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Original Article

Effect of face masks on dyspnea perception, cardiopulmonary parameters, and facial temperature in healthy adults

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Abstract

Respiratory droplets, naturally produced during expiration, can transmit pathogens from infected individuals. Wearing a face mask is crucial to prevent such transmission, yet the perception of dyspnea and uncomfortable breathing remains a common concern, particularly during epidemics. The aim of this study was to investigate the impact of face mask use on the perception of dyspnea, cardiopulmonary parameters, and facial temperature during physical activity. A randomized crossover study was conducted on healthy adults at a physiology laboratory located in the Faculty of Medicine, Universitas Sumatera Utara, Medan, Indonesia, in November 2022. Participants underwent five stages of physical exercise tests based on the Bruce Protocol under three conditions: without any face mask (control), wearing a surgical mask, and an N95 mask, forming the study's main groups. Dyspnea perception (measured by the Modified Borg Dyspnea Scale), cardiopulmonary parameters (heart rate, oxygen saturation, respiratory rate, blood pressure, and mean arterial pressure) and facial temperature were measured before the exercise test (pre-workout), at the end of stage 1, 2, 3, 4, 5, and after the whole exercise test (post-workout). A two-way repeated measures ANOVA was conducted, considering two factors: the type of mask (control, surgical mask, N95 mask) and the various stages of the exercise test. A total of 36 healthy adults were included in the study. We found that dyspnea perception was much worse in the N95 mask group, particularly during vigorous exercise. There was no significant difference between groups in cardiopulmonary parameters. However, participants wearing N95 had a greater supralabial temperature than those wearing surgical masks or no mask at all. It is recommended to undertake a more in-depth evaluation of cardiopulmonary physiological measures.

Keywords: Dyspnea perception, N95 mask, surgical mask, cardiopulmonary parameters, facial temperature

Introduction

Throughout various expiratory activities, such as breathing, speaking, and sneezing, respiratory droplets are released from the mouth and nose [1]. Physiologically, a respiratory droplet is composed of water, several electrolytes (including sodium, potassium, and chloride), and cells from the respiratory tracts, such as epithelial lining cells, ranging in size from 0.1 μm to 1,000 μm [2]. In individuals with respiratory tract infections, droplets can also transmit pathogenic germs. Droplets with sizes less than 10 μm, undergo aerosolization and are dispersed extensively by ventilation, becoming a vector for infectious pathogens [3,4]. Most pandemics, such as the

Received: November 23, 2023 - Accepted: February 26, 2024 - Published online: February 28, 2024

Spanish flu, Hong Kong flu, and coronavirus disease 2019 (COVID-19) pandemic were caused by viral respiratory tract infections [5].

The use of a face mask is one of the known effective methods for preventing the spread of respiratory infections [6]. During the most recent pandemic, numerous studies have proved the efficacy of face masks in preventing the spread of SARS-CoV-2 in communities, minimizing the probability of transmission up to 70% [7,8]. However, many individuals continue to hold a negative sentiment regarding the use of face masks. Approximately 10% of active social media users in the United States still have an unfavorable perception on the use of masks [9]. Common causes for this anti-mask attitude include physical pain, unpleasant impacts, ineffectiveness, and a belief that masks are needless or inappropriate for some individuals or contexts [10]. One of the most common issues experienced by individuals wearing face masks is uncomfortable breathing and the perception of dyspnea [11,12]. Thus, the aim of this study was to investigate the impact of face mask use on the perception of dyspnea, cardiopulmonary parameters, and facial temperature during physical activity in healthy adults.

Methods

Study design, setting and sampling strategy

A randomized crossover study was conducted at a physiology laboratory located in the Faculty of Medicine, Universitas Sumatera Utara, Medan, Indonesia, in November 2022. Participants underwent a series of physical exercise tests under three conditions: without any face mask (control), wearing a surgical mask, and an N95 mask, constituting the three main groups of this study. To compute the required sample size, the authors used G*Power 3.1 (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany) for repeated measures ANOVA. With an α error of 0.05 and a power of 0.9, the analysis revealed that the minimum sample size was 36 participants.

Participants

This study included healthy adults with the following criteria: aged 18–30 years, a body mass index (BMI) of 18.5–25 kg/m^2, and screened without any history of comorbidities based on the physical activity readiness questionnaire (PAR-Q) [19]. Participants with any history of comorbidities, such as cardiopulmonary diseases (hypertension, asthma, etc.), metabolic disorders (diabetes, hyperthyroid, etc.), orthopedic disorders (fractures, sprained limbs, etc.), or any other medical contraindications were excluded from the study.

Intervention

Each participant would perform an exercise test on a treadmill progressively under three conditions: without a face mask, wearing a surgical mask, and an N95 mask. The exercise test was carried out based on the Bruce Protocol. There were five stages to the protocol, with each stage lasting three minutes, i.e.: (S1) walking at a speed of 2.7 km/hour; (S2) walking at a speed of 4.0 km/hour; (S3) walking at a speed of 5.5 km/hour; (S4) jogging at a speed of 6.8 km/hour; and (S5) running at a speed of 8.0 km/hour. The exercise test would be discontinued and the participant would be dropped out from the study if the maximum heart rate (207–(0.7×age)) was reached or if they were unable to sustain the exercise intensity. After completing the exercise test, participants were given a 1-minute rest prior to further assessment while still wearing their respective face masks.

The participants underwent the exercise test once per day for a total of three days, alternating depending on the mask status (day one without a face mask, day two wearing a surgical mask, and day three wearing an N95 mask). Two types of face masks were used: surgical masks (Sensi© 3-ply surgical masks, registered in the Indonesian Ministry of Health AKD 21603410192) and N95 masks (3M© 8210 particulate respirator N95). All masks were securely fastened beforehand by a trained observer according to manufacturers' specifications. All exercise tests procedures were performed in a temperature-controlled laboratory (24–25°C), with all participants in a well-hydrated state and having abstained from vigorous activity for 24 hours prior to the intervention. At least 24 hours were given between adjacent intervention sessions.

Data collection

All characteristics data, including gender, height, weight, and body mass index (BMI) were carried out prior to the intervention. Prior to the procedures, all participants received an explanation regarding the Modified Borg Dyspnea Scale and were instructed to rate their dyspnea perception using this scale at the completion of stage 1, 2, 3, 4, and 5. The scale ranges from 0 to 10, with the following interpretations: (0) nothing at all, (0.5) very, very slight, (1) very slight, (2) slight, (3) moderate, (4) somewhat severe, (5–6) severe, (7–8) very severe, (9) very, very severe, and (10) maximal. Heart rate and oxygen saturation were measured one minute before the exercise test (pre-workout), at the completion of stage 1, 2, 3, 4, 5, and one minute after the whole exercise test (post-workout). Respiratory rate was measured one minute before and after having done exercise test (pre-workout and post-workout), and 30 seconds before the end of stage 1, 2, 3, 4, 5. Blood pressure and facial temperature were assessed one minute before and after having done the exercise test (pre-workout and post-workout). Blood pressure was measured using the mercury sphygmomanometer Nova Ecoline (Riester GmbH, Germany). The mean arterial pressure (MAP) was calculated based on the systolic and diastolic levels obtained from the blood pressure measurement. Respiratory rates were measured by observation for 30 seconds prior to the end of each stage. Oxygen saturation and heart rate were measured using a pulse oximeter Beurer Bluetooth-PO 60 (Beurer GmbH, Germany). Facial temperatures (supralabial and midfrontal area) were measured during pre- and post-workout using an infrared thermometer Omron MC-720 (Omron Corp., Kyoto, Japan).

Statistical analysis

The normality test of variables was carried out using the Shapiro-Wilk test. To determine the differences between the type of masks and the seven variables (dyspnea perception, heart rate, oxygen saturation, respiratory rate, blood pressure, MAP and facial temperatures), a two-way repeated measures analysis of variance (ANOVA) was carried out for normally distributed data. Two-way repeated measures ANOVA was carried out based on two factors, including the type of mask (control vs surgical mask vs N95 mask) and different stages of the exercise test (pre-workout, stage 1, 2, 3, 4, 5, and post-workout). On the other hand, if the normal distribution was not assumed, the Friedman test was carried out. If any significant interaction was found, a post-hoc analysis was performed. A statistically significant difference was considered at a *p*-value of <0.05. Continuous data were reported with means and standard deviations (SD) if the distribution was normal. Conversely, if the distribution was not normal, the data would be reported as median, minimum, and maximum. All statistical analysis was performed using R studio (Posit Software, Boston, USA).

Results

Characteristics of participants

A total of 36 healthy adults were included in the study, as presented in **Table 1**. Both males and females consisted of 18 individuals with the mean age of 20.91±0.49. The healthy adults had an average height of 167.67±9.23, weight of 63.16±10.61, and a BMI of 22.27±1.58.

Table 1. Characteristics of the healthy adults (n=36)

Characteristics	Mean±SD
Gender, (n)	
Male	18
Female	18
Age (years)	20.91±0.49
Height (cm)	167.67±9.23
Weight (kg)	63.16±10.61
BMI (kg/m²)	22.27±1.58

Effects of face mask on dyspnea perception among healthy adults

All participants completed all stages of the Bruce protocol. A gradual increase in the average Borg score was observed among all three groups from stage 1 to stage 5. Overall, the groups wearing a mask had a higher average Borg score than the control, detecting a higher dyspnea perception among healthy adults during physical exercise. Participants wearing the N95 mask exhibited the highest average Borg score (**Figure 1**).

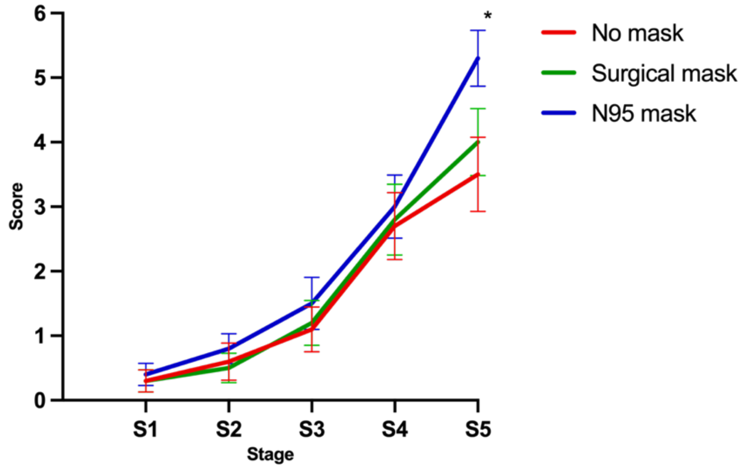

Figure 1. The average score of the Modified Borg Dyspnea Scale between groups.

At stage 1, the surgical mask and control group had the same mean Borg score of 0.3±0.6, while the N95 mask group was 0.4±0.6. Ongoing to stage 5, the mean Borg score of the control, surgical and N95 mask group had increased to 3.5±2, 4±1.8, and 5.3±1.5, respectively. A significant mean difference (p=0.03) was seen between all groups (**Table 2**).

Table 2. The average Modified Borg Dyspnea Scale score in each stage of exercises between groups

Modified Borg Dyspnea scale	No mask	Surgical mask	N95 mask	*p*-value
Stage 1	0.3±0.6	0.3±0.6	0.4±0.6	0.03*
Stage 2	0.6±1	0.5±0.8	0.8±0.8	
Stage 3	1.1±1.2	1.2±1.2	1.5±1.4	
Stage 4	2.7±1.8	2.8±1.9	3±1.7	
Stage 5	3.5±2	4±1.8	5.3±1.5	

* Statistically significant at $p<0.05$

Effects of face mask on cardiopulmonary parameters among healthy adults

There was a consistent increase observed in heart rate, respiratory rate, blood pressure, and MAP throughout all stages of exercise and between pre- and post-workout measurements within both the control and mask-wearing groups. A gradual decrease in oxygen saturation was only revealed in the N95 mask group. Nonetheless, no statistical difference was found between all groups ($p>0.05$) (**Table 3**). A visualization of the cardiopulmonary parameter trends between all groups can be seen in **Figure 2**.

Table 3. Cardiopulmonary parameters at various time intervals between groups

Cardiopulmonary parameters	No mask	Surgical mask	N95 mask	*p*-value
Heart rate (beats/min)				0.223
Pre-workout	81.42±10.75	82.00±7.19	80.25±9.91	
Stage 1	91.83±10.28	96.25±9.06	95.92±10.93	
Stage 2	99.67±11.66	101.92±8.87	104.25±13.48	
Stage 3	116.00±14.64	116.17±12.58	116.83±18.60	
Stage 4	134.50±14.93	144.42±14.28	142.58±17.23	
Stage 5	143.33±13.10	156.75±11.88	153.42±12.87	
Post-workout	95.33±14.55	98.08±6.97	96.42±12.41	
Oxygen saturation (%)				0.488
Pre-workout	98.33±0.89	98.25±1.06	98.42±1.17	
Stage 1	98.08±1.08	98.42±1.17	98.25±1.14	
Stage 2	98.58±1.00	98.50±1.24	97.92±1.08	
Stage 3	98.08±0.79	98.17±0.94	97.75±0.75	
Stage 4	97.58±1.24	98.25±1.14	97.42±0.79	

Cardiopulmonary parameters	No mask	Surgical mask	N95 mask	*p*-value
Stage 5	98.08±0.79	97.67±1.30	97.25±1.22	
Post-workout	98.17±0.84	98.17±0.94	98.17±0.72	
Respiratory rate (times/min)				0.077
Pre-workout	13.00±1.81	12.67±1.56	12.67±1.56	
Stage 1	15.00±2.49	16.00±1.71	16.00±2.41	
Stage 2	17.00±1.81	18.67±3.11	17.50±1.93	
Stage 3	21.33±1.97	22.67±3.55	22.67±2.61	
Stage 4	26.00±2.70	25.00±3.86	27.67±2.67	
Stage 5	30.33±2.67	29.50±3.09	31.00±3.46	
Post-workout	17.67±3.17	16.67±2.31	16.00±2.41	
Systolic blood pressure (mmHg)				0.989
Pre-workout	119.17±4.69	117.50±8.12	116.67±5.37	
Post-workout	120.25±4.56	118.92±7.95	117.92±7.22	
Diastolic blood pressure (mmHg)				0.392
Pre-workout	78.33±4.44	76.25±5.28	73.33±8.35	
Post-workout	80.00±7.07	80.83±7.01	79.17±8.75	
Mean arterial pressure (mmHg)				0.443
Pre-workout	91.94±3.08	90.00±5.60	87.78±6.75	
Post-workout	93.42±5.13	93.53±6.53	92.08±7.29	

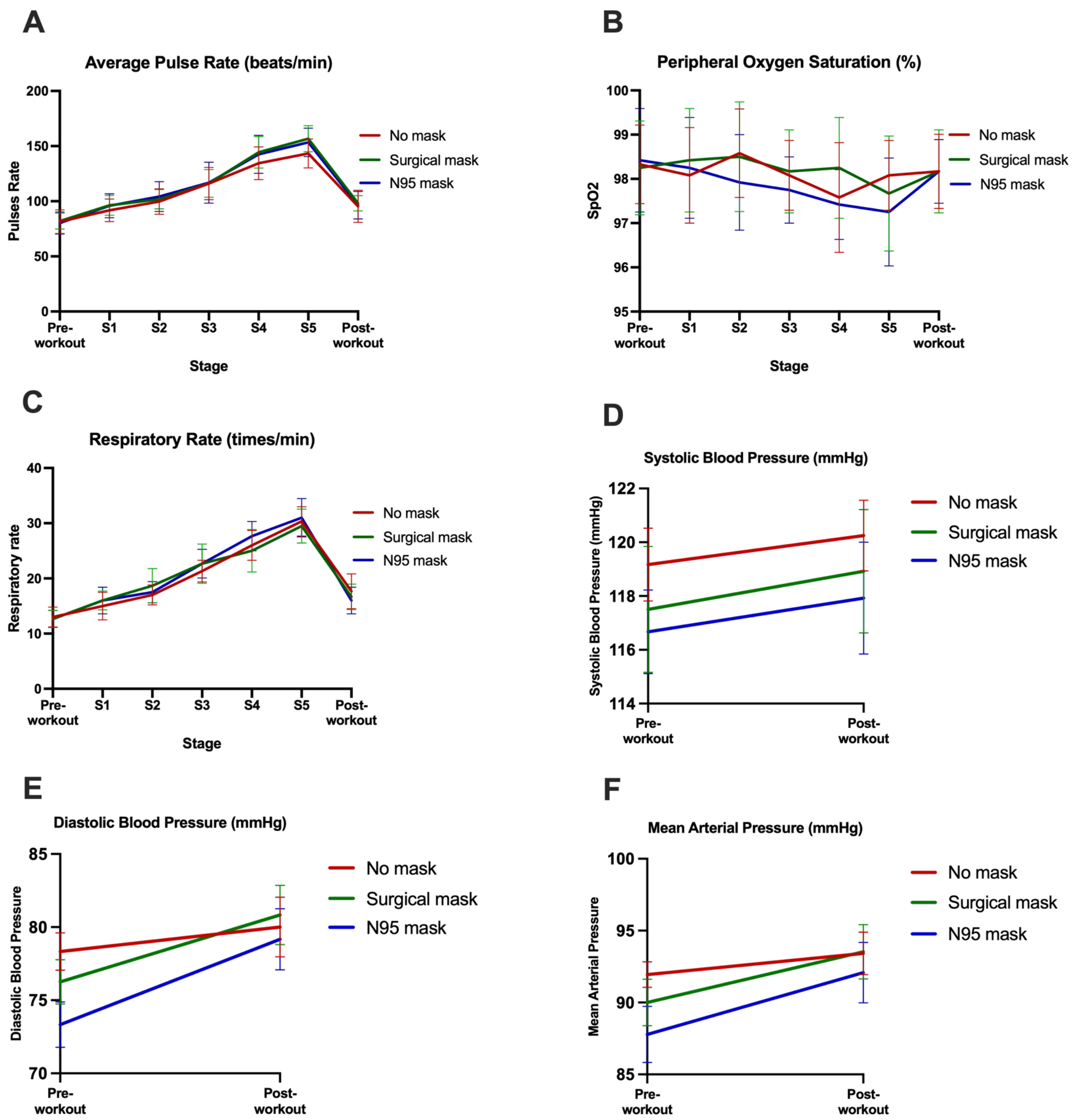

Figure 2. Average values for cardiopulmonary parameters between groups: (A) heart rate; (B) oxygen saturation; (C) respiratory rate; (D) systolic blood pressure; (E) diastolic blood pressure; and (F) mean arterial pressure (MAP).

Effects of face mask on facial temperature among healthy adults

The supralabial temperature was considerably higher among the N95 mask group during post-workout (36.75±0.22°C) compared to the control and surgical mask group which showed almost similar temperatures of 36.52±0.16 and 36.51±0.14, respectively. While the midfrontal temperature had a decreasing trend in the mask group compared to the control group. A significant difference in temperatures was only observed in the supralabial area (p=0.001) (**Table 4**). **Figure 3** presents a visual depiction of the trends in facial temperatures across all groups.

Table 4. Facial temperatures of pre- and post-workout between groups

Facial temperature	No mask	Surgical mask	N95 mask	*p*-value
Supralabial temperature (°C)				0.001*
Pre-workout	36.51±0.15	36.50±0.13	36.49±0.13	
Post-workout	36.52±0.16	36.51±0.14	36.75±0.22	
Midfrontal temperature (°C)				0.501
Pre-workout	36.53±0.20	36.57±0.14	36.63±0.10	
Post-workout	36.53±0.18	36.52±0.15	36.58±0.09	

* Significant if $p<0.05$

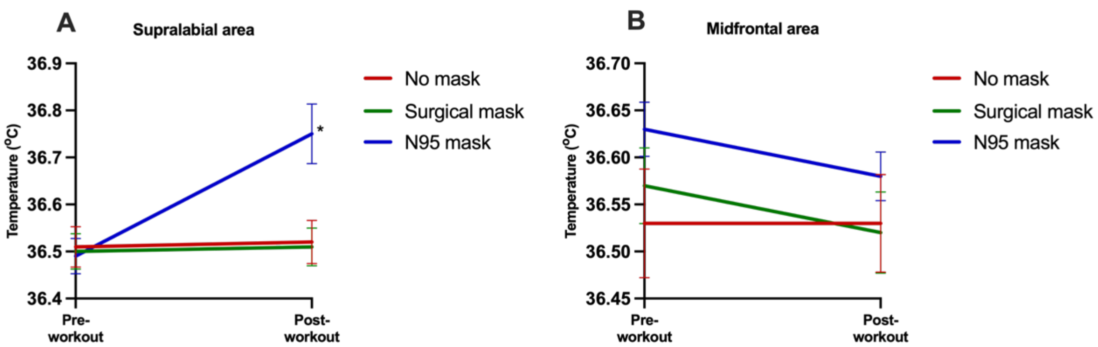

Figure 3. Average facial temperature between groups: supralabial area (A) and midfrontal area (B).

Discussion

At the fifth stage of the physical exercise, the average control group had a Borg score of 3.5 (moderate), the surgical mask group had a score of four (moderately severe), and the N95 mask group had a score of five (severe). There was a statistically significant difference between the mask group and the control group at the fifth stage. The N95 mask raises respiratory resistance by 1.4 cmH_2O and the work of breathing by approximately 5 J/minute, but surgical masks increase respiratory resistance by only 0.8 cmH_2O [21]. Increased respiratory resistance will lower the concentration of breathed oxygen, hence decreasing the volume of oxygen consumed (VO_2) and end-tidal oxygen value ($PETO_2$) [22]. Consequently, the N95 mask induced a greater perception of dyspnea than the control group during vigorous exercise.

This study found neither surgical masks nor N95 masks had an effect on oxygen saturation, this was consistent with the findings of prior studies on surgical masks, cotton masks, and N95 masks [23,24,25]. It has also been stated that the use of surgical masks and cloth masks during progressive cycle ergometer activity tests had a minor and statistically inconclusive effect on oxygen saturation in healthy adults [14,26]. During maximal-intensity exercise tests in healthy volunteers, a study found that the capillary partial pressure of both oxygen (PO_2), and carbon dioxide (PCO_2), and acidity (pH) did not differ substantially between surgical masks and N95 masks, indicating that face masks did not significantly alter alveolar ventilation or gas exchange [27].

A slight increase in inspiratory resistance during the cardiopulmonary exercise test (CPET) causes dyspnea in healthy subjects and has been demonstrated to elevate the resting heart rate by 8 to 10 beats per minute [28]. In the fourth stage of the physical exercise, there was an average increase in heart rate of 8–10 beats/min for the surgical and N95 mask group, whereas in the fifth stage, there was an average increase in heart rate of 10–16 beats/min for the same group. However, the association between a higher heart rate and the usage of a mask has been a topic of controversy in numerous past studies. Previous studies have conducted CPET tests on healthy participants and found no statistically significant difference between heart rate and face mask usage during exercise [14,26,27]. This is consistent with the findings of this study, in which the use of surgical and N95 masks marginally raised heart rate, although the difference was not statistically significant.

A previous study concluded that the cardiopulmonary response to the use of an N95 mask for one hour with low to moderate exercise intensity was relatively small and should be well tolerated by healthy people [29], and another study that conducted an incremental exercise test on ten healthy subjects until maximum intensity concluded that in healthy subjects, short-term moderate-strenuous aerobic physical activity with a mask is feasible, safe, and associated with only minor changes in physiological parameters [26]. This corresponds with our findings for respiratory rate and blood pressure parameters, where it was reported fairly higher for the surgical and N95 mask groups compared to the control group, despite with lack of a statistically significant difference.

Putting on an N95 mask at rest for forty minutes resulted in a 0.7–1.9°C increase in the skin temperature of the covered area, which correlates to a considerable difference in discomfort [12]. A rise in supralabial temperature may generate the perception of dyspnea via local subjective feelings that are frequently reported as "respiratory discomfort," "increased inspiratory/expiratory effort," "breathing constriction," etc. [15]. According to laboratory studies, directing cool air to the face with a fan lowers induced dyspnea in healthy people [16]. This increase in the perception of dyspnea is mediated by cutaneous receptors of the trigeminal nerve, namely trigeminal branches two and three, which are mostly composed of mechanoreceptors, thermoreceptors, and nociceptors [30]. On the basis of the postulated mechanism, the increase in supralabial temperature may have influenced the increased sense of dyspnea in this study.

The sample for this study consisted of 36 young, healthy, adult participants, which to the best of our knowledge is the largest crossover study to date comparing cardiopulmonary parameters and subjective perceptions to the use of commonly worn face masks. However, we were aware of several limitations that could be found in this study. The study was conducted in an indoor setting using a treadmill, which may pose challenges in generalizing the findings to other physical activities. Observed cardiopulmonary parameters were limited to clinical vital signs, whereas other physiological parameters, such as PCO_2, VO_2 max, lactate levels, etc., were not measured.

Conclusion

The N95 mask increased the perception of dyspnea during strenuous exercise without affecting heart rate, peripheral oxygen saturation, respiration rate, or blood pressure. In addition, supralabial temperature was increased while using the N95 mask, which may have contributed to the increased dyspnea perception. More extensive examination of cardiopulmonary physiological measurements is recommended.

Ethics approval

The protocol of this study was approved by the Medicine and Health Research Ethics Committee Universitas Sumatera Utara, Medan, Indonesia and was conducted in accordance with the Declaration of Helsinki and the Nuremberg Code.

Competing interests

All the authors declare that there are no conflicts of interest.

Funding

This study received no external funding.

Underlying data

Derived data supporting the findings of this study are available from the corresponding author on request.

Acknowledgments

We would like to express our deepest appreciation to Yetty Machrina and Anastasya Valentine for this study would not have been possible without them.

How to cite

Ramoti N, Siahaan AMP, Indharty S, Adella CA. Effect of face masks on dyspnea perception, cardiopulmonary parameters, and facial temperature in healthy adults. Narra J 2024; 4 (1): e574 - http://doi.org/10.52225/narra.v4i1.574.

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