Impact of Face Masks on Cardiopulmonary Efficiency During Exercise in Older Adults: A Crossover Study

Abstract

Introduction: The widespread adoption of prolonged use of medical facial masks became particularly prevalent to prevent infectious respiratory diseases. Nevertheless, there is a paucity of information regarding the physiological effect of various types of facial masks on the cardiorespiratory functions of older individuals during physical exercise.

Aims: The current study aims to examine the physiological effects of different face masks on older adults cardiopulmonary efficiency during exercise.

Materials and methods: 26 healthy older adults were assessed under four conditions in the current study: no mask, disposable 3-ply surgical mask, disposable N95 mask, and cloth mask (CM) in random order. The participants' blood pressure, SPO2 level, heart rate, respiratory rate, distance traversed, and pulmonary function were measured at baseline and following a 6-minute walk test for each condition, respectively.

Findings: There were no statistically significant changes in the outcome variables as a result of the participants' use of different masks in this study. With the N95 mask, however, reductions in SPO2 levels were seen upon completion of the 6-minute walk test.

Conclusion: Wearing masks during moderate-intensity physical activity has no significant impact on blood pressure, heart rate, or pulmonary function. However, older individuals with heart or lung conditions should undergo a comprehensive assessment.

Keywords: Covid-19, physical activity, pulmonary function test, elderly, public health

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Introduction

Face masks have progressively become fundamental aspect of our new-normal existence as a part of public health and social measures implemented during the period of coronavirus disease pandemic [1]. Wearing of surgical and KN95/N95 masks was rigorously mandated in public settings. National and worldwide officials have suggested modifying FFP3 masks for enhanced protection in the light of developing variations of the severe acute respiratory syndrome coronavirus-2 [2]. In recent years, the use of facemasks has been adopted more broadly to prevent various infectious respiratory diseases [3]. Transmission risk of infections may also be increased during exercise due to heavy breathing, especially indoors such as in sports and fitness centres [4]. The global health and fitness landscape of the early 2020s was radically transformed with the widespread adoption of face masks as a primary population health measure for mitigating the transmission of respiratory viruses, most notably SARS-CoV-2 (World Health Organization, 2020).

hile critical for restricting viral transmission, the widespread adoption of face masks permeated numerous aspects of living, including physical activity. According to the article "COVID-19 in the Elderly: A Malaysian Perspective," a higher rate of viral transmission has been observed among the elderly, identifying them as the most vulnerable group [5]. While the efficacy of face masks in attenuating the transmission of infectious diseases is well-reported, potential physiological impacts including cardiopulmonary function should be thoroughly investigated, particularly among at-risk populations such as elderly individuals [6]. It was observed that wearing a surgical mask by healthy individuals did not have significant influence on breathlessness, respiratory rate, heart rate and saturation of oxygen during submaximal exercise [7]. Nevertheless, wearing a surgical mask increases the rate of dyspnea when compared to individuals without mask but does not influence the result of 6-minute walk test in normal healthy population [8].

Although we are unable to reverse the biological process of aging, frequent engagement in sports and physical activities might mitigate the physiological changes associated with aging and may enhance overall health and well-being [9]. Consistent physical activity provides significant health advantages for healthy aging and these benefits are thoroughly documented [9]. Physical activity amongst older adults has been recommended below 150min/week [10]. Being physically active has shown a significant association in maintaining mental health, emotional, psychological, social well-being as well cognitive function [11]. However, the widespread adoption of facemask usage to curb the spread of respiratory diseases has also been linked to an increasing trend in physical inactivity [5, 12]. Additionally, wearing facemasks during exercise has raised concerns about potential impacts on the cardiopulmonary system, including increased work of breathing (Wb), altered pulmonary gas exchange, and heightened dyspnea [13]. There is evidence that wearing masks may affect human physiological systems, particularly cardiopulmonary function, to cause augmented airway resistance, hypoxia, carbon dioxide retention, and alterations in lung function that may result in enhanced cardiac workload [14]. In contrast, a previous study indicated that usage of face mask does

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not have harmful effect [15]. To curb the issue, plenty of research on the physiological effects of wearing facemasks has been conducted in recent times [13, 15–23]. Furthermore, a systematic and narrative review conducted on the effect of wearing face mask during exercise reported that utilization of face mask during exercise would exert negligible effect on performance and physiological parameters [13, 15]. Elder individuals have lower physiological reserves and are more vulnerable to impact of external stressors, like respiratory burden caused by wearing face mask, making this group a critical focus for further study [24]. Nevertheless, the usage of facemask among the elderly during exercise is still scarce and the physiological effects still remain unclear [13].

Significant changes to the structures of the respiratory system are associated with healthy aging, resulting in a progressive decline in pulmonary function and an increased ventilatory response to exercise [25]. Therefore, older people have greater levels of mechanical ventilatory constraint than younger people do during exercise, as shown by increased risk of expiratory flow limitation, higher operating lung capacities, and more work of breathing [26]. Despite such alterations in the cardiopulmonary system because of aging and physical performance decline, sedentary living becomes more prevalent and participation in formal exercise programs declines with increasing age in older adults [27]. Earlier study examined the effect of wearing a cloth and surgical masks on pulmonary and vital sign parameters and reported that cloth masks and surgical masks did not produce significant changes on cardiorespiratory fitness at rest and after performing the 6MWT in older adults. The potential effect of face masks on cardiopulmonary function during exercise is one of respiratory mechanics and modifications in gas exchange. Face masks by their nature create an added resistance to breathing during both inspiration and expiration [28]. These changes may have more profound effects in the older population. Age-related changes like decreased elasticity of the lungs, reduced strength of the respiratory muscles, and decreased ventilatory response to hypoxia and hypercapnia can add to the physiological burden of mask-wearing while exercising [29]. Thus, the objective of the current study is to examine the physiological effects of facemask on cardiopulmonary efficiency and exercise performance among the elderly. The current study hypothesized that wearing a facemask will reduce the performance of exercise as the facemask causes a reduction in oxygen uptake, leading to reduced blood and muscle oxygenation, increased carbon dioxide rebreathing, and resistance during breathing effort. This crossover study design would provide a complete assessment of the influence of face masks on significant cardiopulmonary parameters, such as oxygen saturation, heart rate, blood pressure, and rating of perceived exertion, during exercise in older adults. The findings will give valuable information regarding the physiological influence of face mask exercise in this specific group of individuals, thereby assisting in the establishment of exercise recommendations and safe physical activity participation.

Material and Methods

Study design

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This study used a repeated measure approach in an experimental study design. The participants were recruited from three old folks' home. 26 healthy elderly people (n = 14 males and n = 12 females) who met the inclusion and exclusion criteria were recruited using convenience sampling. The participants were non-smoking, healthy elderly people aged 60 to 70 who engaged in recreational aerobic activities such as jogging, running, or cycling on a regular basis. Participants with orthopaedic, cardiac, pulmonary, or inflammatory diseases or any other medical contraindications (uncontrolled diabetes mellitus) were excluded from the current study.

Regarding ethical concerns, the first author informed the participants about the study's methods. Before the experiment began, the subjects gave their written informed consent. The research was conducted in accordance to the ethics committee of INTI International University (INTI-FHLS-03-01-2021).

Variables and study procedure

The variables of interest for the study were oxygen saturation (SPO2), blood pressure, heart rate, respiratory rate, distance walked in 6 minutes, forced vital capacity (FVC) [L], forced expiratory volume in 1 s (FEV1) [L], forced expiratory volume in 1s (FEV1)/FVC [L], peak expiratory flow (l s−1), vital capacity [L] and maximum voluntary ventilation (MVV) [L].

The study objectives were examined under four conditions: no mask (NM), disposable 3-ply surgical mask (SM) (Novid PPE Sdn Bhd, Malaysia), disposable N95 mask (N95) (3M's proprietary filter media, 3M™ Advanced Electret Media, Malaysia) as well as cloth mask (CM) (PROXMASK™ 90V – LITE, Malaysia).

The participants' pulmonary function was measured using the UBREATH® Pro Spirometer System PF680 (e-LinkCare Meditech Co., Ltd, Manchester, UK). Three expiratory manoeuvres with one-minute intervals were recorded for each of the four conditions (NM, SM, N95, and CM) utilising the best results from each pulmonary function test. Whereas the level of SPO2 and heart rate were measured using a pulse oximeter whereas the blood pressure was taken from the digital blood pressure monitor. Prior to the start of the current study, all participants were given a written explanation of the objectives and procedures, and written informed consent was acquired. The baseline assessment was conducted prior to the test commencement.

The participants were given the 6-minute walk test (6MWT) to complete after the evaluation to assess their level of exercise endurance. The participants underwent the 6MWT while wearing a surgical mask (SM), a N95 respirator mask (N95), a cloth mask (CM), and no mask (NM) conditions. The sequence in which the masks were worn varied from person to person based on random allocation. Without running, participants were encouraged to try to cover as much distance as possible in six minutes.

To avoid the impact of anticipation bias, tests were given at the same time of day, separated by at least 24 hours, and individuals were blinded to their own test results. Immediately following the

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6MWT, one assessor was assigned to examine cardiopulmonary function and another assessor was assigned to measure the distance covered by the participants. Data were collected and further analysed.

Statistical analysis

IBM-SPSS Statistics 24 software was used to analyse all of the data after it was transferred from Microsoft Excel. Using a Kolmogorov-Smirnov test, the data's normality was evaluated, and it was discovered that all of the data was normally distributed. Each variable's values are displayed using the mean and standard deviation. For statistical analysis, the differences between each condition (NM, SM, N95, and CM) on oxygen saturation (SPO2), blood pressure, heart rate, respiratory rate, distance walked in 6 minutes, forced vital capacity (FVC) [L], forced expiratory volume in 1 s (FEV1) [L], forced expiratory volume in 1s (FEV1)/FVC [L], peak expiratory flow (l s−1), vital capacity [L], and maximum voluntary ventilation (MVV) [L] were assessed using one-way repeated measure ANOVA. The significant level was set at 0.05 with a 95.0% confidence level in all the analyses.

Results

The demographic details of the participants is displayed in Table 1. In the current study, 26 volunteers with a mean (SD) of 61.75 (4.84), ranging in age from 60 to 70, were enlisted. The subjects' BMI had a mean (SD) of 28.56 (3.10). Table 1 below displays the additional variables, including SPO2 (%), heart rate (beats per minute), respiration rate (breath per minute), systolic blood pressure (mmHg), and diastolic blood pressure (mmHg).

Table 1. Demographic characteristics of the participants (n=24)

Variables	**Mean (Standard Deviation)**
Age [years]	61.75 (4.84)
BMI [kg/m2]	28.56 (3.10)
SPO_2 [%]	97.75 (0.62)
SBP [mmHg]	125.58 (10.21)
DBP [mmHg]	81.67 (9.16)
HR [bpm]	78.67 (8.23)
RR [brpm]	17.25 (1.54)

BMI - body mass index, SPO_2 - oxygen saturation, SBP - Systolic blood pressure, DBP - Diastolic blood pressure, HR- Heart rate, RR - Respiratory rate, bpm - beats per minute, brpm-breath per minute

Table 2 reveals the analysis of the different mask usage patterns during the 6-minute walk test among the 24 elderly participants. There were no significant differences noted in all the variables except the SPO_2 level ($p<0.05$). Further, the post-hoc analysis on SPO_2 level revealed significant differences

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between NM and N95 (p = 0.014) (Table 3). The analysis also shown a significant difference between

Variable	NM M (SD)	SM M (SD)	N95 M (SD)	CM M (SD)	ANOVA
SPO_2 (%)	97.92 (0.99)	96.67 (1.50)	96.17 (1.47)	97.75 (1.36)	0.006*
SBP (mmHg)	136.42 (11.0)	146.83 (25.35)	140.83 (16.63)	136.92 (13.27)	0.442
DBP (mmHg)	80.58 (8.84)	83.08 (9.04)	79.33 (9.24)	88.25 (13.24)	0.165
HR (bpm)	77.08 (22.91)	78.33 (23.63)	84.33 (11.31)	85.00 (15.35)	0.653
RR (brpm)	24.08 (3.30)	25.00 (3.22)	20.83 (3.51)	21.42 (3.45)	0.839
Distance (meter)	305.0 (74.75)	313.17(103.62)	334.33 (85.95)	343.0 (86.11)	0.94
FVC (l)	1.95 (1.15)	2.28 (0.98)	2.27 (0.64)	2.34 (0.79)	0.728
FEV_1 (l)	0.86 (0.53)	1.15 (0.50)	0.96 (0.36)	1.17 (0.87)	0.530
FEV_1/FVC l	0.49 (0.20)	0.51 (0.13)	0.44 (0.18)	0.47 (0.20)	0.784
PEF (l s−1)	0.81 (0.42)	1.40 (0.52)	1.20 (0.77)	1.95 (2.31)	0.185
VC (l)	2.94 (2.25)	3.06 (2.22)	3.12 (2.72)	4.05 (2.09)	0.353
MVV (l)	64.99 (34.67)	50.55 (36.10)	54.28 (41.70)	63.81 (27.17)	0.694

N95 and CM usage (p = 0.030) on SPO_2 level (Table 3).

Table 2. Comparison between different conditions (masks) upon completion of 6-minute walk test

NM - No mask, SM - Surgical mask, CM - Cloth mask, M – Mean, SD - Standard Deviation, SPO2 - oxygen saturation, SBP - Systolic blood pressure, DBP - Diastolic blood pressure, HR - Heart rate, RR - Respiratory rate, bpm - beats per minute, brpm - breath per minute, FVC - Forced Vital Capacity, FEV1 - Forced expiratory volume in 1 sec, PEF - Peak expiratory flow, VC - Vital capacity, MVV - Maximal voluntary ventilation, p<0.05*

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Variable	Post-hoc analysis					
	NM vs SM	NM vs N95	NM vs CM	SM vs N95	SM vs CM	N95 vs CM
SPO_2 (%)	0.119	0.014*	0.990	0.799	0.213	0.030*
SBP (mmHg)	0.468	0.925	1.000	0.834	0.510	0.946
DBP (mmHg)	0.932	0.807	0.272	0.807	0.609	0.159
HR (bpm)	0.998	0.787	0.739	0.866	0.826	1.000
RR (brpm)	0.998	0.931	0.960	0.867	0.910	1.000
Distance (meter)	0.996	0.847	0.718	0.935	0.841	0.995
FVC (l)	0.816	0.831	0.731	1.000	0.999	0.998
FEV_1 (l)	0.638	0.973	0.589	0.872	1.000	0.836
FEV_1/FVC l	0.990	0.897	0.996	0.747	0.954	0.962
PEF (l s−1)	0.666	0.874	0.139	0.980	0.716	0.479
VC (l)	1.000	1.000	0.434	1.000	0.454	1.000
MVV (l)	0.749	0.879	1.000	0.994	0.794	0.911

Table 3. Post-hoc analysis between different conditions (masks) upon completion of 6-minute walk test

NM - No mask, SM - Surgical mask, CM - Cloth mask, M – Mean, SD - Standard Deviation, SPO2 - oxygen saturation, SBP - Systolic blood pressure, DBP - Diastolic blood pressure, HR - Heart rate, RR - Respiratory rate, bpm - beats per minute, brpm - breath per minute, FVC - Forced Vital Capacity, FEV1 - Forced expiratory volume in 1 sec, PEF - Peak expiratory flow, VC - Vital capacity, MVV - Maximal voluntary ventilation, $p<0.05$*

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Discussion

The primary outcome of this research investigation revealed that the use of SM, N95, or CM facemasks during a 6-minute walk test did not provide a significant effect on the blood pressure, heart rate, respiration rate, distance covered, or lung function assessments of older individuals when compared to not wearing a mask. Previous research conducted on a sample of healthy young individuals has yielded comparable results to the present study [12, 30]. Specifically, the findings indicate that the utilization of surgical masks or N95 respirators during physical exercise is both safe and feasible. Furthermore, these masks were shown to have a low and statistically insignificant influence on several physiological indicators such as blood pressure, heart rate, and respiratory rate during exercise [12, 30]. While some research suggests that masks have minimal impact on exercise

performance and physiological parameters [31, 32], others report significant effects on cardiopulmonary function [33, 34]. Masks were found to be safe and feasible for short-term, moderate-to-strenuous exercise in healthy individuals [12]. However, they may lead to increased end-tidal CO2 levels [31, 32], decreased oxygen uptake, and reduced ventilation efficacy [33]. Overall, while masks appear to be tolerable during exercise, they may have varying effects on physiological parameters and subjective experience.

Significant differences were found on the SPO2 level with the use of N95. Previous study has also reported similar trend [30, 35]. According to previous research, the N95 mask offers the most protection and has the highest level of resistance compared to the other masks [12, 13]. Nonetheless, even at a ventilation rate of >100 L · min−1 (25), breathing simulation studies have demonstrated that the resistance exerted by N95 is <2 cm H2O · L−1 · s−1, and remains low even after extended simulation usage [13]. Contrarily, another study among eight participants shown reduction of oxygen level up to 3.2% and rise of carbon dioxide up to 20% and may cause discomfort for the elderly individuals [36]. Significant decreases in SpO2 were observed after prolonged N95 mask wear, ranging from 4-6 hours [37–40]. The reductions, while statistically significant, were generally small in magnitude. For instance, Pradeep Kumar et al. (2023) reported a decrease from 98.7% to 98.3% after 6 hours. Alongside SpO2 changes, increases in heart rate were also noted [37, 39].

From a different research perspective, wearing a mask (surgical or N95) while walking for brief distances (5-6 minutes) will aid in the development of respiratory muscles [8, 30]. The utilization of masks at the onset has demonstrated a decrease in performance. While masks increased ratings of perceived exertion and dyspnea [31], they did not significantly alter arterial oxygen saturation, muscle oxygenation, or primary cardiovascular responses during submaximal or maximal exercise [15, 41]. However, as time progresses, individuals will inevitably acclimate to the practice of wearing a mask. Prolonged use of masks for weeks or even months may potentially enhance the strength and capacity of the respiratory muscles. The study additionally indicated that upon discontinuation of mask usage, the lungs will have an augmented oxygen intake, hence potentially enhancing exercise performance [30, 42].

The emergence of SARS-CoV-2 and its impact on respiratory function have heightened concerns regarding the physiological effects of face masks, particularly during physical exertion in older adults [43]. However, the present research's results were similarly consistent with those published in a prior study of fourteen healthy people, which found no differences with or without face masks in the blood and muscle oxygenation, perceived exertion and heart rate in peak exercise performance [15]. Despite the presence of respiratory resistance associated with the utilization of masks, particularly N95 masks, research findings have indicated that such resistance does not have a discernible impact on dyspnea experienced during moderate-intensity exercise among older individuals [13, 25]. Thus, senior individuals may wear masks even when exercising during outdoor activities or in busy areas without fear of impact on performance, decrease in lung function capacity, increase in carbon dioxide

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rebreathing, or oxygen consumption compromise leading to lower arterial oxygen saturation of hemoglobin.

Several noteworthy limitations were observed in the present investigation, namely the relatively small sample size and the inclusion of only healthy older participants. Moreover, it is important to note that the findings of the present investigation lack generalizability to exercises of higher intensity. It is advised that future research encompasses a bigger sample size, particularly focusing on older persons afflicted with lung and heart diseases. Additionally, it is strongly advised to maintain continuous monitoring of pulmonary function in the lungs during the duration of the testing session.

Conclusions

The present study has determined that the utilization of different masks during moderate-intensity physical activity among older individuals does not exhibit any detrimental effects on blood pressure, heart rate, six-minute walking distance, or pulmonary function. While the use of N95 masks may result in a decrease in SPO2 levels, it is important to note that this does not have any adverse effects on the health of elderly adults. Moreover, it is recommended that older individuals with heart or lung conditions get a thorough assessment before to engaging in physical activity while wearing a mask.

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Institutional Review Board Statement: The research was approved by the INTI International University Ethical Committee (No: INTI-FHLS-03-01-2021).

Informed consent statement: Informed consent was obtained from all subjects involved in the study.

Conflict of interest: None declared

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