual health and particularly appealing to younger demographics, investigating the effects of wearing face masks during such activities on physiological and perceptual responses is essential. Such research could provide valuable insights for athletes, coaches, and sports professionals navigating future pandemics.

Additionally, the variability in mask types utilized across different studies may contribute to inconsistencies in findings. With a pressing need for comprehensive data on this subject, a controlled investigation focusing on maximal exercise and protective interventions, such as commonly used surgical and N-95 masks, is imperative. Furthermore, a rigorous examination of the physiological and perceptual effects associated with mask-wearing during high-intensity exercise can help assuage concerns about potential adverse impacts, thus encouraging continued physical activity during public health crises.

Thus, the present study aims to evaluate the effects of wearing surgical and N-95 masks during maximal exercise on physiological, perceptual, and performance responses in healthy men.

2. Materials and Methods

2.1. Participation

This quasi-experimental study involved 15 healthy young men (mean age 23.78 ± 2.0 years; BMI 23.72±0.24 kg/m²). Participants were recruited through an announcement on the communication channel of Islamic Azad University, Shahrekord Branch, inviting individuals who met the inclusion criteria to participate. Eligible participants were selected based on the following criteria: age between 20-30 years, BMI between 20-25 kg/m², and the absence of cardiovascular, metabolic, respiratory, or inflammatory diseases. Additionally, participants had not engaged in regular physical activity or used tobacco products in the six months preceding the study. All participants completed informed consent forms, and the study adhered to the Helsinki Declaration.

2.2. Instrument

2.2.1. Shuttle run test

The shuttle run test comprises 21 levels, each with 10 intervals, requiring participants to run 20 m back and forth. Levels 1 and 2 serve as a warm-up, mimicking brisk walking. Participants begin at the starting point and cover the 20-meter distance to the sound of a beep. If a participant reaches the end before the beep, they must wait for the signal before continuing. If a participant fails to reach the marker due to fatigue or misstep, they receive a warning. After two consecutive errors or three non-consecutive errors, they are disqualified from the test. The final score, representing the total completed laps, is recorded and used to calculate maximal oxygen consumption (VO_2max) using the following formula:

$$VO_2max\ (ml/min/kg) = 31.025 + 3.238 \times speed - 3.248 \times age + 0.1536 \times speed \times age$$

In this formula, age is measured in years, and speed is the final speed achieved during the test. The initial running speed for the first level is set at 8.5 km/h, with an increment of 0.5 km/h added at each subsequent level [2]. This test has been validated in various populations, with studies demonstrating strong validity (r= 0.90) in adults [16].

Heart rate and oxygen saturation levels were measured before the test and immediately after the shuttle run using a portable fingertip pulse oximeter (Beurer model 80PO).

Blood lactate concentration was assessed before the test and immediately following the shuttle run. Capillary blood samples (approximately 1 microliter) were collected from fingertip pricks and analyzed using a portable analyzer (Lactate Plus, Nova Biomedical, Waltham, Massachusetts) [3].

2.2.2. Perceptual variables

Rate of Perceived Exertion (RPE) was

evaluated using the Borg scale, ranging from 6 to 20, where 6 indicates "no exertion" and 20 signifies "maximum effort". Participants reported their perceived exertion at baseline and immediately after completing the shuttle run.

2.2.3. Comfort/Discomfort scale

Participants rated their comfort/discomfort using a visual analog scale from 0 to 10, where 0 indicates "not at all" and 10 indicates "extremely". The scale addressed ten aspects: breath resistance, tightness, discomfort, moisture, heat, odor, fatigue, itchiness, saltiness, and overall discomfort [4]. Immediately following the perceived exertion assessment post-shuttle run, participants were asked to provide feedback on exercising with a mask during the test.

2.3. Procedure

One week prior to the commencement of the study, participants visited the university laboratory for initial assessments. Resting heart rate, height, and weight were recorded. Participants were familiarized with the shuttle run test procedure, both with and without masks, as well as the completion of the Borg Rate of Perceived Exertion (RPE) scale and a comfort/discomfort questionnaire.

The maximal exercise test was conducted using the 20 m shuttle run test. This test, executed a week after the familiarization phase, was conducted on separate days under controlled conditions: without a mask, with a surgical mask, and with an N95 mask, with a one-week interval between each test. Immediately following the shuttle run test, heart rate, blood lactate concentration, and oxygen saturation were measured. Perceived exertion and comfort/discomfort levels were also evaluated using the corresponding questionnaires. The duration of the test and the maximum oxygen consumption of participants were recorded post-exercise. Tests were conducted under standard environmental conditions (temperature: 20-25°C, relative humidity: 40-60%). Mask comfort was assessed using visual analog scales or Likert scales.

Standard N95 masks (Benehal Model-8265, NIOSH-Approved) and surgical masks (Suavel Protec Plus, Meditrade, Kiefersfelden, Germany) were utilized. Typically, these masks consist of three main layers: an inner layer (spunbond polypropylene fabric), a middle layer (meltblown polypropylene), and an outer layer (spunbond polypropylene), with the middle layer acting as a filter to prevent the ingress of harmful particles [1].

2.3.1. Dietary and Exercise control

Participants were instructed to refrain from caffeine and alcohol consumption for 24 hours prior to each shuttle run test. They were also asked to document their dietary intake over the preceding 24 hours before the first exercise test and replicate the same dietary intake before the subsequent tests. All participants maintained a food diary and provided photographic evidence of their pre-test meals.

2.4. Statistic

Data were analyzed using SPSS software (version 22). Descriptive statistics, including means and standard deviations, were reported for all variables. The Shapiro-Wilk test was employed to assess the normality of data distribution. Repeated measures ANOVA was utilized to compare mean differences across the three testing conditions: no mask, surgical mask, and N95 mask. A significance level of $P < 0.05$ was established.

3. Results

All participants completed the 20 m shuttle run test under three conditions: without a mask, wearing a surgical mask, and wearing an N-95 mask. Their data were included in the final analysis. The participants' demographic characteristics, including height, weight, body fat percentage, and maximal heart rate, are presented in Table 1. No significant differences were observed in any variables prior to the start of the shuttle run test.

Table 1. Characteristics of participants

Variable	Mean ± SD
Number of participants	15
Age (years)	23 ± 2.78
Height (m)	1.73 ± 0.10
Weight (kg)	70.5 ± 4.5

The results of the repeated measures analysis indicated that wearing a surgical mask or an N-95 mask during the shuttle run test significantly affected physiological variables, leading to increased blood lactate concentration ($P \leq 0.05$) and decreased oxygen saturation ($P \leq 0.05$). However, no significant differences were observed between the two types of masks (Table 2).

Additionally, perceptual variables, such as the rate of perceived exertion ($P \leq 0.01$) and the sense of comfort/discomfort (Table 3), were significantly influenced by wearing a mask. Moreover, it appears that the significant changes in physiological and perceptual variables due to mask use during maximal exercise were associated with notable performance reductions. Specifically, maximal oxygen uptake, test duration, and distance covered during the shuttle run test significantly decreased ($P \leq 0.01$) (Table 2).

Table 2. Mean physiological, performance, and perceived exertion responses with and without masks

Variable	Exercise with N95 mask (mean ± SD)	Exercise with Surgical mask (mean ± SD)	Exercise without mask (mean ± SD)	P
Heart rate (beats per minute)	185 ± 8.5	183 ± 6.9	179 ± 5.2	0.126
Oxygen saturation (%)	95.3 ± 1.3	96.4 ± 1.4	97.5 ± 1.5	0.043*
Blood lactate concentration (mmol/L)	6.6 ± 0.87	6.4 ± 0.39	5.1 ± 0.35	0.026*
Perceived exertion (0-10)	9.1 ± 1.4	8.9 ± 0.35	7.8 ± 1.4	0.001**
Maximal oxygen consumption (mL/kg/min)	36.5 ± 3.14	37.9 ± 3.35	43.8 ± 3.98	0.001**
Duration of shuttle run test (min)	5.02 ± 0.251	5.22 ± 0.235	6.35 ± 1.35	0.001**
Distance of shuttle run test (m)	859 ± 65.239	1157 ± 49.357	1295 ± 41.295	0.001**

*= Significant at the 0.05 level

** = Significant at the 0.01 level

Table 3. Comfort/Discomfort feelings during exercise with masks

Feelings	Exercise with N95 mask (mean ± SD)	Exercise with surgical mask (mean ± SD)
Humidity feeling	7.4 ± 1.35	7.4 ± 1.02
Heat feeling	6.9 ± 1.22	6.2 ± 1.13
Shortness of breath feeling	7.1 ± 0.58	7.3 ± 0.89
Itching feeling	3.5 ± 1.25	2.5 ± 1.13
Mask tightness feeling	3.2 ± 0.89	2.2 ± 0.75
Salty feeling	2.9 ± 0.65	3.2 ± 0.46
Mask fit feeling	1.8 ± 1.68	1.87 ± 1.24
Bad odor feeling	4.5 ± 1.55	3.12 ± 1.03
Fatigue Feeling	5.6 ± 0.57	5.2 ± 0.87
Total	4.9 ± 1.33	4.8 ± 1.04

4. Discussion

This study investigated the physiological, perceptual, and performance effects of wearing surgical and N95 masks during maximal exercise among healthy men. The results showed that both masks significantly decreased oxygen saturation (*P*= 0.043) and increased blood lactate concentration (*P*= 0.026). Participants reported higher perceived exertion and experienced reductions in maximal oxygen consumption, exercise duration, and distance covered during the shuttle run (*P*< 0.001), with no significant differences between the two mask types. Additionally, both masks contributed to increased sensations of moisture, heat, shortness of breath, and fatigue.

Notably, the use of masks did not significantly affect heart rate, consistent with previous studies showing minimal impact of mask-wearing on heart rate [1, 2, 3]. A systematic review also reported no significant heart rate changes while using masks [4]. However, Li et al. (2005) noted a decrease in heart rate with N95 masks [5]. The lack of significant differences in heart rate in this study may stem from the homogeneity of the sample, which comprised only healthy individuals, contrasting with studies that included diverse populations [3]. This suggests that the physiological impact of masks during progressive exercise on heart rate is limited and unlikely to affect overall performance significantly.

Potential physiological mechanisms may involve reduced respiratory rates and increased effort, leading to enhanced muscular engagement without significant changes in heart rate, possibly due to participant youth, as age affects heart rate responses to mask-wearing [7]. Further research is needed to explore cardiovascular responses under various exercise conditions.

The study also found that wearing masks significantly reduced oxygen saturation during the shuttle run, consistent with prior research indicating compromised oxygen saturation [8]. This reduction could be due to increased end-tidal carbon dioxide ($PetCO_2$) and inadequate gas exchange from CO_2 rebreathing [9]. Elevated $PetCO_2$ may result in hypercapnia, further decreasing oxygen saturation. Additionally, airflow restrictions caused by masks might limit fresh air intake, constraining oxygen supply [3]. Although reductions in oxygen saturation were observed, they typically remained within clinically insignificant ranges of 95-100% [10]. Importantly, no significant differences in oxygen saturation reduction were found between the mask types, indicating that the physiological effects may depend more on factors like participants' physical condition and age than on the specific mask used.

Furthermore, the study revealed increased blood lactate concentration, decreased VO_2max, and reduced exercise duration while wearing masks. These findings align with research highlighting physiological challenges linked to exercising with masks [1, 9]. The increase in lactate concentration may arise from heightened respiratory resistance, leading to increased respiratory muscle activity and competition for oxygen between respiratory and working muscles, shifting energy production to anaerobic pathways [1]. The reduction in aerobic capacity and shuttle run duration likely stems from increased respiratory resistance and gas exchange limitations, contributing to heightened fatigue and reduced exercise intensity, as previously reported [2].

This study also indicated that mask-wearing significantly increased perceived exertion and discomfort during the shuttle run test, supporting previous findings that masks can elevate psychological and physical discomfort during high-intensity activities [3, 11]. The increase in perceived exertion associated with surgical masks may result from greater respiratory resistance and reduced pulmonary performance [3]. Additionally, environmental factors such as temperature and humidity may exacerbate discomfort, as high ambient conditions can intensify sensations of heat and discomfort from masks [2, 11].

In conclusion, the findings indicate that wearing surgical and N95 masks during intense exercise negatively impacts various physiological, perceptual, and performance responses. Increases in blood lactate concentration and decreases in maximal oxygen consumption and shuttle run duration highlight limitations in exercise performance. However, no significant differences were observed between the two mask types. These results have implications for refining exercise guidelines during pandemic conditions and underscore the need for further research on the long-term effects of mask use in diverse athletic context.

This study has limitations, including a small sample size; thus, it is recommended that future research utilize larger and more diverse samples to enhance the credibility of the results. The type and intensity of the physical activity studied may influence the outcomes; therefore, future studies should include various types of exercises at different intensities to determine whether similar results can be obtained under different conditions. Additionally, this research focused solely on two specific types of masks, and future investigations could explore a broader range of masks and their various usage conditions to more comprehensively assess their impacts on athletic performance. The lack of examination of the long-term effects of mask use is another limitation of this study.

5. Conclusions

The results of this research indicate that wearing masks during intense exercise can negatively affect certain physiological, perceptual, and performance responses. The increase in lactate concentration and decrease in maximal oxygen consumption and shuttle run duration among groups using surgical and N95 masks suggest limitations in exercise performance under these conditions. However, no significant differences were observed between the two types of masks. These findings may aid in refining exercise guidelines during pandemic conditions, but further research is necessary to evaluate the long-term and broader effects of mask use in various athletic contexts.

Conflict of interest

The authors declared no conflicts of interest.

Authors' contributions

The author contributed to the original idea, study design.

Ethical considerations

The author has completely considered ethical issues, including informed consent, plagiarism, data fabrication, misconduct, and/or falsification, double publication and/or redundancy, submission, etc.

The ethical guidelines approved by the Ethics Committee of Islamic Azad University, Shahrekord branch (IR.IAU.SHK.REC.1401.096).

Data availability
The dataset generated and analyzed during the current study is available from the corresponding author on reasonable request.

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