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# Exercising at the time of the COVID-19 pandemic: acute physiological, perceptual and performance responses of wearing face masks during sports activity

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# Title: Exercising at the time of the COVID-19 pandemic: acute physiological, perceptual and performance responses of wearing face masks during sports activity

Running head: Effects of wearing a face mask during exercise

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BACKGROUND: The COVID-19 pandemic requires the adoption of strict preventive measures, such as wearing a protective face mask , but few studies investigated its impact during exercise. We investigated the effects of wearing a protective face mask while exercising at different intensities and verified whether differences between two types of protective face masks exist.

METHODS: Twenty subjects performed 4-min running at 8 km•h$^{-1}$ and at 10 km•h$^{-1}$, 8 x 90-m Intermittent running bouts and the Yo-Yo Intermittent Recovery Test Level-1, while wearing either a surgical mask, a sports-reusable mask or no mask. Physiological responses (HR, [La], $SpO_2$), overall and breathlessness perceived exertion and YYIRT1-distance were assessed.

RESULTS: Breathlessness RPE was greater with surgical than without mask at the end of the run at 8 km•h$^{-1}$ (+7.18 [3.21, 11.50]) and with both surgical and sports-reusable mask than without mask at the end of the run at 10 km•h$^{-1}$ (+8.09 [4.09, 12.60] and +8.21 [4.53, 12.70]) and intermittent exercise (+11.10 [6.41, 16.10] and +10.50 [6.18, 15.30]). Overall RPE was greater with surgical than without mask at the end of the run at 8 (+3.71 [1.15, 6.91]) and 10 km•h$^{-1}$ (+5.29 [2.26, 8.85]). Furthermore, YYIRT1 performance was lower with surgical (-150 m [44, 240]) and sports-reusable mask (-201 m [108, 286]) than without mask.

CONCLUSIONS: Regardless of exercise intensity and mask type, wearing a protective face mask mostly affects perceptual responses, also causing a performance reduction during maximal exercise. These findings must be considered when prescribing/practicing exercise while wearing a protective face mask.

**Key words:** Coronavirus; Sports; Respiratory Protective Devices; Physical Functional Performance; Perception;

## Introduction

Recent Coronavirus disease (COVID-19) outbreak throughout 2020 has created major challenges all over the world in terms of economy, social interactions, and individual lifestyles. Preventive measures limiting the spread of COVID-19, adopted in several countries worldwide, have impacted upon sport activities for both professional and recreational athletes.

The adoption of prevention protocols for a safe return to training and competitions implied the application of some protective measures not always easy to combine with performance goals, like wearing personal protective equipment (e.g., face masks) and maintaining social distancing.[1]

Although the contextual relevance of the topic is high, the impact of covering mouth and nose with face masks or other respiratory devices, on the physiological and perceptual responses to specific exercise tasks, has been poorly studied and the results are controversial.[2–7] The retained moisture from the exhaled breath and facial sweat accumulation (which interfere with heat dissipation at facial's skin level) [4] has been shown to increase the perception of discomfort [8] and impact exercise perceptual responses (e.g. rate of perceived exertion)[9]. However, while some authors reported an increase in both heart rate (HR) and respiratory frequency (Rf)[3,9] wearing different kinds of face mask (i.e. disposable respirators and surgical masks) during low and moderate intensity exercises, others reported no changes in these physiological variables at all.

Besides, to the best of our knowledge, only few studies focused on high intensity exercises and maximum performance tasks, showing discordant results. Lerman et al.[7] observed a reduction in exercise performance (Time to Exhaustion test at 80% of $VO_2$max), associated to increased external inspiratory resistance, wearing different protective respiratory devices. Recently, Fikenzer et al.[11] found a decrease in power output, $VO_{2max}$, ventilatory parameters and lactate concentration ([La]) at the end of a maximal cardiopulmonary exercise test (CPET) wearing a FFP2/N95 mask and lower heart rate wearing a surgical mask. On the other hand, Shaw et al.[12] showed no differences neither in physiological and perceptual responses nor in performance during an incremental cycling CPET, wearing a surgical mask, a cloth mask or no mask.

As these observations are disparate and pertain to several kind of devices, the impact of wearing a face mask on physiological and perceptual responses to different exercise tasks, as well as on maximal exercise performance is currently unclear and deserves further investigations. Moreover, the introduction of new types of sports-reusable face masks represents a further confounding factor, as this may translate into dissimilar physiological and perceptive responses among the different types of face mask and exercise intensities.[13]

Therefore, the aim of this study was twofold: 1) to investigate the effects of wearing a face mask while running at low, moderate and high intensity on performance and physiological (i.e., pulse oxygen saturation, heart rate and blood lactate levels) and perceptual responses (i.e., rate of perceived exertion, RPE); 2) to point out whether two different types of mask (surgical mask vs sports-reusable mask) would impact differently on the physiological and perceptual outcomes. We hypothesized that wearing a face mask would not affect physiological parameters but could increase perceptual responses during low intensity exercise and impair the high intensity performance. Due to controversial results of previous studies, we cannot postulate any reasonable hypothesis about physiological responses during moderate and high intensity activity and differences between the two masks considered.

## Materials and methods

### Experimental approach to the problem

The study design was a crossover randomized control trial. Subjects were tested on three different occasions separated by one week, in which several physiological, perceptual and performance parameters were monitored while wearing a surgical mask (SM), a sports-reusable mask (SRM) or no mask (CON) (see protocol in Fig. 1). The order of the three conditions was randomized using a balanced randomization (www.randomization.com). To avoid any possible influence of prior heavier exercises on lighter ones, exercise order was arranged from the lightest (i.e., steady state 8 km/h running) to the heaviest exercise intensity (see online supplementary material). The recovery between drills was sufficient to allow HR to return to baseline values before starting the next exercise. During the study, subjects were asked to continue the individual training program provided by the strength and conditioning coaches of their soccer teams and to observe a day rest before each session. Subjects were tested at the same time of the day throughout all sessions in order to minimize the influence of weekly activities and circadian rhythms on the outcomes. Subjects were asked to avoid caffeine consumption during the 12 hours before the test and to consume a similar meal and amount of water before each session. Ad libitum ingestion of water was allowed during all the sessions. The test sessions were structured to provide physical stimuli of different intensities that are typical of several sport activities (e.g., running, soccer, basketball), and were carried out on an outdoor artificial turf. Weather conditions were sunny with temperatures between 21° C and 24° C, and relative humidity around 50%. Subjects were asked to use the same shoes in all sessions. The entire protocol was conducted between the 28th of May 2020 and 12th of June 2020, during the period of sport activity suspension, at non-professional level, due to the COVID-19 pandemic restrictions; all procedures were carried out following the safest national and international preventive guidelines and strategies related to COVID-19 infection.[14]

**Subjects**

Twenty-one adult male soccer players (age 25 ± 5 years, body mass 72.7 ± 6.6 kg and height 179 ± 5 cm), belonging to four different amateur teams, took part in the study.

**Ethical statement**

All procedures were carried out according to the Declaration of Helsinki on humans right and the study protocol was approved by Ethics Committee of University of Verona (15/2020). Before the commencement of the study each subject was properly informed about the study procedure and data treatment and provided his written consent.

**Procedure**

In the first session body mass (Seca 762, SECA, Birmingham, UK) and height (wall mounted stadiometer, GIMA, Gessate, Italy) of each subject were measured. A heart rate belt was worn by subjects as soon as they arrived on the field to ensure optimal registration of both heart rate and position by global position system (Polar Team Pro, Finland). CR-100 Borg Scale with instructions was presented and explained for both overall ($RPE_O$) and breathlessness ($RPE_B$) perceived exertion rate [15,16]. In order to verify if the subjects' recovery condition before the test were similar throughout the sessions, overall perception of physical recovery was collected by Total Quality Recovery scale (TQR) [17] and lower limb perception of delayed onset muscular soreness by a visual analogue scale for delayed onset muscular soreness (VAS DOMS)[18] before starting the exercise. Resting Blood Lactate and peripheral oxygen saturation ($SpO_2$) were measured after the subjects waited for at least 5 minutes with no mask, surgical or sports mask, respectively (depending on the session's condition). After baseline measurements, subjects performed 4 minutes running at 8 $km \cdot h^{-1}$ (WU1), 4 minutes at 10 $km \cdot h^{-1}$ (WU2), 8 bouts of 20 seconds at 16 $km \cdot h^{-1}$ with 20 seconds of recovery (IT) and the Yo-Yo Intermittent Recovery Level 1 (YYIRT) [19] with two minutes of recovery between WU1, WU2 and IT and 5 minutes between IT and YYIRT. Since the low intensity of WU1 and WU2, they were used as warm-up phase. IT simulated an intermittent exercise, normally used both in running and in team sports to improve aerobic characteristics[20]. Audio feedback (beep sound) was provided to maintain the correct pace during WU1, WU2 and IT; subjects had to synchronize their speed run with beep sounds and cones placed on the pitch. YYIRT, as incremental exercise, was used to both simulate a high intensity exercise and evaluate the specific aerobic fitness related to team sports' performance. $SpO_2$, $RPE_O$, $RPE_B$ and [La] were collected immediately at the end of WU1, WU2 and IT phases. $RPE_O$, $RPE_B$ were also asked throughout YYIRT, specifically during the recovery phase before the two last shuttle runs for each level, starting from the 12$^{th}$.[21] As soon as subjects finished the YYIRT1, $SpO_2$, $RPE_O$ and $RPE_B$ were collected. Moreover, [La] was measured after 3 and 5 minutes of exercise completion.[22]

**Perceptual measures**

The VAS DOMS consisted in a 100 mm line in which 0 indicated ‘‘no pain’’ and 100 represented ‘‘extreme pain’’. The subjects were asked to mark the level of perceived soreness on the line, after the execution of a single squat and palpation of lower limbs. The distance from the left end of the scale to the mark was indicated as the soreness rate.[18]

Total Quality of Recovery (TQR) was assessed using TQR scale. Subjects were asked to give a rate of their perception of recovery between 6 and 20, where higher rates correspond to better recovery state. [17] The rating of perceived exertion was collected using Borg's Category Ratio Scale 0-100 (CR-100), asking subjects to separately focus their attention on overall and breathing effort during each part of the protocol. Seventeen out of all involved subjects were used to CR-100 and used it during last season training sessions: for this reason, $RPE_O$ and $RPE_B$ data of four subjects have not been analysed. To compare

$RPE_O$ and $RPE_B$ collected throughout the YYIRT, the slopes of the time course were calculated ($Slope_O$ and $Slope_B$ respectively).[23]

**Physiological measures**

A pulse oximeter probe (WristOx$_2$® Model 3150, Nonin, Plymouth, Minnesota, USA) was applied on the third finger of the right hand, to measure the peripheral oxygen saturation. $SpO_2$ values were measured within five seconds at the end of each of the four exercises.

Heart rate was recorded continuously using a HR monitor (HR monitor, Polar, Vantaa, Finland) at 1-second intervals; the data were downloaded and analysed using a dedicated cloud, managed by the system's company, with restricted access by personal username and password. Mean heart rate ($HR_{mean}$) during the last minute of WU1 and WU2 and throughout all IT and YYIRT were calculated and maximal value ($HR_{max}$) was obtained at the end of YYIRT.[19] Moreover, six intensity zones were defined (<70, 70 - 75, 75–85, 85–90, 90-95 and >95% of $HR_{max}$) and the time spent in each zone during YYIRT was calculated.

To assess [La], a sample of peripheral blood (20μL) from the earlobe was taken and collected in a capillary tube with glucose solution. The sample was analysed by a blood lactate analyser (Biosen C-line, EKF Diagnostic, GmbH, Magdeburg, Germany).

**Performance measures**

The distance covered during the YYIRT (Distance) was considered as an index of performance due to its reliable and valid relationship with aerobic fitness and match performance in team sports at different levels, especially in soccer.[24] YYIRT consists in a sequence of shuttle runs (20 + 20m) interspersed by 10 seconds of recovery. The mean speed to cover the shuttle distance starts at 10 $Km•h^{-1}$ and increases progressively. The correct pace was provided to the subjects by a "beep sound". The end of the test was defined by either (i) the voluntary exhaustion of the subject or (ii) when the pace sound was not respected for two consecutive times.[19]

**Statistical analysis**

Descriptive statistics of subjects' characteristics are presented as means ± standard deviations. Normal distribution of data was checked by the Kolmogorov-Smirnov test; data were analysed after log transformation, to reduce bias due to non-uniformity error, when a skewed distribution was found ($p < 0.05$). A repeated measures ANOVA was carried out for all dependent variables using the three experimental conditions (CON, SM and SRM) as the within-subjects factor, and when an effect was found ($p < 0.05$) a pairwise comparison with Bonferroni adjustment was computed. Estimated means, 95% confidence intervals and p values were reported. Effect size (ES) with 95% confidence intervals was also calculated according to Cohen's d and interpreted as: ≤ 0.2 trivial, 0.2 – 0.6 small, 0.6 – 1.2 moderate, 1.2 – 1.99 large, and ≥ 2.0 very large.[25] Data analysis was performed using IBM® SPSS® (version 21.0.0, IBM Corp., Somers, NY, USA) and the website https://www.estimationstats.com/.

## Results

The results related to all the outcomes considered are presented in Table I. When statistical significance was found (main effect of condition in repeated measure ANOVA), graphs effect sizes with 95% CI have been shown (Fig. 2 and 3). Mean differences with 95%CI (MD), effect size with 95% CI (ES) and p values for CON-SM, CON-SRM and SM-SRM paired comparisons were also presented.

**Baseline**

At baseline, condition's main effect on $SpO_2$, [La], TQR and VAS DOMS showed no differences among conditions ($p = 0.252$, $p = 0.830$, $p = 0.902$ and $p = 0.166$ respectively).

**WU1 (running at 8 km•h$^{-1}$)**

The main effect of conditions on both $RPE_O$ (p = 0.024) and $RPE_B$ (p = 0.005) showed differences, at the end of exercise, among conditions. $RPE_O$ was higher in SM than CON (MD = 3.71 [1.15, 6.91], ES = 0.86 [0.21, 1.55] moderate, p = 0.019). Greater $RPE_B$ was found in SM (7.18 [3.21, 11.50], 1.06 [0.29, 1.70] moderate, p = 0.003]). when compared with CON. Only a trend of higher $RPE_B$ was shown for SRM (4.21 [0.82, 8.53], 0.63 [-0.02, 1.17] moderate, p = 0.056) compared to CON.

**WU2 (running at 10 km•h$^{-1}$)**

At the end of exercise, we found an effect of conditions on both $RPE_O$ and $RPE_B$ (p = 0.011 and p = 0.004). SM showed higher values of $RPE_O$ than CON (5.29 [2.26, 8.85], 1.04 [0.41, 1.74] moderate, p = 0.006) . Similar differences were found in $RPE_{B,}$ where values increased in SM (8.09 [4.09, 12.60], 1.2 [0.53, 1.91] large, p = 0.003) and SRM (8.21 [4.53, 12.70], 1.08 [0.51, 1.70] moderate, p = 0.011) compared to CON.

**IT (8 x 20''/20'')**

Evidence of condition's effect on $RPE_B$ (p = 0.002) but not on $RPE_O$ (p = 0.072). $RPE_B$ was higher in SM (11.10 [6.41, 16.10], 1.3 [0.76, 1.91] large, p = 0.004) and SRM (10.50 [6.18, 15.30], 1.16 [0.66, 1.68] moderate, p = 0.001) than CON.

**YYIRT**

Distance covered during YYIRT and $Slope_O$ showed a main effect of conditions. Distance was higher in CON compared to SM (150 m [44, 240], 0.34 [0.08, 0.55] small, p = 0.027) and SRM (201 m [108, 286], 0.46 [0.23, 0.71] small, p = 0.002). There was a trend for [La] peak to be higher in CON but the p value did not reach statistical significance. The $Slope_O$ was greater in SRM than CON (0.012 [0.003, 0.020], 0.62 [0.56, 1.10] moderate, p = 0.045).

## Discussion

The main findings of the study are that 1) running while wearing a face mask caused significant impairments of perceptual responses (i.e. increased RPEo and RPEb) at both low (WU1 and WU2) and moderate (IT) exercise intensities, whilst scarce or no influence was observed on physiological parameters (same HR, $SpO_2$ and [La]) regardless of exercise intensity; 2) a reduction in the distance covered during the YYIRT was observed while wearing either a surgical (~150 m) or a sports reusable mask (~200 m), suggesting that, despite no meaningful physiological modifications (i.e. HR and $SpO_2$), the increased perception of effort (higher $Slope_O$) can impair maximal exercise performance. Interestingly, these effects seem to be independent of what kind of mask is worn.

**Low-intensity exercises (WU1 and WU2)**

Numerous studies[2,4,8,13,26] proposed low-to-moderate intensity exercise to determine the influence of respirators on work capacity of healthcare workers, but very few of them[6,9] effectively tested surgical or other types of face masks instead of respirators. Roberge et al.[9] found a minimal clinically significant effect of wearing a surgical mask on HR (111 vs 120 bpm, without vs with a surgical mask, respectively) over the course of 1 h of walking at a low-moderate pace (i.e. 5.6 km•h$^{-1}$). However, according to our hypothesis, our results show no differences in HR, $SpO_2$ and La in both WU1 and WU2, in line with the outcomes of the study of Person et al.[6] in which subjects performed the Six-minute walk test wearing a surgical mask. One reason for no changes in physiological parameters is that, for both face masks (especially surgical mask) used in the current study, the breathing resistance was probably quite low, and at higher ventilations the fit became looser on the face, so that the breathing effort was not excessive compared to other respirators[9]. In this scenario, it is possible that exhaled gases were not trapped into the mask, leading to greater $O_2$ availability and lower $CO_2$ retention, avoiding $SpO_2$ reduction. This is supported by Kim et al.[13], showing that, despite the fact that $O_2$ partial pressure in respirators dead-space is below ambient levels, it had no clinically significant effect on $SpO_2$ while exercising, as those levels are consistent with an arterial oxygen saturation of 95%[8]. To further support the hypothesis of the low breathing resistance of the masks, Li et al.[27] demonstrated that during intermittent low-to-moderate intensity exercise (from 3.2 to 6.4 km•h$^{-1}$), HR was significantly lower when wearing surgical masks if compared to respirators. However, also when considering respirators, cardiopulmonary variables responded in a dose-related fashion to increasing work rate (i.e. HR was significantly higher while wearing a respirator at high but not low exercise intensities), further confirming our study's outcomes[3].

Considering perceptual responses, we found a significant effect of SM on RPEo and RPEb in both WU1 and WU2 (+5 and +8 in WU1; +7 and +10 in WU2), and of SRM on RPEb in WU2 (+7). In this regard, Person et al.[6] found a clinically significant increase in perception of dyspnoea calculated on a 10 cm-VAS dyspnoea scale while performing the Six-minute walk test with a surgical mask (+5.6 cm with mask vs +4.6 cm without mask). Those changes seemed to be related to a greater inspiratory and/or expiratory resistance[28] linked to the use of mask itself, leading to a generally greater discomfort which influences individual perceptions while exercising.[6] In addition, Kim et al.[13] suggested that the thermo-sensitivity of the portion of the face covered by the mask can result in a perception of a greater temperature, consequently leading to discomfort thus influencing rate of perceived exertion (RPE). On the other hand, no differences in RPE were found while walking at 5.6 km•h$^{-1}$with or without wearing a surgical mask.[9] However, Li et al.[27] suggested that overall discomfort of wearing a surgical mask while exercising increases gradually with time and increased workload; thus, it might be possible that the higher speeds tested in our study when compared to that used by Roberge et al.[9] (i.e. running at 8 and 10 km•h$^{-1}$vs walking at 5.6 km•h$^{-1}$), had a greater influence on RPE.

**Moderate-to-high intensity exercises (IT and YYIRT)**

Interval training and intermittent runs are typical training drills in several sports' context (e.g. running, soccer, rugby) and they are characterized by repeated bouts of exercise interspersed with recovery phases, resulting in a range of intensity from moderate to severe[20]. Our results showed that wearing a face mask during IT, which can be described as a moderate-intensity domain exercise (pooled $HR_{mean}$: 82% of $HR_{max}$ and [La]: 3.22 mmol/L) did not result in altered HR [La] nor $SpO_2$ responses, even though the perception of breathlessness ($RPE_b$) was higher with both SM and SRM (average + ~10 points) compared to CON. Moreover, an increase in the overall rating of perceived exertion ($RPE_O$) using SM was demonstrated (average + ~10 points). As the main aim of interval training is to maximize the time spent above 90% of maximal oxygen consumption ($VO_{2max}$) during exercise that lasts several minutes (> 20-25 minutes) or until exhaustion, from a practical point of view the increase in $RPE_O$ and $RPE_B$ that we have noticed after only 5 minutes of IT could have an important influence on longer interval training performances, especially if the requested intensity is higher than the one we tested.

Since during training sessions and competitions, players are asked to perform repeated high intensity bouts, covering a wide distance, we used the YYIRT as high intensity exercise (~75% of time spent above 90% $HR_{max}$) and the distance covered during it as an index of endurance performance[24]. Compared to CON, the distance covered during YYIRT showed an average decrement of ~150 m (-10%) and ~200 m (-13%) for SM (Fig. 2) and SRM (Fig. 3), respectively. Our findings confirmed the results of Lerman et al.[7], who showed a reduction in time to exhaustion at 80% of $VO_{2max}$ in healthy subjects wearing different kind of respirators whereas were in contrast to the outcomes of Shaw et al.[12] who did not find evidence of an effect of wearing a face mask on physiological responses (heart rate, arterial oxygen saturation), perception of effort (Borg's CR10) and performance (time to exhaustion and peak power). Fikenzer et al[11] recently found a detrimental effect on performance and pulmonary parameters during a cycling test to exhaustion while wearing FFP2/N95, but no effect of surgical mask was seen on these variables; however, heart rate at the end of the test was lowered wearing both surgical and FFP2/N95 mask compared to no-mask condition.

The reported decrement in performance could be related to an increase in RPE throughout the test [29]. Indeed, despite the similar HR responses among conditions, we found a rising trend in RPE Slopes wearing both SM and SRM, compared to CON (Table I). Analysing individual data, 10 subjects out of 17 and 12 out of 17 presented respectively higher $Slope_O$ and $Slope_B$ using SM compared to CON. This trend was more noticeable in the SRM condition, where 14 subjects out of 17 presented both slopes greater than CON. These considerations seemed confirmed by the tendency ($p = 0.065$) of higher peak blood lactate values in CON if compared to SM and SRM. Although the physiological responses do not seem to be affected by wearing a face mask, accordingly to the psychobiological model of endurance performance, an athlete who performs a high intensity exercise for a long time or to exhaustion might experience a larger decrease in exercise intensity or might stop due to an increase in RPE [30]. Furthermore, the same physiological responses (i.e. HR, [La]) linked to a higher RPE while wearing a face mask could represent an issue when coaches prescribe exercise intensity using RPE [31]. Practically, since the high intensity distance covered by players is considered a determinant factor of performance, and it is related to distance in YYIRT [24], an athlete who wears a face mask could experience a reduction in his specific high intensity performance, consequently leading to a potential impairment of the entire team's performance. Moreover, the prescription of the use of face masks might be required for a long period and in this scenario, athletes could be frequently exposed to a situation of altered perception, possibly impacting negatively on the chronic adaptations to training. Thus, further research is needed to clarify the long-term impact of wearing a face mask during sports activities.

**Limitations**

This study is not free of limitations. Unfortunately, since the practical and ecological nature of the study (i.e., field study), we were not able to assess other important physiological parameters (e.g., respiratory frequency, ventilation, gas exchange) which might have allowed us to better explain the physiological mechanisms that underpin our findings. Moreover, although HR and [La] data show the moderate nature of IT exercise, we are aware that individualized target exercise intensities could have been used to provide each subject with a similar internal load. Moreover, the participants involved in this study were healthy active adults (soccer players) and therefore these findings may not be directly generalizable to other less active populations (e.g., sedentary, clinical, or elderly populations) or to other sports activities.

## Conclusions

Regardless of exercise intensity (submaximal vs maximal) and device type (surgical vs sports mask), wearing a face mask during exercise mostly affects perceptual responses, causing an increase in the rate of perceived breathlessness and overall exertion, with limited influence on pulse oxygen saturation, blood lactate and heart rate responses. During progressive exercise conducted to exhaustion the increased perception of effort seems to lead to decreased performance. Both the increased perceived exertion and the reduced exercise capacity are two factors that must be considered when prescribing/practicing exercise while wearing a face mask. The long-term impact of wearing a face mask during daily training practice also deserves further investigation.

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***Conflicts of interest.*—**

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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***Authors' contributions.*—**

Roberto Modena contributed to the design of the study and development of the protocol, participated in the data collection and data reduction/analysis. Alessandro Fornasiero, Alexa Callovini, Aldo Savoldelli and Lorenzo Bortolan participated in the design of the study and development of the protocols, took part in the data collection. All authors took part in the results' interpretation and manuscript writing. All authors have reviewed and approved the final version of the manuscript and agree with the order of presentation of the authors.

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# TABLES

Table I.— Physiological and Perceptual outcomes at low-to-moderate intensity

| | Estimated mean (95% CI) | | | P value |
|---|---|---|---|---|
| | CON | SM | SRM | |
| ***Baseline*** | | | | |
| $SpO_2$ (%) | 97.2 (96.4, 98) | 97.3 (96.8, 97.9) | 96.6 (95.6, 97.5) | 0.252 |
| [La] (mmol/L) | 0.98 (0.84, 1.15) | 0.96 (0.8, 1.15) | 1 (0.87, 1.15) | 0.830 |
| TQR | 15.7 (14.6, 16.9) | 16 (14.9, 17.1) | 16 (15, 17.1) | 0.902 |
| VAS DOMS (mm) | 5.1 (3.1, 8.3) | 3.3 (2, 5.6) | 4.4 (2.6, 7.3) | 0.166 |
| ***WU1 (running at 8 km•h$^{-1}$)*** | | | | |
| $HR_{mean}$ (bpm) | 127 (121, 132) | 126 (120, 133) | 126 (119, 133) | 0.917 |
| $SpO_2$ (%) | 96.4 (95.1, 97.8) | 96.8 (96.2, 97.3) | 96.6 (95.8, 97.4) | 0.867 |
| [La] (mmol/L) | 1.32 (1.11, 1.58) | 1.39 (1.15, 1.68) | 1.38 (1.2, 1.59) | 0.617 |
| $RPE_O$ | 4.9 (3.3, 7.4) | 9.9 (7.9, 12.4) * | 6.1 (4, 9.2) | **0.024** |
| $RPE_B$ | 4.9 (3.1, 7.7) | 12.3 (9, 16.7) * | 9 (6.2, 13.2) * | **0.005** |
| ***WU2 (running at 10 km•h$^{-1}$)*** | | | | |
| $HR_{mean}$ (bpm) | 142 (136, 149) | 143 (136, 150) | 142 (135, 149) | 0.780 |
| $SpO_2$ (%) | 95.6 (94.2, 97.1) | 96.3 (95.7, 96.9) | 96.1 (95.2, 97) | 0.676 |
| [La] (mmol/L) | 1.57 (1.28, 1.93) | 1.66 (1.35, 2.05) | 1.63 (1.35, 1.95) | 0.482 |
| $RPE_O$ | 7.6 (5.1, 11.3) | 15.1 (12.8, 17.9) * | 11.4 (7.6, 17.3) * | **0.011** |
| $RPE_B$ | 8.3 (5.3, 12.9) | 18.7 (15.6, 22.3) * | 15.5 (10.2, 23.7) * | **0.004** |
| ***IT (8 x 20''/20'')*** | | | | |
| $HR_{mean}$ (bpm) | 153 (148, 159) | 154 (149, 161) | 154 (148, 160) | 0.822 |
| $SpO_2$ (%) | 96.1 (95.2, 97) | 95.6 (94.6, 96.5) | 95.7 (95, 96.4) | 0.547 |
| [La] (mmol/L) | 2.86 (2.34, 3.5) | 2.98 (2.44, 3.63) | 3.09 (2.56, 3.72) | 0.381 |
| $RPE_O$ | 19 (14.6, 24.7) | 27 (23.1, 31.7) | 22 (16.6, 29) | 0.072 |
| $RPE_B$ | 20 (15.1, 26.4) | 34.8 (30.9, 39.1) * | 30.5 (24.7, 37.6) * | 0.002 |
| ***YYIRT*** | | | | |
| Distance (m) | 1599 (1410, 1814) | 1431 (1221, 1678) # | 1386 (1189, 1615) # | **0.004** |
| $HR_{mean}$ (bpm) | 175 (171, 179) | 174 (170, 178) | 174 (169, 178) | 0.380 |
| $HR_{max}$ (bpm) | 189 (185, 193) | 189 (185, 193) | 188 (184, 193) | 0.888 |
| $HR_{<70\%}$ (%) | 2.6 (1.2, 3.9) | 3.5 (1.8, 5.2) | 2.8 (1.3, 4.3) | 0.420 |
| $HR_{70-75\%}$ (%) | 1.8 (1.3, 2.3) | 1.9 (1.4, 2.4) | 1.7 (1.3, 2.1) | 0.900 |
| $HR_{75-80\%}$ (%) | 3.1 (1.8, 4.5) | 2.6 (1.5, 3.6) | 2.7 (2, 3.5) | 0.747 |
| $HR_{80-85\%}$ (%) | 5.8 (4, 7.6) | 5.3 (3.8, 6.7) | 4.9 (3.5, 6.3) | 0.578 |
| $HR_{85-90\%}$ (%) | 9.9 (7.2, 12.6) | 9.9 (7.5, 12.2) | 11 (7.9, 14.1) | 0.766 |
| $HR_{90-95\%}$ (%) | 26.8 (21.1, 32.5) | 27.1 (20.3, 33.9) | 25.1 (21.1, 29) | 0.761 |
| $HR_{>95\%}$ (%) | 50 (39.5, 60.4) | 49.8 (38.8, 60.8) | 51.8 (44.1, 59.5) | 0.900 |
| $SpO_2$ (%) | 93.5 (92, 95.1) | 93.6 (92.6, 94.6) | 92.8 (91.7, 94) | 0.267 |
| [La] (mmol/L) | 8.63 (7.48, 9.95) | 7.84 (6.84, 9) | 7.82 (6.88, 8.88) | 0.065 |
| $RPE_O$ | 84.5 (75.2, 95) | 88.87 (80.27, 98.4) | 80.56 (70.2, 92.45) | 0.265 |
| $RPE_B$ | 89.3 (80.4, 99.3) | 93.6 (84.5, 103.8) | 94.4 (87.4, 101.9) | 0.118 |
| $Slope_O$ | 0.039 (0.031, 0.048) | 0.044 (0.037, 0.052) | 0.047 (0.038, 0.059) * | **0.046** |
| $Slope_B$ | 0.043 (0.036, 0.052) | 0.046 (0.039, 0.054) | 0.052 (0.042, 0.065) | 0.173 |

***Notes:*** * Greater than CON, # Lower than CON.

Abbreviations: $SpO_2$ = oxygen saturation; [La] = lactate concentration; TQR = Total quality recovery; VAS DOMS = visual analog scale for delayed onset muscular soreness; $HR_{mean}$ = average heart rate; $HR_{max}$ = maximal heart rate; $RPE_O$ = overall rate perceived of exertion; $RPE_B$ = breathlessness rate perceived of exertion; YYIRT = Yo-Yo Intermittent Recovery Test Level 1; $Slope_O$ = Slope of linear regression of overall RPE; $Slope_B$ = Slope of linear regression of breathlessness RPE

## TITLES OF FIGURES

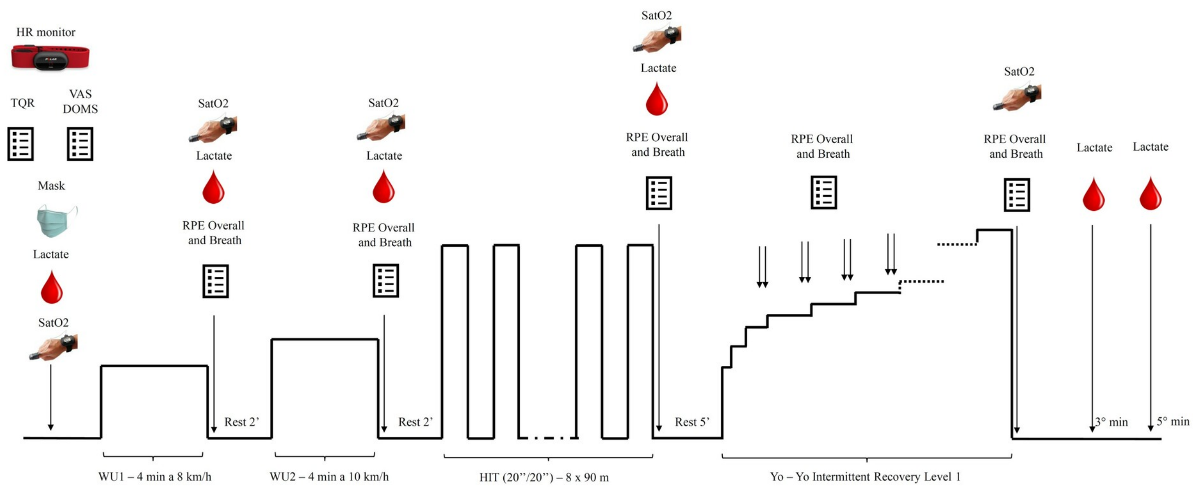
Figure 1 – Schematic representation of the protocol

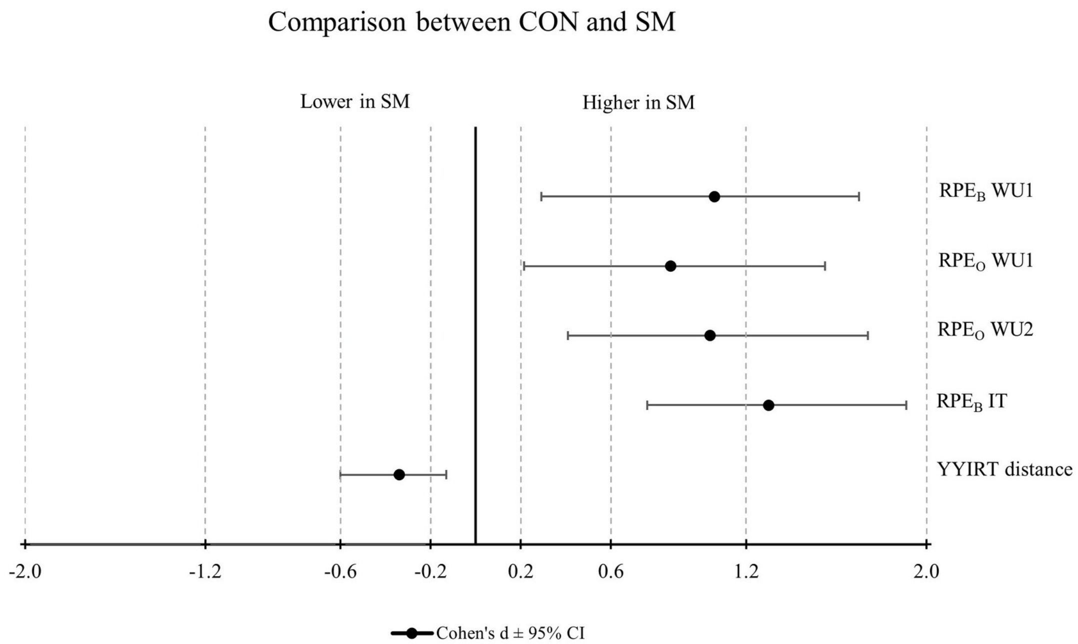
Figure 2 — *Pairwise comparison between CON and SM*

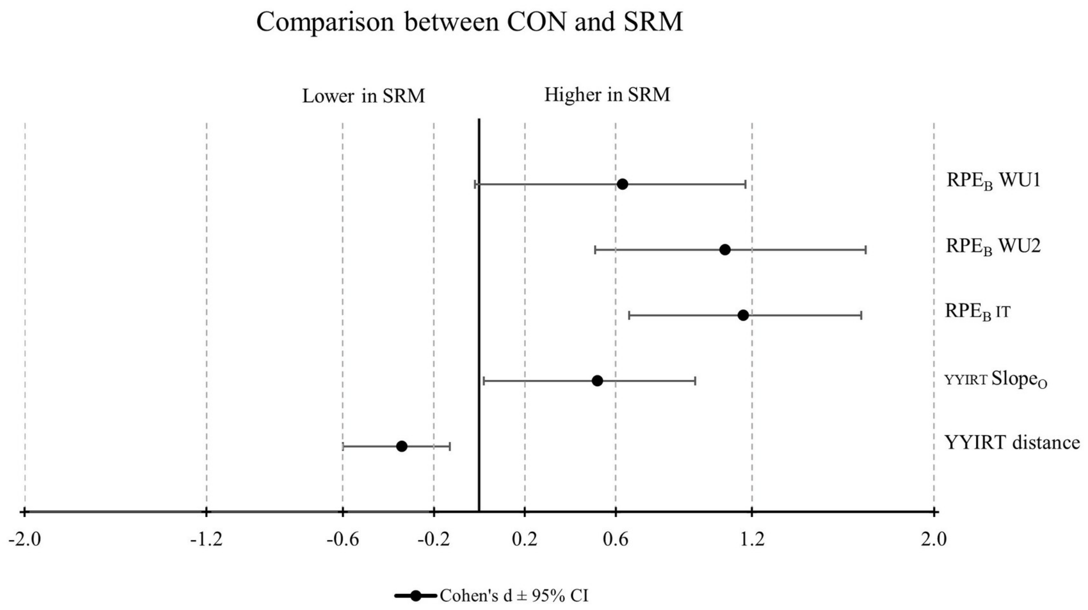
*Caption:* Hedges' g (filled circles) with 95% CI (error bars) for pairwise comparison between CON and SM conditions; lower values for SM condition below zero (left) and higher values for SM condition above zero (right). CON = control condition (no mask); SM = surgical mask condition; $RPE_B$ WU1 = breathlessness perceived exertion at the end of 8 km•h-1; $RPE_O$ WU1 = overall perceived exertion at the end of 8 km•h-1; $RPE_O$ WU2 = overall perceived exertion at the end of 10 km•h-1; $RPE_B$ IT = 8 bouts of 20 seconds at 16 km•h-1 with 20 seconds of recovery; YYIRT distance = distance covered during the Yo-Yo Intermittent Recovery Level 1.

Figure 3 — *Pairwise comparison between CON and SRM*

*Caption:* Hedges' g (filled circles) with 95% CI (error bars) for pairwise comparison between CON and SRM conditions; lower values for SM condition below zero (left) and higher values for SRM condition above zero (right). CON = control condition (no mask); SRM = sports-reusable mask condition; $RPE_B$ WU1 = breathlessness perceived exertion at the end of 8 km•h-1; $RPE_B$ WU2 = breathlessness perceived exertion at the end of 10 km•h-1; $RPE_B$ IT = 8 bouts of 20 seconds at 16 km•h-1 with 20 seconds of recovery; YYIRT $Slope_O$ = Slope of linear regression of overall RPE during the Yo-Yo Intermittent Recovery Level 1; YYIRT distance = distance covered during the Yo-Yo Intermittent Recovery Level 1.


HR monitor
TQR
VAS DOMS
Mask
Lactate
SatO2
SatO2
Lactate
RPE Overall and Breath
SatO2
Lactate
RPE Overall and Breath
SatO2
Lactate
RPE Overall and Breath
RPE Overall and Breath
SatO2
RPE Overall and Breath
Lactate
Lactate
Rest 2'
Rest 2'
Rest 5'
3° min
5° min
WU1 – 4 min a 8 km/h
WU2 – 4 min a 10 km/h
HIT (20''/20'') – 8 x 90 m
Yo – Yo Intermittent Recovery Level 1


Comparison between CON and SM
Lower in SM
Higher in SM
RPE$_B$ WU1
RPE$_O$ WU1
RPE$_O$ WU2
RPE$_B$ IT
YYIRT distance
-2.0
-1.2
-0.6
-0.2
0.2
0.6
1.2
2.0
Cohen's d ± 95% CI


Comparison between CON and SRM
Lower in SRM
Higher in SRM
RPEB WU1
RPEB WU2
RPEB IT
YYIRT SlopeO
YYIRT distance
-2.0
-1.2
-0.6
-0.2
0.2
0.6
1.2
2.0
Cohen's d ± 95% CI