Exercise Physiology at "Conversational Level" Is Not Impaired in Healthy Young Subjects Wearing Masks or Respirators

Wearing Masks at Low Intensity Exercise

Violeta Sanchez-Migallón[a], César Calvo-Lobo[b], Sandra Sanchez-Jorge[a], Mónica Arce[a], Alejandra Vicente[a], Elena Bello[a], David Rodriguez-Sanz[b], Ricardo Becerro-de-Bengoa-Vallejo[b], J.L. Chicharro[b] and Davinia Vicente-Campos[a]

[a]Faculty of Health Sciences, Universidad Francisco de Vitoria, Madrid, Spain

[b]Faculty of Nursing, Physical Therapy and Podiatry, Universidad Complutense de Madrid, Madrid, Spain

Correspondence to: César Calvo-Lobo, cescalvo@ucm.es

Abstract

Objective

The aim of this study was to evaluate the effects of the use of both surgical masks and FFP2 respirators on the inspiratory muscle strength, metabolic parameters, heart rate, subjective perceived exertion, and dyspnea perception, before and during 30 min stable load exercise at "conversational level".

Methods

A randomized cross-over study was carried out. Nineteen healthy adults completed 3 conditions (without a mask, with a surgical mask or an FFP2 respirator) during a 30-min steady-state test at the lactate threshold intensity. Inspiratory muscle strength was measured before and after the test, and metabolic parameters, heart rate, subjective perceived exertion, and dyspnea perception were collected at baseline, during, and after the test.

Results

There was a significant reduction in inspiratory muscle strength after the 30-min test in all conditions (control: 6.26 mm Hg, $p < 0.5$; surgical mask: 8.55 mm Hg, $p < 0.01$; FFP2 respirator: 12.42 mm Hg, $p < 0.001$), but without significant differences between them ($p = 0.283$). Data showed a statistically significant effect for time, but did not show a statistically significant interaction between condition and time for heart rate ($p = 0.674$), oxygen saturation ($p = 0.297$), blood lactate level ($p = 0.991$), rating perceived exertion ($p = 0.734$) and dyspnea ($p = 0.532$) comparisons.

Conclusions

The present study findings suggested that inspiratory muscle strength and physiological parameters during "conversational level" exercise were not impaired under wearing masks in healthy, nonsmoking young adults.

Trial Registration

ClinicalTrials.gov (NCT04832893).

Keywords: Coronavirus disease 2019; Face masks; Low intensity exercise; Sport; Personal distancing

Introduction

On March 11, 2020, the World Health Organization (WHO) declared the novel coronavirus (COVID-19) outbreak as a worldwide pandemic. Due to the lack of effective vaccines and treatments, most countries provided general preventive actions against this virus. Avoiding people overcrowding, traveling reduction, staying at home, drastically reducing social contacts, and wearing protective masks were some of the provided recommendations [1].

Worldwide, the use of protective face masks in order to reduce the virus transmission [2–5] was considered as one of the most accepted preventive actions with a strong scientific evidence about its effectiveness [2, 6, 7]. Different facial mask types were proposed, with surgical masks and FFP2 filtering respirators being considered as the most commonly used facial masks. These masks are used daily for long periods of time by healthcare providers, as well as young people and children [8–10]. Nevertheless, the use of these masks during physical exercise presented more reluctance by healthy population, showing contradictory findings in the limited studies published to date about the effects of the use of these masks during physical exercise.

The study carried out by Epstein et al. [11] used a progressive test up to exhaustion by cycloergometer (starting at 25 w and increasing 25 w for each 3 min until exhaustion) in 16 healthy volunteers and did not find differences in time until exhaustion, maximum heart rate, maximum blood pressure, and oxygen saturation, performing the test without a mask or with FFP2 or surgical masks. In accordance with this research line, a recent study performed on 12 healthy subjects, who carried out spirometry at rest and a moderate-high intensity steady-state exercise test, concluded that despite the use of masks was linked to a significant reduction in spirometry and cardiorespiratory parameters at rest and peak exercise, their use was safe even during maximum aerobic exercise [12]. On the one hand, a study carried out during the performance of exercise at a constant load corresponding to the intensity of the maximum stable state of lactate for 30 min showed an increase in the resistance to the passage of air and heart rate in healthy volunteers. Nevertheless, the perception of effort and performance in the test were not different with or without a surgical mask [12]. On the other hand, Fikenzer et al. [13] reported a reduction in physical capacity and maximum ventilation in a progressive exercise up to maximum intensity performed with a mask (surgical and FFP2), as well as an increase in the perception of effort and dyspnea in healthy subjects. The increase in respiratory resistance under mask use [14] may contribute to generate early fatigue of respiratory muscles after long time use during exercise performance.

To date, most performed studies were focused on the assessment of the masks' use during moderate-high intensity physical exercises without considering exercise at the lactate threshold (LT) [11, 12, 14–16]. Nevertheless, elective physical exercise for the majority of population seems to be performed at a "conversational level" under LT (~60% VO_2max) [17]. Exercise at LT intensity presents a steady status regarding cardiometabolic, ventilatory, and perceived exertion parameters [18]. To the authors' knowledge, there is a lack of studies assessing the effects of wearing masks under the performance of exercise at LT intensity for long periods of time. According to the previous statements, we hypothesized that healthy adults who wear masks or filtering respirators could not show differences in inspiratory muscle strength, metabolic parameters, heart rate, subjective perceived exertion, and dyspnea perception performing stable load exercise at LT intensity. Thus, the purpose of our research was to evaluate the effects of the use of both surgical masks and FFP2 respirators, the most commonly used mask types, on the inspiratory muscle strength, metabolic parameters, heart rate, subjective perceived exertion, and dyspnea perception before, during, and at 30 min after stable load exercise according to LT intensity.

Methods

Study Design

This was a multiple crossover, self-controlled trial. Each subject served as his/her own control and performed the test up to three times, in a randomized order to avoid bias (GraphPad Quickcalcs [13]): (a) without a face mask (control); (b) wearing a surgical mask (Suavel® Protec Plus, Meditrade, Kiefersfelden, Germany); and (c) wearing a FFP2 respirator (FFP2 NR Filtering half mask; Zheijang Luyao Electronic Technology Co., Ltd). In addition, the order of the 3 conditions was counterbalanced among participants due to an equal number of participants performing the conditions in the different possible orders. The minimal time interval between tests was 48 h. Strenuous physical activity was

prohibited during the 24 h preceding the tests, and a night sleep of at least 7 h was mandatory. In order to control the effects of diet, participants were required to fill out a food diary at 24 h before the first exercise test. They received a copy of this diary and were asked to replicate it as closely as possible before subsequent testing occasions. Information on this trial was reported in adherence to the CONSORT checklist [19], and all the details can be found in the supplementary material (for all online suppl. material, see www.karger.com/doi/10.1159/000524490) of this manuscript.

Demographic data were collected by a questionnaire. Height (cm) and weight (kg) were measured for each participant and body mass index was calculated. All the exercise tests were performed in a standardized manner on the same electrically braked bicycle ergometer (Ergoselect 100; Ergoline GmbH) located in an air-conditioned room with ambient temperature at 20–25°C and low relative humidity.

Participants visited the laboratory a total of 4 times. On the first visit, they performed a LT test without a mask to obtain the LT value. Furthermore, on the three subsequent visits, they performed a 30-min steady-state test at the LT intensity, measured previously, with (surgical or FFP2) or without a mask. The study was carried out from April to May 2021.

Sample Size Calculation

A priori sample size calculation was based on the *F* test family for statistical tests of within-between interaction analysis of variance (ANOVA) for repeated measures by the G × Power 3.1.9.2 considering a general large effect size of $f = 0.40$ according to Salkind [20], due to the lack of prior similar studies comparing surgical masks and FFP2 respirators under LT exercise. Thus, expected differences between the measured parameters may not be used for the sample size calculation. In addition, an error probability of $\alpha = 0.05$, a power of $1-\beta$ error probability = 0.80, a number of 3 conditions (control, surgical masks, and FFP2 respirators), a number of 4 measurement times (at baseline, 10, 20, and 30 min of exercise), a correlation among repeated measurements of 0.5, and a non-sphericity correction of $\varepsilon = 1$ were utilized following the study protocol (NCT04832893). According to these analyses, a total sample size of 15 participants was required to achieve an actual power of 0.873. Considering a possible 50% loss to receiving the intervention or follow-up due to the current pandemic, an initial sample of 30 participants was considered.

Participants

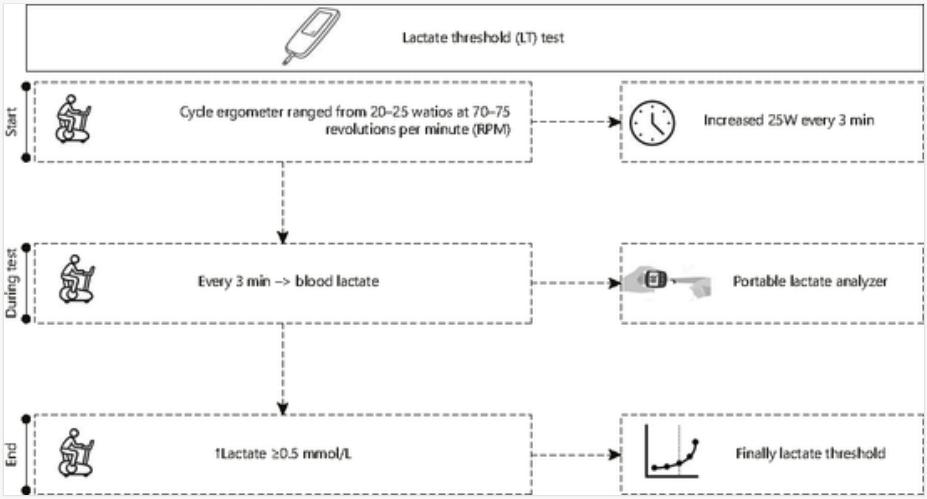
From a total of 30 participants who met the inclusion and exclusion criteria, the study population, who finally participated in the present study, consisted of 19 healthy, nonsmoking volunteer young adults (age>18 years) who participated in regular recreational physical activity for at least 3 days/week. Subjects were not awarded for participating in the present study and could be students or nonstudents if they met inclusion criteria. Subjects were excluded if they presented any known medical condition that may be exacerbated by physical activity, including diabetes mellitus, any chronic respiratory or cardiovascular disease, or acute respiratory illness (i.e., pneumonia or upper respiratory tract disease) within 2 weeks before the study.

Procedures

Lactate Threshold Test

The LT was calculated through a described lactate test in a cycle ergometer whose methodology has been previously described by Weltman et al. [21] and was determined through the relationship between lactate concentration and power (w). Thus, the higher power that was not associated with an increase in lactate concentrations was proposed as the power corresponding to the LT. This always occurred just before the curvilinear increase in blood lactate observed with the following exercise intensities. An increase in lactate concentrations within at least 0.5 mmol/L was necessary for the determination of the LT. A portable lactate analyzer (Lactate Pro 2) was used to determine lactate concentrations from a blood sample obtained from the ball of a finger (Fig. 1). The Lactate Pro 2 showed a good agreement with respect to the stationary hospital blood gas analyzer ABL800 Flex as the gold standard and did not present systematic errors of measurement, indicating an adequate validity [22]. The accuracy and reliability of this device were considered better than other hand-held blood lactate analyzers for the study population [23]. The starting power output on the cycle ergometer ranged from 20 to 25 w depending on the fitness level and was increased by 25 w every 3 min until LT was obtained, with participants cycling at 70–75 revolutions per minute.

Fig. 1.



LT determination. LT, lactate threshold; RPM, revolutions per minute.

30-min Steady-State Test

This test was carried out on a cycle ergometer at the intensity corresponding to the LT. The participant performed three 30-min steady-state tests on a cycle ergometer at the intensity corresponding to the LT, previously calculated, and separated at least 48 h between them. In each of the tests the participants cycled during 30 min at the same intensity without a mask, with a surgical mask or with a FFP2 respirator (in a randomly manner). The cadence was fixed at 70–75 revolutions per minute.

Outcome Measures

Blood lactate concentrations measured in mmol/L, heart rate determined in beats per minute (bpm), oxygen saturation measured in %, subjective perception of effort assessed with the Borg´s Scale and dyspnea level assessed by a visual analogue scale were collected at baseline, at 10 min, at 20 min, and at the end of the 30-min steady-state test. The maximum inspiratory pressure (PI_{max}), measured in cm H_2O, was collected before and after each test to measure inspiratory muscle strength.

Inspiratory Muscle Strength

Inspiratory muscle strength was assessed by measuring PI_{max} using a POWERbreathe® KH1 device (POWERbreathe International Ltd.) from residual volume, according to the rules of the American Thoracic Society and European Respiratory Society [24, 25]. Each measurement was obtained in the reference unit of centimeter of water column (cm H_2O). The procedure was repeated at least 3 times or until 2 reproducible efforts (i.e., within 5% of each other). An interval of about 1 min was allowed between the measurements to avoid short-term fatigue for respiratory muscles. The highest of 2 reproducible values was considered in the data analysis [26]. The advantage of this test is that it is a quick and noninvasive way to assess the strength of the inspiratory muscles through the PI_{max}. The PI_{max} measurement was performed before and after the 30-min steady-state test, with the aim of assessing if the use of the mask affected the strength of the inspiratory muscles during the exercise. This electronic inspiratory loading device was considered valid during a loaded breathing task with respect to a laboratory system as the gold standard [27], showing adequate reliability [28]. On the first visit to the laboratory, participants were familiarized with this test.

Blood Lactate Concentration

Capillary blood samples were extracted from the participant's fingertip in order to determine the blood lactate concentration using the Lactate Pro 2 portable device [22]. These samples were obtained before, at 10 min, at 20 min, and at 30 min of the 30-min steady-state test. As it was detailed previously, this device was considered valid [22] and reliable [23].

Heart Rate

Heart rate was monitoring during the entire 30-min steady-state test through a Polar H10 heart rate monitor connected to a Polar-measuring band around the chest. Data at baseline, at 10 min, at 20 min, and at 30 min of the test were

considered in the data analysis. The chest-strapped Polar H10 HR monitor (Polar Electro Oy) was used as our criterion device due to its concurrent validity of similar Polar devices against echocardiogram and reliability were well established [29].

Oxygen Saturation

Oxygen saturation was measured with a finger pulse-oximeter placed on the participant´s index finger (Palco Laboratories P-340). This tool was used as valid and reliable to measure oxygen saturation according to prior studies [30, 31].

Dyspnea Level

Dyspnea level was measured by a dyspnea visual analogue scale with a range of 0 (no sensation of breathlessness) to 10 (maximum sensation of breathlessness). Participants were asked to report their sensation of breathlessness, marking in a 10-cm line at the point that they felt as the representation of their current state on a sheet, at baseline, at 10 min, at 20 min, and at 30 min of the 30-min steady-state test. This scale was shown as a valid tool to measure dyspnea [32], providing more reliable measurements than the Borg scale [33].

Subjective Perceived Exertion

The subjective perceived exertion during exercise was measured by the Borg´s rating of perceived exertion (RPE) scale [34], previously described as a valid and reliable measure [35]. This scale ranged from 6 to 20 points, identifying the 6 value with the minimum possible effort and the 20 value with the maximum possible effort. The participants were asked at baseline, at 10 min, at 20 min, and at 30 min of the 30-min steady-state test.

Statistical Analysis

Power

Statistical analyses were performed by the Statistical Package for the 22.0 version of the Social Sciences (SPSS) software. Normal distribution was analyzed by the Shapiro-Wilk test. Frequency with n (%) for categorical data and mean ± standard deviation completed with the lower and upper limits of the 95% confidence interval (CI) for quantitative data were used to describe these data. Two-way ANOVAs for repeated measures with time (at baseline, 10 min, 20 min, and 30 min of exercise) as a within-subject factor and condition (control, surgical masks, and FFP2 respirators) as between-condition factor were used to analyze all outcome measurements (baseline measurements were not carried out for RPE and dyspnea, as well as measurements at 10 and 20 min of exercise were not performed for PI_{max}) [36]. The Greenhouse-Geisser's significance correction was considered if the Mauchly's test rejected the sphericity [37]. Post-hoc comparisons were carried out by using the Bonferroni's correction. Effect size for F-tests was assessed by the Eta squared coefficient (η^2) considering a $\eta^2 = 0.01$ coefficient for a small effect size, a $\eta^2 = 0.06$ coefficient for a medium effect size and a $\eta^2 = 0.14$ coefficient for a large effect size [38]. p values <0.05 was considered as statistically significant for a 95% CI and completed within F statistics for ANOVA analyses adjusted by the Greenhouse-Geisser`s correction [37].

Results

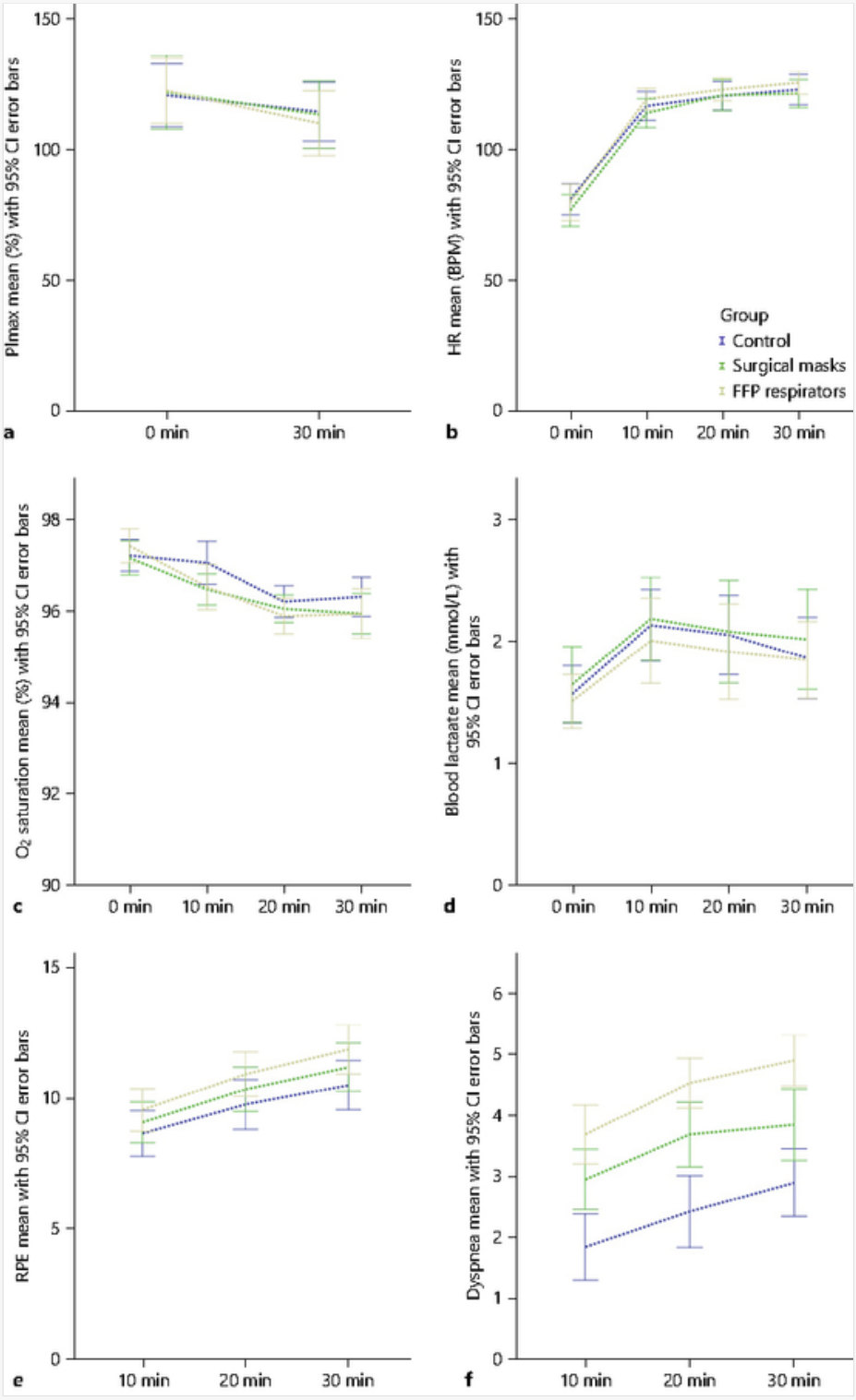
Descriptive Data

From a total population of 30 participants, 15 males and 15 females, eligible for this study, 11 females did not receive the baseline measurements nor interventions due to their failure to show up for their scheduled appointment. Thus, a total sample of 19 participants, divided into 15 (78.95%) males and 4 (21.05%) females, completed the study by a cross-over design, and all participants performed the study under 3 different conditions, including control, surgical masks, and FFP respirators. Mean ± standard deviation (95% CI) of this sample showed an age of 23.15 ± 3.20 (21.61, 24.70) years, a height of 1.74 ± 0.09 (1.70, 1.79) m, a weight of 69.10 ± 12.84 (62.91, 75.29) kg, a body mass index of 22.37 ± 2.33 (21.24, 23.49) kg/cm^2, and a threshold for lactate test of 78.94 ± 24.86 (66.96, 90.93) W.

Inspiratory Muscle Strength

There were no statistically significant interactions ($F_{2.000}$ = 1.294; p = 0.283; η^2 = 0.046) between the use of FFP2 respirators, surgical masks, and control conditions during the different measurement moments for PI_{max} comparisons. All groups exhibited a PI_{max} reduction ($F_{1.000}$ = 32.907; p < 0.001; η^2 = 0.379) after 30 min of exercise for the difference mean (95% CI) of −12.42% (−6.93, −17.91) for FFP2 respirators, −8.55% (−3.03, −14.01) for surgical masks, and −6.26% (−0.77, −11.75) for control condition (Fig. 2a).

Fig. 2.



Linear graphs showing the outcome measurements means with the 95% CI error bars for between-groups interaction and within-group comparisons PI_{max} (**a**) HR (**b**) O_2 saturation (**c**) Blood lactate level (**d**) RPE (**e**) Dyspnea (**f**). BPM, beats per minute; CI, confidence interval; HR, heart rate; mmol/L, millimoles per liter; O_2, oxygen; PI_{max}, maximum inspiratory pressure; RPE, rating of perceived exertion.

Heart Rate

Participants who wore FFP2 respirators, surgical masks and control condition did not show any statistically significant interaction ($F_{4.042}$ = 0.588; p = 0.674; η^2 = 0.021) during all measurement moments for heart rate. All conditions

displayed a HR increase ($F_{2.021}$ = 498.173; $p < 0.001$; η^2 = 0.902), within a difference mean ranging from 6.26 to 45.47 BPM for FFP2, from 8.78 to 44.36 BPM for surgical masks and from 6.26 to 41.63 BPM for control condition, between all measurements moments, except for the nonsignificant comparisons ($p > 0.05$) at 20 min versus 30 min in all conditions and, specifically, the comparison at 10 min versus 20 min in the FFP2 respirators condition (Fig. 2b).

Oxygen Saturation

Also, the use of FFP2 respirators, surgical masks, and control condition did not show statistically significant interactions ($F_{4.042}$ = 5.349; p = 0.297; η^2 = 0.044) during any measurement of oxygen saturation. All conditions determined an O_2 saturation reduction ($F_{2.674}$ = 39.488; $p < 0.001$; η^2 = 0.422), showing a difference mean ranging from −0.63 to 1.52% for FFP2, from −0.42 to −1.21% for surgical masks and from −0.73 to −1.00% for control condition, between different measurements moments, except for the comparisons ($p > 0.05$) at 0 min versus 10 min and 20 min versus 30 min in the control condition, as well as 10 min versus 30 min and 20 min versus 30 min in the surgical masks and FFP respirators conditions (Fig. 2c).

Blood Lactate Level

In addition, participants wearing FFP2 respirators, surgical masks, and control conditions did not present any statistically significant interaction ($F_{5.354}$ = 0.115; p = 0.991; η^2 = 0.004) during measurement times of blood lactate level. These conditions showed a blood lactate level increase ($F_{2.677}$ = 16.860; $p < 0.001$; η^2 = 0.238) at 0 min versus 10 min, detailing a difference mean (95% CI) of 0.49 (0.86, 0.12) mmol/L for FFP2, 0.53 (0.90, 0.16) mmol/L for surgical masks, and 0.56 (0.93, 0.19) for the control condition, and, specifically, 0.48 (0.92, 0.04) at 0 min versus 20 min in the control condition. The rest of the comparisons did not show any statistically significant difference ($p > 0.05$) for each condition (Fig. 2d).

Rating of Perceived Exertion

FFP2 respirators, surgical masks and control conditions did not display statistically significant interactions ($F_{3.007}$ = 0.115; p = 0.734; η^2 = 0.016) during all measurements of RPE. All conditions determined a progressive RPE increase ($F_{1.504}$ = 100.131; $p < 0.001$; η^2 = 0.650) between all measurement moments, within a difference mean ranging from 0.94 to 2.31 points for FFP2, from 0.84 to 2.10 points for surgical masks, and from 0.83 to 1.84 points for control condition (Fig. 2e).

Dyspnea

Finally, FFP2 respirators, surgical masks, and control conditions did not show any statistically significant interaction ($F_{3.056}$ = 0.742; p = 0.532; η^2 = 0.027) during all measurement moments for dyspnea comparisons. Nevertheless, higher dyspnea scores were shown between surgical masks and FFP respirator conditions with respect to the control condition, showing a difference mean (95% CI) of 1.10 (1.94, 0.26) and 1.84 (2.68, 1.00) points at 10 min, 1.26 (2.11, 0.40) and 2.10 (2.96, 1.25) points at 20 min, and 0.94 (1.82, 0.07) and 2.00 (2.87, 1.12) points at 30 min, respectively, and specifically, a difference mean (95% CI) of 1.05 (1.92, 0.17) points for the FFP respirator condition with respect to the surgical masks condition after 30 min of exercise. In addition, all conditions showed a progressive dyspnea increase ($F_{1.528}$ = 56.609; $p < 0.001$; η^2 = 0.512) between all measurement moments, within a difference mean ranging from 0.36 to 1.21 points for FFP2, from 0.73 to 0.89 points for surgical masks, and from 0.47 to 1.05 points for control condition, except for the nonsignificant comparison ($p > 0.05$) at 20 min versus 30 min in the surgical masks condition (Fig. 2f).

Discussion

To the authors' knowledge, this is the first study examining the effects of wearing masks or filtering respirators under continuous exercise performance during a 30 min stable load exercise according to LT intensity on inspiratory muscle strength reduction, metabolic parameters alteration, heart rate increase, subjective perceived exertion, and dyspnea perception increases. According to disproving false myths of the individual protective equipment during the current COVID-19 pandemic [39], our findings suggested that inspiratory muscle strength and physiology parameters at "conversational level" exercise were not impaired by wearing masks or filtering respirators.

To date, research studies focused on the masks use effects during moderate-high intensity physical exercises without considering LT intensity [11, 12, 14, 15], while our study analyzed the most common elected physical exercise by general population under LT, called "conversational level" exercise performed during 30 min under LT (~60% VO_2max) [17, 18, 21, 22]. According to these moderate-high intensity exercises, ventilation, cardiopulmonary capacity, and comfort may be impaired by surgical masks and worsened by FFP2 filtering respirators' use in healthy individuals [11, 12, 14, 15], perceiving higher lack of breath and claustrophobic sensation at greater exercise intensities [40], although without any episode of hypoxemia or hypercapnia [41]. Since dyspnea was not assessed at baseline in our study, but only during exercise, there was a "condition" main effect, where wearing the facemasks overall resulted in higher dyspnea scores, in spite of the lack of statistically significant interactions between condition and time. In addition, the different conditions of our study did not show relevant differences for O_2 saturation, although a reduction of O_2 saturation was usually observed during the 30-min steady-state test in accordance with other studies using moderate-to-high intensity physical exercises [11, 12, 14–16].

In accordance with our research findings, a recent systematic review and meta-analysis carried out by Shaw et al. [42] showed that face masks or FFP2 filtering respirators may be worn during exercise with a minimal impact on physiological variables such as increases in perceived exertion and dyspnea, end-tidal CO_2, and heart rate. According to Shaw et al. [42], although some studies showed impairments during moderate-high intensity exercise while wearing masks, most studies did not. A limitation for some of these studies was the use of a rubber or silicone mask that was worn over the surgical mask or FFP2 respirator to collect gases. This issue may have interfered with the proper function and normal breathability of the surgical mask or FFP2 respirator by sealing of the mask or respirator to the face. Possibly, surgical masks or FFP2 respirators prevented a proper seal of the rubber or silicone mask to the skin surface, resulting in leakage of gases. This may have led to decreased measures of ventilation and oxygen consumption in these studies. Our study may add to this meta-analysis that exercise performance wearing masks or filtering respirators at continuous low-intensity after stable load according to LT produced no-impact on physiological parameters or inspiratory muscle strength, encouraging the use of both masks under "conversational level" exercise.

Despite there were no difference between FFP2, surgical mask, and control condition, there was an impairment of inspiratory muscle strength and oxygen desaturation during the trial, which could not be expected as an usual response in healthy young subjects. All tests were accurately carried out in the laboratory according to the described protocol, and participants were healthy young adults without neither pathology nor Covid-19 infection in their medical records. A plausible explanation for these findings may be that all measurements were performed during and immediately after the 30-min steady-state test [43], without any interval or resting period, which could have produced hyperventilation status, justifying these progressive impairments of inspiratory muscle strength and oxygen saturation parameters. The trial protocol proposed by the authors did not include intervals or resting periods in order to increase inspiratory fatigue testing differences between FFP2, surgical mask, and control in these conditions.

Future Studies and Limitations

Despite the novelty of this study was the comparison of respirators and masks during exercise at "conversational level," the main limitation of the present study was that it was carried out in healthy subjects and future studies should be performed in patients with different conditions, including severe respiratory patients, due to increased resistance or minor blood gases flow changes may evoke increases in exercise dyspnea and therefore exercise capacity alterations [44]. In addition, post hoc analyses of dyspnea in our study showed a tendency to increase with exercise time wearing surgical masks and much more when wearing FFP2 filtering respirators. These changes should be studied under exercise at LT intensity for more than 30 min. Regarding external validity, the low number of females must be considered as a limitation due to its possible influence on physiological parameters [16], and future studies should consider a paired matched sample for sex distribution. Despite we tried to get a balanced composition of both sexes (15 males and 15 females) according to the initial sample of the trial protocol (NCT04832893), 11 females did not receive baseline measurements nor the required interventions. Considering internal validity, between-groups' CI of the difference mean showed a change of sign, which may suppose a threat to internal validity, and further studies should replicate our study within larger sample sizes to ensure the accuracy of our procedure. In accordance with Fikenzer et al. [13], our study presented similar limitations that have been pointed out by Hopkins et al. [45] regarding the effects of surgical and FFP2 respirators on cardiopulmonary exercise capacity. Finally, further studies should be carried out in the next future to upgrade sample features and size, including different groups, in order to improve sample composition and, consequently, statistical strength. In spite of both surgical masks or filtering respirators usually worn by all

participants in daily life, their preferred mask type during exercise performance or occupational work was not registered and should be taken into account for further studies.

Conclusions

According to disproving false myths, the present study findings suggested that inspiratory muscle strength and physiological parameters during “conversational level” exercise at low-intensity stable load according to LT were not impaired under wearing masks or filtering respirators in healthy, nonsmoking young adults, who participated in regular recreational physical activity for at least 3 days per week.

Statement of Ethics

The Ethics Committee of Francisco de Vitoria University approved this study, approval number: 20/2021. Signed informed consent was obtained from all participants. The research was conducted ethically in accordance with the World Medical Association Declaration of Helsinki. The study was registered on clinicaltrials.gov (NCT04832893).

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Funding Sources

There was no funding source for this study.

Author Contributions

Conceptualization: Sanchez-Migallón V., Calvo-Lobo C., Sanchez-Jorge S., Arce M., Vicente A., Bello E., Rodriguez-Sanz D., Becerro-de-Bengoa-Vallejo R. Chicharro JL., and Vicente-Campos D.; methodology: Sanchez-Migallón V., Calvo-Lobo C., Vicente A., Bello E., Rodriguez-Sanz D., Becerro-de-Bengoa-Vallejo R. Chicharro JL., and Vicente-Campos D.; validation: Sanchez-Jorge S. and Arce M.; formal analysis: Rodriguez-Sanz D. and Becerro-de-Bengoa-Vallejo R.; investigation: Chicharro JL. And Vicente-Campos D.; resources: Chicharro JL. and Vicente-Campos D.; data curation: Calvo-Lobo C.; writing − original draft preparation: Vicente-Campos D. Calvo-Lobo C.; writing − review and editing: Sanchez-Migallón V., Calvo-Lobo C., Sanchez-Jorge S., Arce M., Vicente A., Bello E., Rodriguez-Sanz D., Becerro-de-Bengoa-Vallejo R. Chicharro JL., and Vicente-Campos D.; methodology: Sanchez-Migallón V., Calvo-Lobo C., Vicente A., Bello E., Rodriguez-Sanz D., Becerro-de-Bengoa-Vallejo R. Chicharro JL., and Vicente-Campos D.; supervision: Vicente-Campos D.; project administration: Arce M., Vicente A., and Bello E. All the authors have read and agreed to the published version of the manuscript.

Data Availability Statement

All data generated or analyzed during this study are included in this article. Further inquiries can be directed to the corresponding author.

References

The corrections made in this section will be reviewed by journal production editor.

[1] Koo JR, Cook AR, Park M, Sun Y, Sun H, Lim JT, et al. Interventions to mitigate early spread of SARS-CoV-2 in Singapore: a modelling study. Lancet Infect Dis. 2020 Jun;20(6):678–88.

[2] Liang M, Gao L, Cheng C, Zhou Q, Uy JP, Heiner K, et al. Efficacy of face mask in preventing respiratory virus transmission: a systematic review and meta-analysis. Travel Med Infect Dis. 2020;36:101751.

[3]

Leung NHL, Chu DKW, Shiu EYC, Chan KH, McDevitt JJ, Hau BJP, et al. Respiratory virus shedding in exhaled breath and efficacy of face masks. Nat Med. 2020 May;26(5):676–80.

[4] Cowling BJ, Zhou Y, Ip DK, Leung GM, Aiello AE. Face masks to prevent transmission of influenza virus: a systematic review. Epidemiol Infect. 2010 Apr;138(4):449–56. http://dx.doi.org/10.1017/S0950268809991658.

[5] Eikenberry SE, Mancuso M, Iboi E, Phan T, Eikenberry K, Kuang Y, et al. To mask or not to mask: modeling the potential for face mask use by the general public to curtail the COVID-19 pandemic. Infect Dis Model. 2020;5:293–308.

[6] Chu DK, Akl EA, Duda S, Solo K, Yaacoub S, Schünemann HJ. Physical distancing, face masks, and eye protection to prevent person-to-person transmission of SARS-CoV-2 and COVID-19: a systematic review and meta-analysis. Lancet. 2020 Jun;395(10242):1973–87. http://dx.doi.org/10.1016/S0140-6736(20)31142-9.

[7] Cheng VCC, Wong SC, Chuang VWM, So SYC, Chen JHK, Sridhar S, et al. The role of community-wide wearing of face mask for control of coronavirus disease 2019 (COVID-19) epidemic due to SARS-CoV-2. J Infect. 2020 Jul;81(1):107–14.

[8] De-Yñigo-Mojado B, Madera-García J, Becerro-de-Bengoa-Vallejo R, Losa-Iglesias ME, Rodríguez-Sanz D, San-Antolín M, et al. Fit factor of masks used by physicians in clinical settings. Int J Med Sci. 2020;17(17):2696–702.

[9] De-Yñigo-Mojado B, Madera-García J, Becerro-De-Bengoa-Vallejo R, Losa-Iglesias ME, Rodríguez-Sanz D, Calvo-Lobo C, et al. Fit factor compliance of masks and FFP3 respirators in nurses: a case – control gender study. J Adv Nurs. 2021;77(7):3073–82.

[10] Villani A, Bozzola E, Staiano A, Agostiniani R, Del Vecchio A, Zamperini N, et al. Facial masks in children: the position statement of the Italian pediatric society. Ital J Pediatr. 2020 Sep;46(1):132.

[11] Epstein D, Korytny A, Isenberg Y, Marcusohn E, Zukermann R, Bishop B, et al. Return to training in the COVID-19 era: the physiological effects of face masks during exercise. Scand J Med Sci Sports. 2021;31(1):70–5.

[12] Lässing J, Falz R, Pökel C, Fikenzer S, Laufs U, Schulze A, et al. Effects of surgical face masks on cardiopulmonary parameters during steady state exercise. Sci Rep. 2020;10(1):22363.

[13] Fikenzer S, Uhe T, Lavall D, Rudolph U, Falz R, Busse M, et al. Effects of surgical and FFP2/N95 face masks on cardiopulmonary exercise capacity. Clin Res Cardiol. 2020;109(12):1522–30.

1 Lee HP, Wang de Y. Objective assessment of increase in breathing resistance of N95 respirators on human subjects. Ann Occup Hyg. 2011 Oct;55(8):917–21. http://dx.doi.org/10.1093/annhyg/mer065.

[15] Mapelli M, Salvioni E, De Martino F, Mattavelli I, Gugliandolo P, Vignati C, et al. You can leave your mask on": effects on cardiopulmonary parameters of different airway protection masks at rest and during maximal exercise. Eur Respir J. 2021 Mar;58(3):2004473.

16. Ahmadian M, Ghasemi M, Nasrollahi Borujeni N, Afshan S, Fallah M, Ayaseh H, et al. Does wearing a mask while exercising amid COVID-19 pandemic affect hemodynamic and hematologic function among healthy individuals? Implications of mask modality, sex, and exercise intensity. Phys Sportsmed. 2021 May:1–12. Online ahead of print.

[17] Kashihara K, Nakahara Y. Short-term effect of physical exercise at lactate threshold on choice reaction time. Percept Mot Skills. 2005 Apr;100(2):275–91. http://dx.doi.org/10.2466/pms.100.2.275-291.

[18] De Sousa NMF, Magosso RF, Pereira GB, Souza MVC, Vieira A, Marine DA, et al. Acute cardiorespiratory and metabolic responses during resistance exercise in the lactate threshold intensity. Int J Sports Med. 2012;33(2):108–13.

[19] Schulz KF, Altman DG, Moher D. CONSORT 2010 Statement: updated guidelines for reporting parallel group randomised trials. Trials. 2010 Mar;11:32. http://dx.doi.org/10.1186/1745-6215-11-32.

[20] Salkind N. Cohen's f statistic. Encyclopedia of research design. SAGE Publications, Inc.; 2012.

[21] Weltman A, Snead D, Stein P, Seip R, Schurrer R, Rutt R, et al. Reliability and validity of a continuous incremental treadmill protocol for the determination of lactate threshold, fixed blood lactate concentrations, and VO2max. International J Sports Med. 1990 Feb;11(1):26–32.

[22] Raa A, Sunde GA, Bolann B, Kvåle R, Bjerkvig C, Eliassen HS, et al. Validation of a point-of-care capillary lactate measuring device (Lactate Pro 2). Scand J Trauma Resusc Emerg Med. 2020 Aug;28(1):83.

[23] Bonaventura JM, Sharpe K, Knight E, Fuller KL, Tanner RK, Gore CJ. Reliability and accuracy of six hand-held blood lactate analysers. J Sports Sci Med. 2015;14(1):203–14.

[24] Graham BL, Steenbruggen I, Barjaktarevic IZ, Cooper BG, Hall GL, Hallstrand TS, et al. Standardization of spirometry 2019 update an official American Thoracic Society and European Respiratory Society technical statement. Am J Respir Crit Care Med. 2019;200(8):e70-88.

[25] Graham BL, Brusasco V, Burgos F, Cooper BG, Jensen R, Kendrick A, et al. ERS/ATS standards for single-breath carbon monoxide uptake in the lung. Eur Respir J. 2017;49(1):1600016.

[26] Martin-Sanchez C, Barbero-Iglesias FJ, Amor-Esteban V, Martin-Nogueras AM. Comparison between two inspiratory muscle training protocols, low loads versus high loads, in institutionalized elderly women: a double-blind randomized controlled trial. Gerontology. 2021;67(1):1–8. http://dx.doi.org/10.1159/000511009.

[27] Langer D, Jacome C, Charususin N, Scheers H, McConnell A, Decramer M, et al. Measurement validity of an electronic inspiratory loading device during a loaded breathing task in patients with COPD. Respir Med. 2013 Apr;107(4):633–5.

[28] Minahan C, Sheehan B, Doutreband R, Kirkwood T, Reeves D, Cross T. Repeated-sprint cycling does not induce respiratory muscle fatigue in active adults: measurements from the Powerbreathe® inspiratory muscle trainer. J Sports Sci Med. 2015;14(1):233–8.

[29] Cheatham SW, Kolber MJ, Ernst MP. concurrent validity of resting pulse-rate measurements: a comparison of 2 smartphone applications, the polar H7 belt monitor, and a pulse oximeter with bluetooth. J Sport Rehabil. 2015 May;24(2):171–8. http://dx.doi.org/10.1123/jsr.2013-0145.

[30] Laire G, Viaene MK, Veulemans H, Masschelein R, Nemery B. Nocturnal oxygen desaturation, as assessed by home oximetry, in long-term solvent-exposed workers. Am J Ind Med. 1997;32(6):656–64. http://dx.doi.org/10.1002/(sici)1097-0274(199712)32:6<656::aid-ajim12>3.0.co;2-0.

[31] Hassan AT, Ahmed SM, AbdelHaffeez AS, Mohamed SAA. Accuracy and precision of pulse oximeter at different sensor locations in patients with heart failure. Multidiscip Respir Med. 2021;16(1):742. http://dx.doi.org/10.4081/mrm.2021.742.

[32] Gift AG, Narsavage G. Validity of the numeric rating scale as a measure of dyspnea. Am J Crit Care. 1998;7(3):200–4. http://dx.doi.org/10.4037/ajcc1998.7.3.200.

[33]

Reychler G, Beaumont M, Latiers AC, Pieters T, Fremault A. Dyspnea could be accurately assessed by a caregiver in hospitalized patients with respiratory diseases: interrater reliability and agreement study. Braz J Phys Ther. 2021 Nov–Dec;25(6):735–40. http://dx.doi.org/10.1016/j.bjpt.2021.04.010.

[34] Borg GA. Psychophysical bases of perceived exertion. Med Sci Sports Exerc. 1982;14(5):377–81. http://dx.doi.org/10.1249/00005768-198205000-00012.

[35] Chen MJ, Fan X, Moe ST. Criterion-related validity of the Borg ratings of perceived exertion scale in healthy individuals: a meta-analysis. J Sports Sci. 2002;20(11):873–99. http://dx.doi.org/10.1080/026404102320761787.

[36] Blanca MJ, Alarcón R, Arnau J, Bono R, Bendayan R. Non-normal data: Is ANOVA still a valid option? Psicothema. 2017;29(4):552–7. http://dx.doi.org/10.7334/psicothema2016.383.

[37] Haverkamp N, Beauducel A. Violation of the sphericity assumption and its effect on type-I error rates in repeated measures ANOVA and multi-level linear models (MLM). Front Psychol. 2017 Oct;8:1841. http://dx.doi.org/10.3389/fpsyg.2017.01841.

[38] Cohen J. Eta-squared and partial eta-squared in fixed factor ANOVA designs. Educ Psychol Meas. 1973;33(1):107–12. http://dx.doi.org/10.1177/001316447303300111.

[39] Kebede Y, Birhanu Z, Fufa D, Yitayih Y, Abafita J, Belay A, et al. Myths, beliefs, and perceptions about COVID-19 in Ethiopia: a need to address information gaps and enable combating efforts. PLoS One. 2020 Nov;15(11):e0243024.

[40] Driver S, Reynolds M, Brown K, Vingren JL, Hill DW, Bennett M, et al. Effects of wearing a cloth face mask on performance, physiological and perceptual responses during a graded treadmill running exercise test. Br J Sports Med. 2022;56(2):107–13.

[41] Shein SL, Whitticar S, Mascho KK, Pace E, Speicher R, Deakins K. The effects of wearing facemasks on oxygenation and ventilation at rest and during physical activity. PLoS One. 2021 Feb;16(2):e0247414. http://dx.doi.org/10.1371/journal.pone.0247414.

[42] Shaw KA, Zello GA, Butcher SJ, Ko JB, Bertrand L, Chilibeck PD. The impact of face masks on performance and physiological outcomes during exercise: a systematic review and meta-analysis. Appl Physiol Nutr Metab. 2021;46(7):693–703. http://dx.doi.org/10.1139/apnm-2021-0143.

[43] Bräuer EK, Smekal G. VO2 steady state at and just above maximum lactate steady state intensity. Int J Sports Med. 2020 Aug;41(9):574–81.

[44] Hopkins SR, Dominelli PB, Davis CK, Guenette JA, Luks AM, Molgat-Seon Y, et al. Face masks and the cardiorespiratory response to physical activity in health and disease. Ann Am Thorac Society. 2021 Mar;18(3):399–407.

[45] Hopkins SR, Stickland MK, Schoene RB, Swenson ER, Luks AM. Effects of surgical and FFP2/N95 face masks on cardiopulmonary exercise capacity: the numbers do not add up. Clin Res Cardiol. 2020 Dec;109(12):1605–6. http://dx.doi.org/10.1007/s00392-020-01748-0.

Queries and Answers

Q1

Query: Please provide forename for author “J.L. Chicharro.”

Answer: JL