RESEARCH ARTICLE

Effects of wearing different facial masks on respiratory symptoms, oxygen saturation, and functional capacity during six-minute walk test in healthy subjects

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Background: During the current COVID-19 pandemic and increased air pollution levels, wearing a facial mask has been recommended. This study aimed to compare the impact of wearing different masks when performing a submaximal functional activity (six-minute walk test; 6MWT) on respiratory symptoms, oxygen saturation, and functional capacity.

Methods: Twenty-nine subjects (10 men, 19 women; age 22 ± 1 yr.; FEV_1/FVC 0.90 ± 0.01) performed four rounds of 6MWT wearing different masks (surgical (Medima SK, Thailand), handmade cloth, and N95 (3M AuraTM 1870$^+$, USA)) and while not wearing a mask. Respiratory symptoms (dyspnea and breathing effort), oxygen saturation, and other physiological parameters were assessed before and after each walking trial.

Results: Six-minute walking distances were comparable between walking trials ($P = 0.59$). At the end of minute 6, a significant difference between groups was found on dyspnea ($P = 0.02$) and breathing effort ($P < 0.001$). Post hoc tests showed that wearing a cloth mask significantly increased dyspnea ($P = 0.004$) compared to wearing a surgical mask. Wearing a cloth mask also significantly increased breathing effort compared to wearing a surgical mask ($P < 0.001$) and not wearing a mask ($P < 0.001$). Likewise, while wearing an N95 mask, breathing effort significantly increased compared to wearing a surgical mask ($P = 0.007$) and not wearing a mask ($P = 0.002$).

Conclusions: Wearing different masks while performing submaximal functional activity results in no differences in functional performance, oxygen saturation, heart rate, or blood pressure. However, wearing cloth masks and N95 masks results in higher respiratory symptoms.

Key Words: *COVID-19; air pollution; dyspnea; breathing effort; exercise; hypoxia*

INTRODUCTION

Recently, wearing facial masks to protect individual health became much more common due to the COVID-19 pandemic and ambient air pollution [1, 2]. Worldwide, there have been over 452 million confirmed COVID-19 cases and over 6 million deaths due to COVID-19 from 2019 to mid-March 2022 [3]. COVID-19 has affected many aspects of the global economy and day-to-day life (e.g., healthcare burden, disruption of normal social interaction, and accumulated individual stress) [4, 5].

Studies about the effect of mask wearing during exercise on physiological parameters are limited and inconclusive. The World Health Organization (WHO) recommends that people not wear masks during vigorous exercise or activity because masks may reduce breathing comfort [2]. Several studies have reported deterioration of cardiopulmonary physiological parameters during exercise with facial masks, such as reduced exercise capacity, decreased oxygen saturation (SpO_2), and increased respiratory symptoms (e.g., dyspnea and breathing effort) [6–10]. One study indicated that exercise with facial masks poses more health risks by affecting various physiological systems of the human body, especially the pulmonary, circulatory, and immune systems [11]. Exercise with facial masks may induce hypercapnic hypoxia, resulting in a hypoxic environment for vital organs, increased cardiorespiratory stress, and altered immune responses, renal function, and brain metabolism [11]. Another study stated that wearing masks for everyday use causes adverse effects due to psychological and physical deterioration [12]. However, many studies have demonstrated that exercise with masks has no influence on performance and has minimal impact on physiological variables, safety, and feasibility in healthy and clinical subjects [13–15].

Several types of masks are used in healthcare settings and communities. Each type has unique qualities for heath protection, such as the ability to filter small particles, fluid resistance, breathability, and fit [2]. Surgical masks are usually flat or pleated, composed of 3–4 layers, and tested by a set of standardized methods to achieve 3-micrometer droplet filtration, adequate breathability, and optimal fluid resistance [2, 16]. N95 respirators are designed to filter particles smaller than 0.3 micrometers according to qualification standards (e.g., National Institute for

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Occupational Safety and Health (NIOSH) 42 CFR, European standard EN 149) [2, 16, 17]. The design also ensures that the maximal breathing resistance is not hindered and that the seal around the face can prevent leakage. N95 is considered a medical device and has been developed to protect the wearer from infectious airborne aerosol [2, 16]. Cloth masks are constructed using breathable fabric (cotton, cotton blends, polyesters, nylon, etc.). Filtration efficacy of a single layer fabric ranges from 5% to 80% for particles smaller than 0.3 micrometers and from 5% to 95% for particles larger than 0.3 micrometers. However, filtration efficacy increases when multiple layers of different fabrics are used [2, 18]. Current evidence shows that cloth masks have limited filtration efficacy on viral infection transmission [19].

While wearing facial masks in daily life has become more common, the physiological effect of wearing different mask types during physical activity is still unclear. Evaluating the physiological effect of wearing different mask types during physical activity would help individuals select appropriate masks considering all the risks and benefits. Most physical activities performed in daily living are at a submaximal level of exertion [20]. Therefore, the six-minute walk test (6MWT) was chosen as a standard test to evaluate functional exercise capacity at a submaximal level. This study aims to compare the impact of wearing different masks during a 6MWT on respiratory symptoms, SpO_2, and functional capacity.

MATERIALS AND METHODS

Subjects

Healthy adults (aged 18–25 years) were included in the study using a convenience sampling method. Written informed consent was obtained from all the subjects. Dyspnea intensity on a 10-point Borg CR scale was a primary outcome of the study. Sample size calculation was performed using G-Power version 3.1.9.4 [21]. Using the mean and standard deviation (SD) from the previous study [8], the calculated effect size was rather large. In this study, to establish a medium effect size, a minimum of 25 subjects was required. To account for the possibility that some subjects might not complete all the trials, a final number of 30 subjects was recruited.

The exclusion criteria included that the subject had been previously diagnosed with cardiopulmonary diseases or had conditions that prevented the participant from performing the pulmonary function and walking tests (e.g., neurological, musculoskeletal, or cognitive problems).

Design

This study is a prospective crossover study designed to compare physiological parameters of healthy young individuals during 6MWT while wearing different types of facial masks. The Human Research Ethics Unit, Faculty of Associated Medical Sciences, Chiang Mai University, Thailand, approved the study (study code AMSEC-63EX-063, date of approval: 28 October 2020). After assessing inclusion criteria for each subject, the subjects were instructed to perform a pulmonary function test (spirometry). Then they were randomly assigned to perform four trials of the 6MWT wearing different types of facial masks in each trial. The trials were performed 24–48 h apart to ensure that the effect of the previous trial (e.g., leg fatigue) did not influence the result of the following one. The subjects were asked to avoid excessive exercise during the testing period. Physiological parameters such as blood pressure (BP; Omron Healthcare Co., Ltd, Kyoto, Japan), heart rate (HR), and SpO_2 (Smiths Medical PM, Inc., Wisconsin, USA) were assessed before and after the walking test. Dyspnea intensity, breathing effort, and leg fatigue scores were evaluated using a Borg CR-10 scale at rest and at the end of the walking test. Heart rate recovery was measured 1 min after finishing the test.

Pulmonary function test

After daily calibration, spirometry (NDD Medical Technologies, Zurich, Switzerland) was performed according to the American Thoracic Society and European Respiratory Society (ATS/ERS) guidelines [22, 23] to assess subjects' pulmonary function. Each subject was asked to perform forced vital capacity (FVC) maneuvers; after checking the acceptability criteria of the maneuver, FVC volume and forced expiratory volume at the first second (FEV_1) were acquired. Subjects were allowed to repeat the test no more than eight times until three maneuvers passed the repeatability criteria. The largest FVC and FEV_1 values were determined, and all values were recorded for interpretation.

Six-minute walk test

A 6MWT is a self-paced walking test used to assess a submaximal level of functional exercise capacity. In this study, 6MWT was performed according to the American Thoracic Society Statement [20]. In short, the participants were asked to walk as far as possible at their own pace in a 30-m straight, flat, hard-surfaced corridor. Subjects were allowed to stop walking, if necessary, but the walking time was not paused. The walking distance was recorded at the end of 6 min.

Facial masks

There were three types of masks used in this study: surgical, N95, and cloth masks. The make and model of each type of mask was chosen by convenience (already stocked for use in the institute). The surgical mask (Medima SK, MED-CON CO., LTD, Bangkok, Thailand) is a disposable three-ply mask made of polypropylene spunbond and meltblown nonwoven fabric with adjustable nose strip and flat or round elastic ear loop [24]. The N95 mask (3M Aura^{TM} 1870^{+}, 3M Health Care, St. Paul, MN, USA) is a flat-fold 3-panel design made from fluid-resistant material with a comfortable inner side, 3M proprietary filter media, adjustable nose clip, and soft nose foam [25]. The cloth mask was made from two layers of fabric pleated in the middle. It was chosen from a selection of handmade masks that are available in the community market. These masks are uniform with the regulatory requirements of each type of masks, as mentioned in the introduction. Particularly, the N95 mask is approved by NIOSH, the surgical mask complies with ISO 13485, 9001, and 14001, and the cloth mask is constructed using two layers of fabric [2, 17, 24, 25].

Statistical analyses

All data were analyzed using SPSS software (SPSS V.17, IBM, Armonk, New York, USA). Data are presented as mean ± SD or median (upper-lower quartile). Test of normality was performed using Shapiro–Wilk test. Comparisons between conditions were made using one-way-repeated ANOVA. If normality was not met, nonparametric tests (e.g., Friedman test) were performed. Post hoc tests were performed using Bonferroni test and Wilcoxon Signed Rank test. Statistical significance was considered at $P < 0.05$.

RESULTS

Thirty subjects were included in the study, and one subject did not complete all the walking trials for personal reasons. Therefore, data from 29 subjects were analyzed. The baseline characteristic and pulmonary function of the subjects are reported in Table 1. All subjects presented with normal body mass index and pulmonary function.

Physiologic variables measured at rest

At rest, all subjects presented with normal vital signs, normal oxygen saturation, and no respiratory or leg fatigue symptoms. The physiological variables measured while not wearing a mask at rest before starting the 6MWT test are presented in Table 2. There were no significant differences in any of the physiological variables measured at rest before starting each walking trial.

Physiologic variables in response to 6MWT

The comparisons of 6-min walking distances showed no significant differences in walking distance among all masked and unmasked trials ($P > 0.05$, Table 3). In response to the submaximal exercise test at minute 6 of the 6MWT, subjects achieved higher HR, BP, dyspnea, breathing effort, and leg fatigue scores. There was a significant difference in dyspnea intensity and breathing effort ($P = 0.02$ and $P < 0.001$, respectively; Table 3) during the walking tests while wearing different mask types.

TABLE 1

Baseline characteristics at study enrollment

	All subjects (*n* = 29)
Overall characteristics	
Male: Female, *n*	10:19
Age, years	22.0 ± 0.9
Height, cm	165 ± 9.0
Weight, kg	57.8 ± 8.6
Body mass index, kg/m²	21.2 ± 1.8
Pulmonary function (spirometry)	
FEV_1, L (% predicted)	3.58 ± 0.76 (96 ± 10)
FVC, L (% predicted)	3.14 ± 0.57 (99 ± 10)
FEV_1/FVC, (% predicted)	0.90 ± 0.01 (102 ± 6)
$FEF_{25–75\%}$, L/sec (% predicted)	7.67 ± 1.67 (97 ± 18)
PEF, L/min (% predicted)	3.58 ± 0.76 (96 ± 10)

Note: All values are mean ± SD; FEV_1 = forced expiratory volume in one second; FVC = forced vital capacity; FEV_1/FVC = forced expiratory volume ratio; $FEF_{25–75\%}$ = forced expiration flow rate; PEF = peak expiratory flow.

TABLE 2

Physiologic variables at rest before starting the six-minute walk tests in each condition (all were measured while not wearing a mask)

Resting	**No mask**	**Surgical mask**	**N95 mask**	**Cloth mask**	***P***
HR, bpm	87 ± 10	91 ± 12	85 ± 12	86 ± 10	0.10
Systolic blood pressure, mmHg	112 ± 11	112 ± 12	111 ± 12	114 ± 11	0.63
Diastolic blood pressure, mmHg	74 ± 8	73 ± 7	75 ± 9	76 ± 8	0.63
SPO_2, %	97 (96–98)	97 (96–98)	97 (97–98)	97 (97–98)	0.97
Dyspnea, Borg units	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0.19
Effort of breathing, Borg units	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0.72
Leg fatigue, Borg units	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0.87

Note: Values are means ± SD or median (upper-lower quartile); HR = heart rate; bpm, beats per minute; SPO_2 = oxygen saturation.

There were no significant differences in other physiological variables measured ($P > 0.05$, Table 3) among the different types of masks at minute 6. The physiological variables measured at minute-6 in each walking trial are presented in Table 3.

Post hoc analysis of the dyspnea score shows a significant difference in dyspnea intensity between walking while wearing no mask and walking while wearing a cloth mask ($P = 0.004$, Table 4 and Figure 1). There were significant differences in breathing effort between wearing no mask and wearing an N95 mask, between no mask and cloth mask, between surgical mask and N95 mask, and between surgical mask and cloth mask ($P = 0.002$, $P < 0.001$, $P = 0.007$, and $P < 0.001$, respectively; Table 4 and Figure 2).

DISCUSSION

Main finding

The main finding of this study was that wearing different masks during a 6MWT results in significantly different respiratory symptoms but had no impact on SpO_2, functional capacity, or other physiological parameters. Wearing a cloth mask during a 6MWT results in significantly higher dyspnea compared to wearing a surgical mask. Likewise, wearing a cloth mask also results in significantly higher breathing effort than wearing a surgical mask or no mask. Wearing an N95 mask also significantly increases breathing effort compared to wearing a surgical mask or no mask.

Subjects' characteristic and physiological responses during 6MWT

Initially, 30 subjects were recruited into the study. One subject could not complete all four walking trials for personal reasons. Therefore, 29 healthy adults with normal BMI and pulmonary function were included (Table 1). Subjects' physiological parameters were comparable before starting each walking trial (Table 2, $P > 0.05$). The subjects presented with normal resting HR, BP, and SpO_2, and they had no dyspnea, increased breathing effort, or leg fatigue (Table 2). Regardless of the significant difference in physiological parameters measured between trials, at minute 6 the subjects exhibited expected physiological responses to submaximal exercise: rising HR, increasing systolic blood pressure, and no change in diastolic blood pressure [26, 27] (Tables 2 and 3). Oxygen saturation was normal at baseline and remained so to the end of the 6MWT (Tables 2 and 3) as anticipated [28, 29]. Respiratory and leg fatigue symptoms also rose at the end of the walking test from 0/10 at baseline to 2–4/10, 2–3/10, and 2–3/10 for dyspnea, breathing effort, and leg fatigue, respectively (Tables 2 and 3). On the 10-point Borg CR scale, these scores represent "moderate" to "somewhat strong" symptoms, which is anticipated during the test [30]. Only the dyspnea and breathing effort scores were found to be significantly different between the trials at the end of 6MWT (Table 3). The reduction of heart rate reserve (HRR) at 1 min by 24–32 beats (Table 3) could indicate the normal cardiovascular fitness of the subjects [31]. Six-minute walking distances (6MWD) were 589 ± 56 to 599 ± 66 m, which reflect the subjects' normal functional capacity according to reference values in healthy young adults and middle-aged to older adults [32–35]. Estimated maximal oxygen consumption (VO_2max) calculated from the predicted equation also indicated the average aerobic fitness of the participants (Table 3) [26, 36].

Impact of mask wearing on functional capacity

Our study demonstrated that wearing different types of masks performing the 6MWT has no impact on functional exercise capacity. The subjects achieved the expected walking distances, which were comparable between all trials (Table 3, $P = 0.59$). This result is in line with the previous studies that found no changes in functional capacity (walking distance) while wearing different types of masks during a 6MWT in healthy subjects [8, 37]. A recent systemic review and meta-analysis assessed the impact of wearing a mask during exercise from 22 studies with a total of 1573 subjects. The review found that wearing a surgical or N95 mask did not impact exercise performance in healthy and clinical subjects [14]. Another study also found that wearing cloth or disposable surgical masks had no discernable detrimental effect on exercise performance during vigorous exercise in healthy subjects [38]. Several studies found that exercise capacity was reduced due to wearing a facial mask; however, the level of exercise in those studies was higher (maximal exercise) compared to our study [6, 7, 10]. It can thus be inferred that wearing any of these three types of masks does not alter a healthy person's capacity to perform most of the activities in daily living.

Impact of mask-wearing on respiratory symptoms

Regardless of the lack of change in functional capacity, wearing different masks during a 6MWT resulted in significantly different dyspnea values (Table 3; $P = 0.02$). The post hoc analysis indicated that wearing a cloth mask during a 6MWT results in a significant increase in dyspnea when compared to wearing a surgical mask (Figure 1; $P = 0.004$). A similar finding was demonstrated in the recent systemic review and meta-analysis, which found that wearing facemasks during exercise can result in increased perceived exertion and dyspnea [14]. A recent study also found a significant difference in perception of dyspnea without any changes in 6MWD while walking with and without a facial mask among 20 healthy subjects. However, the masks worn in that study were not controlled by the researcher. Instead, the subjects brought their own masks, including 10 droplet masks and 10 cloth masks [37]. Therefore, it cannot be concluded whether the increase in dyspnea perception was a result of wearing a droplet mask or a cloth mask. Meanwhile, in our study, we did not find any significant differences in dyspnea while wearing a cloth mask or

TABLE 3

Physiologic variables at minute 6 and after 6-minute walk tests in each condition

End	No mask	Surgical mask	N95 mask	Cloth mask	*P*
HR, bpm	137 ± 20	133 ± 20	134 ± 16	133 ± 21	0.84
Systolic, mmHg	125 ± 14	124 ± 14	125 ± 14	125 ± 14	0.96
Diastolic, mmHg	77 ± 7	77 ± 8	77 ± 8	77 ± 9	0.99
SPO_2, %	97 (96–97)	96 (95–97)	96 (95–97)	97 (96–97)	0.051
Dyspnea, Borg unit	2 (0.5–4)	2 (2–4)	2 (1–4.5)	3 (2–5)	0.02*
Effort of breathing, Borg unit	2 (0.5–4)	2 (1.5–4)	3 (2–5.5)	4 (2.5–6)	< 0.001*
Leg fatigue, Borg unit	2 (1–5.5)	3 (1.5–5)	3 (1.5–4)	2 (1–5)	0.47
HRR at 1 min, bpm	105 ± 17	109 ± 13	108 ± 17	105 ± 13	0.22
6MWD, meters	599 ± 66	593 ± 55	593 ± 56	589 ± 56	0.59
Estimated VO_2 max, ml/kg/min	42.7 ± 4.2	41.7 ± 4.1	42.9 ± 4.5	42.6 ± 4.2	0.11

Note: Values are means ± SD or median (upper-lower quartile). HR = heart rate; bpm = beats per minute; HRR = heart rate reserve; SPO_2 = oxygen saturation; VO_2 max = maximal oxygen consumption; 6MWD = 6 minutes walking distance.
**P* < 0.05 statistically significant differences between four groups by one-way repeated ANOVA or Friedman test.

TABLE 4

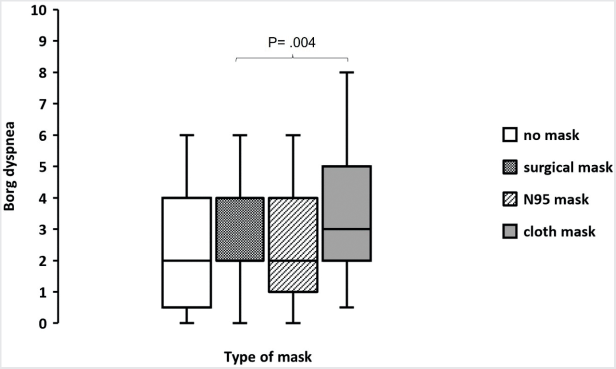
Post hoc analysis for multiple comparisons of the dyspnea and breathing effort score at the end of 6MWT

	P					
	No mask vs surgical	No mask vs N95	No mask vs cloth	Surgical vs N95	Surgical vs cloth	N95 vs cloth
Dyspnea score	0.69	0.22	0.009	0.30	0.004*	0.08
Breathing effort	0.068	0.002	< 0.001*	0.007*	< 0.001*	0.044

*Bonferroni-adjusted significance level *P* < 0.008 indicated a significant difference between conditions (type of mask) based on Friedman test with Wilcoxon Signed Rank post hoc tests.

FIGURE 1

Effects of wearing no mask, surgical mask, N95 mask, and cloth mask on dyspnea (Borg-10 CR scale) at minute 6 (end) of the six-minute walk test. Bonferroni-adjusted significance level *P* < 0.008 indicated a significant difference between conditions (type of mask) based on Friedman Test with Wilcoxon Signed Rank post hoc tests. Values represented as median (upper-lower quartile).



a surgical mask when compared to no mask during a 6MWT (Figure 2; *P* > 0.05).

In contrast, Person et al. [8] found clinically and significantly increased dyspnea when performing a 6MWT while wearing a surgical mask as compared to performing a 6MWT with no mask among healthy subjects. However, the subjects in Person et al. [8] could achieve longer distances within 6 min compared to the subjects in our study, with 6MWD of 708 ± 62 m and 593 ± 55 m in Person et al. [8] and this study, respectively; They also reached higher dyspnea scores on the Borg-10 CR scale compared to our subjects' scores: 5.6 ± 1.8 and 2 [2–4], respectively. This indicates that the subjects in Person et al. [8] performed a higher intensity of exercise while wearing a surgical mask, resulting in a significant increase in dyspnea perception compared to wearing no mask.

Higher breathing effort was reported during the 6MWT while wearing a cloth mask compared to a surgical mask and no mask (Figure 2; P < 0.001 and *P* < 0.001, respectively). Likewise, wearing an N95 mask also results in higher breathing effort than wearing surgical masks and no mask (Figure 2; *P* = 0.007 and *P* < 0.002, respectively). These results suggest that wearing a cloth mask or an N95 mask increases breathing effort compared to wearing no mask and a surgical mask. Of note, our results demonstrate the difference in breathing effort without a significant difference in dyspnea. As it was predefined and rated separately, the sensation of dyspnea is not identical to breathing effort [39–41]. Increased breathing effort is not necessarily perceived as uncomfortable but rather as a sense of raised respiratory work or an awareness of the intensity of the outgoing motor command [39, 40]. Therefore, the sensation of breathing effort could be a proximate source of perceived dyspnea during exercise [40].

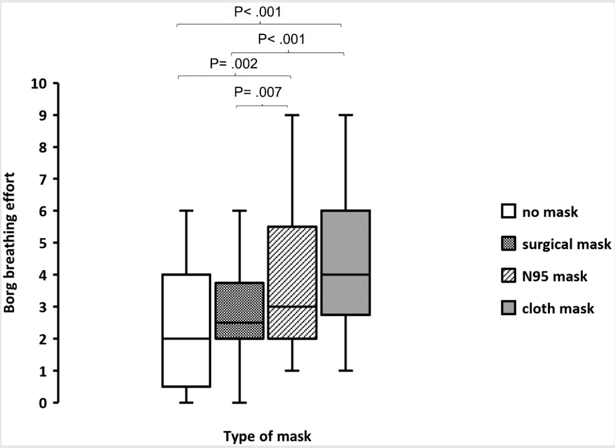
An increased pressure differential of mask material might be a cause of increased respiratory effort. The pressure differential is an indicator of comfort and breathability of the material. Several studies evaluated the pressure differential of various face mask materials using airflow rates that replicate human breathing during rest and exertion [18, 42, 43]. The results showed that the pressure differentials across materials with and without gap (e.g., 1- or 2-layer cotton fabric, surgical, or N95 mask materials) were similar, ranging from 2.2 to 3.0 Pa and 8.7 to 13.9 Pa with low (35 L/min) and high (90 L/min) flow rate, respectively [18]. These results indicate good breathability across sampling materials [18]. In contrast, another study found a higher pressure differential ranging from 5.4 Pa to 651 Pa from many different materials while performing the test with an airflow of 85 L/min. Some results include 73 Pa for an N95 mask, 433 Pa for 5-layer bedsheets, or 153 Pa for coffee filters [43]. A different study found a comparable pressure differential across different types of 1-layer cotton, surgical masks, and N95 masks; however, when combining several fabric types or increasing layers, the pressure differential was higher [42]. Based on the literature, we assume that the materials used for N95 and cloth masks in our study were perhaps less breathable than the material for surgical masks, leading to a higher pressure differential and resulting in higher breathing effort.

Impact of mask-wearing on oxygen saturation

It can be speculated that wearing a mask can lead to inadequate oxygen supply for the increased metabolic demand during physical activity, which can result in reduced exercise capacity [44]. However, the results of our study suggest that wearing different masks during a 6MWT had no impact on oxygen saturation in healthy adults. Several studies showed evidence supported this finding [8, 13, 14, 37]. A meta-analysis revealed

FIGURE 2

Effects of wearing no mask, surgical mask, N95 mask, and cloth mask on breathing effort (Borg-10 CR scale) at minute 6 (end) of the six-minute walk test. Bonferroni-adjusted significance level *P* < 0.008 indicated a significant difference between conditions (type of mask) based on Friedman Test with Wilcoxon Signed Rank post hoc tests. Values represented as median (upper-lower quartile).



that there is no difference in arterial oxygen saturation during exercise regardless of the mask used, especially in healthy individuals; a small significant reduction of oxygen saturation was observed during maximal exercise but not during submaximal exercise [14]. Another study found that wearing common mask types (cloth, surgical, or FFPS) during short-term high-workload activity (work-typical levels 50/75/100W for 3 min) results in a measurable but clinically irrelevant change in blood gases and vital parameters, including oxygen saturation [13].

Hypercapnic hypoxia was suspected to occur during exercise with masks for several reasons. First, wearing a mask increases dead space volume, allowing carbon dioxide (CO_2) retention and increasing CO_2 rebreathing [45–47]. Second, higher metabolic demand during exercise requires substantial oxygen supply, resulting in inadequate oxygen and CO_2 exchange [11, 48]. It seems that, in our study, neither the exercise intensity nor the CO_2 rebreathing was at a level high enough to induce hypercapnic hypoxia in our population. Considering the lack of significant difference in oxygen saturation when wearing any type of mask, we can assume that the dead space volume created from each mask type used in this study did not lead to a significant amount of CO_2 retention. In addition, during exhalation, CO_2 leakage from the gap between the mask and the face of some masks might result in less CO_2 retention. However, as seen in other studies, wearing a mask when performing higher intensity exercise could lead to a hypercapnic hypoxia environment, resulting in a reduction in oxygen saturation.

Strengths, limitations, and recommendations

This study compared the physiological parameters and perceived respiratory symptoms during submaximal exercise rather than during maximal exercise, which better reflects the activities commonly performed in daily life. The repeated measured design of the study helped reduce the variability between subject groups. However, the subjects included in this study were healthy adults, so the results cannot be generalized to a different population. Nevertheless, for safety purposes, performing the test first in a healthy population was appropriate. Although three types of masks (surgical, N95, and cloth) were used in this study, it cannot be assumed that different makes and models of the same types of masks would yield the same results. Further study on more specific makes and models within a particular category of masks needs to be performed to draw conclusions about the impact of each type of mask. We would recommend including the measurement of the physiological parameters and respiratory symptoms while wearing a mask at rest. Also, it might be useful to gather data on mask user satisfaction, such as the comfort or confidence when wearing each mask.

Study's implications

The findings of this study can help an individual to decide what type of mask one should wear during daily activity. Indeed, difference in protective quality is the main reason for selecting a mask. However, many types of masks give the same protection but impact the wearer differently. For example, surgical, N95, and cloth masks can all prevent spread of droplets, but one might perceive higher respiratory symptoms during submaximal intensity activities when using an N95 or cloth mask. In this case, a surgical mask might be more suitable.

CONCLUSION

Wearing different masks while performing submaximal functional activities results in no difference in oxygen saturation and functional exercise performance. However, wearing cloth masks and N95 masks results in increased dyspnea and breathing effort.

DISCLOSURES

Acknowledgments

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Contributors

SD, KSu, and PW performed literature search. SD, BC, KSu, PW, and KSo contributed to the conception and design of the study. SD, KSu, and PW contributed to the data collection and organized the database. SD and KSo performed the statistical analysis. SD wrote the first draft of the manuscript. All authors contributed to the manuscript revision and read and approved the submitted version.

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Competing interests

All authors have completed the ICMJE uniform disclosure form and declare: no financial relationships with any organizations that might have an interest in the submitted work in the previous 3 years; no other relationships or activities that could appear to have influenced the submitted work.

Ethical approval

Informed consent was obtained from all participants. The Institutional Review Board of the Faculty of Associated Medical Sciences, Chiang Mai University, Thailand, approved the study.

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