The Physiological Effects of Face Masks During Exercise Worn Due to COVID-19: A Systematic Review

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Context: Use of facemasks in sport has been a particularly complex issue during the COVID-19 pandemic.

Objectives: A systematic review to examine the physiological effects the different types of masks have on healthy adults when doing physical exercise.

Data sources: PubMed, SPORTDiscus, Scopus, and Litcovid were searched up to March 20, 2021, following the PRISMA model. Articles published in the last 5 years with healthy adults.

Study Selection: A total of 633 studies related to the use of masks during physical exercise were found, of which 8 articles met the criteria to be included.

Study Design: Systematic review.

Level of Evidence: Level 2.

Data Extraction: The search process and the review of the articles were carried out by independent expert researchers. The risk of bias and the methodological quality of the different studies included in the systematic review were calculated following the Cochrane criteria using an adaptation for random cross-studies. Once the information was properly structured, the results were extracted, and the findings of the study analyzed.

Results: There were significant changes in the following physiological variables when engaging in physical exercise using masks: 25% in the heart rate and dyspnea, 37.5% in the rating of perceived exertion, 50% in the pulmonary variables, and 37.5% in discomfort. The oxygen saturation, blood pressure, systolic blood pressure, diastolic blood pressure, and the concentration of blood lactate did not present any significant effect in this study.

Conclusions: The usage of masks by a healthy adult population during the performance of physical exercise has shown minimal effects with regard to physiological, cardiorespiratory, and perceived responses. Some symptoms can be dyspnea, effort perceived, or discomfort, among others. These findings indicate that the use of masks is not harmful to individuals' health. It does not present any significant detrimental effect on physical performance or risk to their well-being. However, further experiments are required to corroborate the findings of this review.

Keywords: coronavirus; exercise; facemask; physical activity; physiology.

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In 2020, the World Health Organization (WHO) declared the outbreak of a Public Health Emergency of International Concern due to the virus SARS-CoV-2 (COVID-19).[8] This pandemic has so far been responsible for several million deaths globally. Owing to the rapid spread of the virus, governments were forced to take urgent measures with the goal or hope of delaying the spread and preventing further infection. Some of those basic rules for prevention included frequent hand washing, social distancing, and the use of facemasks. This issue affected people's lives all over the world.[10,54] The correct use of face masks has therefore attracted much interest and controversy. Differences in preventing infection between the various types of medical-quality masks were not made.[38]

Physical exercise and sport have played a key part in people's health, as well as the fight against the virus and the sedentary lifestyle generated by lockdowns.[30,31,40] Wearing a mask during any type of physical activity was obligatory, as well as during any social or recreational activity, with the exception of professional sports players. The reason behind this rule was that virus particles could be easily transmitted by any sort of respiratory droplets, especially indoors.[24,49]

There has been a shortage of studies published in the last few years, because the start the COVID-19 pandemic. They are based on the effects of different types of facemasks, differentiating between surgical masks, FFP2/N95, and cloth masks. Previous research had focused on special masks, not masks for general use.[19]

Use of facemasks caused controversy regarding the cardiopulmonary, respiratory, physiological, and perceived effects on healthy subjects engaging in exercise. Studies have been carried out showing safety, limited effects on health, reduced or no impact on performance in moderate to light exercise,[15,34,47] and even intense activity.[35] Other studies have reported clear changes and deterioration in the cardiopulmonary, respiratory, physiological, and perceived variables,[16,22,29,55] and even suggest adapting the intensity of the physical exercise or task undertaken.[16,55] These adjustments are not considered sufficiently significant to present a health risk, according to other authors, even at maximum output, though they do produce a reduction in performance.[29] They even state that prolonged use of a facemask could improve the muscle function of the respiratory system.[18]

We also examined studies carried out on children and youths[17,27] and on adults and the elderly with pathologies such as chronic obstructive pulmonary disease (COPD)[21,43] and sarcopenia.[39] Information about the cardiopulmonary, respiratory, physiological, and perceived effects of facemasks on healthy adults during exercise could be important for different groups of people, sportsmen and women, and professionals.[16]

The hypothesis raised here is based on the existence of relevant effects, which need to be looked at in context, in relation to the use of preventive masks when engaging in physical exercise. The main objective of this study was to analyze the cardiopulmonary, respiratory, physiological, and perceived effects of the use of the typical preventive facemasks for COVID-19 by healthy people during physical exercise. Consequently, this study will conduct a systematic review with the perspective of providing an appropriate directory of knowledge that allows the establishment of a practical application and improvement to the proposals of intervention in exercise, physical activity, and sport. In addition, it will be a reference for future research on this subject.

MATERIAL AND METHODS

The present study follows the guidelines of the PRISMA statement (Preferred Reporting Items for Systematic Reviews and Meta-Analyses[26,36]).

Eligibility Requirements/Criteria

The population under study was taken from articles studying subjects during physical exercise. The research sample was selected according to the following inclusion criteria: (a) empirical studies on the search terms, (b) studies published in the last 5 years, (c) those carried out on healthy subjects, (d) adults between 18 and 60 years old, and (e) N95/FFP2 masks, surgical masks, and cloth masks. The exclusion criteria were: (a) articles not published in English, (b) studies on training masks, (c) studies that did not examine the effect of facemasks during training, (d) studies on children, youths, and the elderly, (e) people with pathologies, and (f) people with pain or musculoskeletal injuries during the 6 months prior to the physical test.

Information Sources

The search for information for this systematic review was completed using an electronic search in the databases of PubMed, SPORTDiscus, Scopus, and Litcovid up to March 20, 2021, which included studies published in the last 5 years.

Search Strategy

This study conducted a systematic review of the scientific literature available. For the research, with the objective of analyzing the physiological impact of masks during physical exercise, combinations of MESH terms have been made, using the loose terms widely used in previous literature with the operators OR and AND. The research strategy was the following: *(mask OR facemask) AND (exercise OR physiology OR "physical activity") AND (COVID-19 OR coronavirus)*.

The studies chosen were no more than 5 years old. The studies were selected based on the title and abstract and then on further reading of the full article following the selection criteria. Finally, the articles were organized and each was assigned an identification number (Figure 1).

Selection Process

The studies were analyzed by 2 supervisors who examined each independently. First, the supervisors analyzed all citations and abstracts and then they analyzed the full articles. In this way, the articles are analyzed independently by both supervisors to ensure they meet the established criteria. The grade was

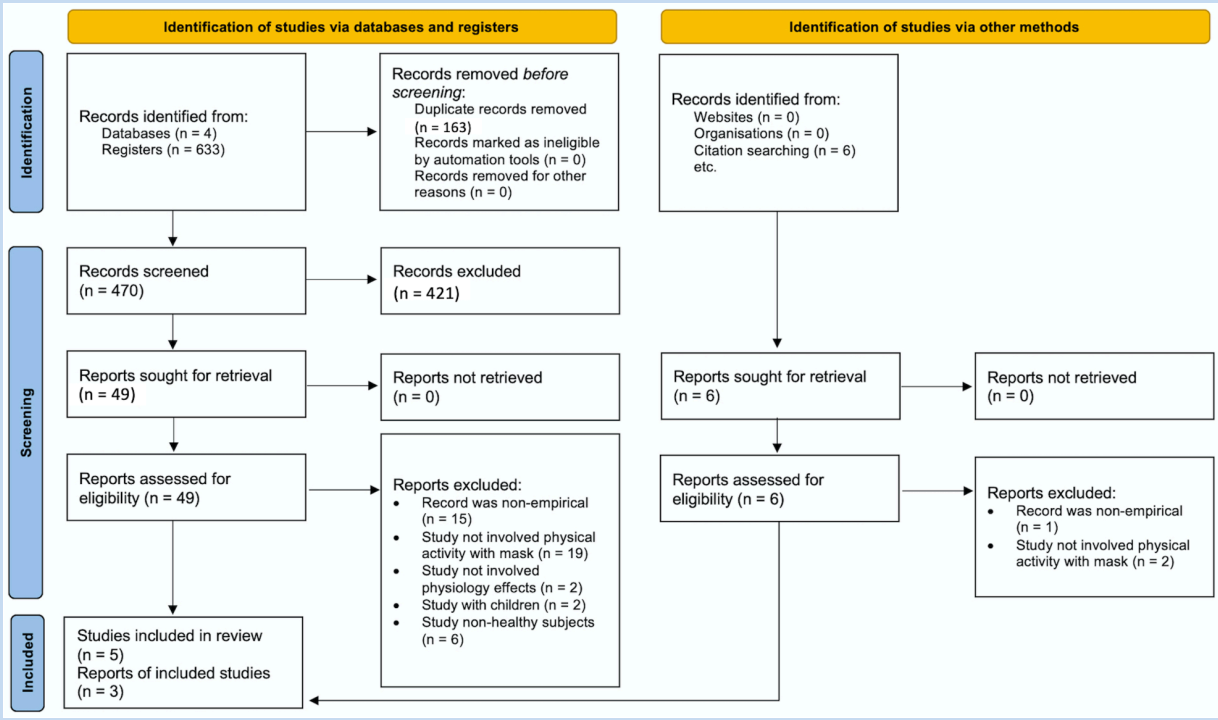

Figure 1. Flow chart of selection process of eligible studies for qualitative synthesis PRISMA 2020.[26,36]

checked by the researchers using the Cohen kappa coefficient, the result of concordance was $k = 0.94$. In addition, disagreements between the independent supervisors were resolved through a third senior supervisor.

Data Extraction and Synthesis

The information was structured by an expert supervisor in the field of databases: date of publication, authors, title, study design, data set size, participant characteristics (gender and age), health, protocol followed for physical exercise, time of measurements, types of masks used, physiological variables, and subjective perceptions. Once the information was properly structured, the results were extracted, and the findings of the study analyzed.

Risk of Bias and Criteria of Methodological Quality

The risk of bias and the methodological quality from the different studies included in the systematic review were calculated following the Cochrane criteria and using an adaptation for random cross-studies.[11] Two expert investigators reviewed this, resolving any differences through discussion. This time, the coefficient of concordance was $k = 0.90$.

RESULTS

Study Selection

After researching the different databases, a total of 633 studies related to the use of face masks during physical exercise were found. However, after identifying and deleting duplicates, a total of 470 studies remained. A total of 49 studies underwent a full text selection and, after applying the exclusion and inclusion criteria, 5 articles were finally chosen and included in the revision.[15,29,34,47,55] Furthermore, a total of 6 articles were identified using other methods from the citation search, out of which 3 were included in the review.[6,22,35] In total, 8 articles with 105 participants (79 men and 26 women) complied with our inclusion criteria. Five of the selected studies were random cross-studies,[15,16,22,29,47] one was a nonrandom cross-study,[34] another was an experimental essay,[35] and the last was a study with repeated measures.[55] The selection process is presented in the form of a flow chart (see Figure 1) and the summary of the studies selected is represented in Appendix Table A1 (available online).

Characteristics of the Participants

All participants in the studies selected in the systematic review were healthy subjects that did not present any health issues. Most of the studies used participants with an active life through regular physical exercise (6 out of 8). In 4 of the studies, subjects engaged in moderate to vigorous exercise several days a week.[15,22,47,55] In Mapelli et al,[29] the participants had an active lifestyle. Two of the studies were conducted with subjects working in a hospital. The participants in Fikenzer et al[16] subjects had a very active life, whereas in another study they did not exercise regularly.[35] The participants in Morris et al,[34] the participants were workers from different sectors. However, none of the studies specified the type of physical activity performed by the participants.[15,16,22,29,34,35,47,55]

Exposure Duration and Protocol Physical Activity

Five studies used a physical test of progressive intensity until exhaustion in a cycloergometer.[15,16,29,35,47] One of the studies used a treadmill with a 10% incline for 6 min at 4 km/h.[55] Another used a physical exercise test with a constant charge in a cycloergometer with a moderate to vigorous intensity for 30 min.[22] In the last study,[34] the participants completed 45 min of light exercise without specifying the protocol at 100 W (Appendix Table A1).

Type of Face Mask Used

Three of the studies used N95 and surgical masks.[15,16,29] Another 3 studies used only surgical masks.[22,35,55] Finally, the last study employed both surgical masks and cloth masks.[47] One of the other studies[34] used N95 masks (Appendix Table A1).

RELEVANT PHYSIOLOGICAL MEASURES

Heart Rate

Only 2 studies presented significant differences in the increase of the heart rate with the use of masks during physical exercise. In both studies the mask employed was of the surgical type.[22,55] It is worth indicating that 1 of the studies presents a high risk of bias, which implies that it may be inconclusive.[55] The other study is of better quality and relates to the increase of the heart rate with a greater respiratory or muscular effort during constant strength exercise wearing a mask[22].

Rating of Perceived Exertion

Six of the studies measured the effort perceived during physical exercise while wearing a mask. In 3 of the studies, the perception of effort while wearing a surgical mask[29,35,55] was increased significantly. Furthermore, in Mapelli et al,[29] N95 masks were also used, thus showing the increase of the variable concerning the effect produced by the surgical mask. The remaining 3 studies did not show any significant evidence.[15,22,47]

Dyspnea

Significant differences in the values of shortness of breath/dyspnea were found in 2 of the studies.[29,34] In Morris et al,[34] an increase in dyspnea while using the N95 mask during physical exercise was observed. However, this result is inconclusive given its high risk of bias. Nevertheless, Mapelli et al,[29] which has a low risk of bias, also showed the increase in dyspnea during physical exercise with N95 masks as well as surgical marks, therefore giving more significative results for N95 masks. The other 6 studies did not evaluate dyspnea.[15,16,22,35,47,55]

Pulmonary Function Parameters

Four of the studies with low risk of bias presented significant differences in some of the respiratory physiological measures while doing moderate to vigorous physical exercise using facemasks.[15,16,22,29] Epstein et al[15] showed an increase in end tidal caron dioxide ($EtCO_2$) while performing exercise with an N95 mask. Mapelli et al[29] also showed evidence of significant differences in the majority of the cardiovascular parameters that they measured oxygen uptake (VO2); carbon dioxide production (CO2); end-tidal oxygen pressure (PetO2); end-tidal carbon dioxide pressure (PetCO2); respiratory rate (RR); minute ventilation (VE); forced expiratory volume in 1 second (FEV1); forced vital capacity (FVC); inspiratory time (Ti); expiratory time (Te); , inspiratory + expiratory time (Ttot) and demonstrated that the use of N95 masks produces a greater effect in the reduction of pulmonary ventilation compared with the use of surgical masks. These differences were even greater in the study carried out by Fikenzer et al,[16] where the spirometry showed reduced values of VO_2max/kg, VE, VT, alveolar ventilation (VA), and breathing frequency. Finally, Lässing et al,[22] demonstrated that the use of surgical facemasks was associated with a significant increase of airways (VO_2, RR, Ti, CO_2, VE, and arteriovenous oxygen difference ($avDO_2$)). The other 4 studies did not show any significant evidence.[34,35,47,55]

Discomfort

Three of the studies[15,16,34] reviewed reported that wearing a face mask when engaging in physical activities produced a feeling of discomfort. In addition, Fikenzer et al[16] reported that the subjects experienced more discomfort when wearing an N95 mask than when wearing a surgical equivalent.

Variables with Insignificant Differences

Four of the studies from the review that measured the oxygen saturation (SpO_2) did not show any significant evidence of differences.[15,22,29,47] In addition, the tissue oxygenation index did not present any changes.[47] Four of the studies that measured blood pressure (BP), systolic blood pressure (SBP), and diastolic blood pressure (DBP) do not present any significant differences.[15,16,22,29] Finally, all the studies in which the blood lactate concentration was measured did not present any changes.[16,22]

Risk of Bias in Studies

The results for the evaluation of the risk of bias of the quality of the study are presented in the online appendix, Figures A1 and A2 (available online). Most of the studies presented a minimal risk of bias or a risk that is not clear cut. There is only 1 study that presents a greater risk of bias compared with the rest, given that it indicates the randomization of the study and presents criteria with a high risk of bias or 2 unclear criteria.[34] The blinding criteria presents a high risk of bias in 5 of the studies, and by failing to recognize this process there is a possibility it may affect the results.[15,22,34,35,55] In 4 of the studies, the data appear to be incomplete or unclear; in many of them it was difficult to analyze some aspects because of the lack of detailed information.[29,34,47,55] In some of the studies, it was considered that the lack of information could be related to other problems with different biases during the analysis of the study.[15,29,34,35,55] To clarify, 2 studies that presented a high risk of bias or unclearness were used in the systematic review due to the lack of empirical investigations (in terms of the use of face masks

during physical exercise) but also because of the relevant conclusions that could contribute to the systematic review.[34,55] Given that the majority of the studies were cross-essays (6 out of 8), a Cochrane scale has been employed for cross-essays adjusting it to the studies included in this systematic review.[11]

DISCUSSION

The main finding in this sample study shows that exercise can be performed in a safe and feasible way using N95 masks, surgical masks, and cloth masks without any significant effects on sports performance or health. However, evidence from the studies analyzed shows an impact on some physiological values. The use of surgical masks and N95 masks saw a slight increase in heart rates, rating of perceived exertion (RPE), cardiorespiratory parameters, end-expiratory carbon dioxide, and dyspnea.[15,16,22,29,34,35,55]

Despite the fact that these effects were statistically notable with regard to the heart rate in the studies reviewed, an increase of up to 5 beats per minute was all that was recorded.[22,55] In principle, this would not imply a health risk for the subjects and could be interpreted as the result of a greater respiratory effort due to the restricted ventilation caused by the mask. However, special attention should be paid to the behavior of the heart rate at the end of the exercise period because a slow recovery during the first minute after exercise could be related to a higher risk of cardiovascular mortality in asymptomatic individuals and cardiac patients.[1,9]

As far as the RPE is concerned, it will increase as the intensity of the training load increases.[33] In those studies in which an incremental test of training intensity was carried out, a marked increase was noted (2-4 phases/stages) in the perception of effort with surgical masks and N95 masks, the latter type had a greater impact.[29,35,55] Within the Borg scale, RPE went from a fairly strong perception to a highly strong perception.[4,5] Furthermore, the marked dyspnea values could be related to the high rates of perceived exertion, as the shortness of breath or subjective difficulty breathing raised the RPE levels. Warren et al[53] connected this dyspnea to an increased resistance in the airways and Kim et al[20] linked this result to a rise in facial temperature. Both studies confirmed the findings of our review.[29,34] However, the randomized study by Molgat-Seon et al[32] on healthy subjects performing exercise of moderate intensity with restricted ventilation concluded that there is no significant effect on the feeling of breathlessness under these conditions. Moreover, a recent study attributed severe dyspnea to the suction of the deformed mask, which was wet, and was more likely to happen when using surgical masks rather than the N95.[14] Person et al[37] did not link the increase in dyspnea to a physiological origin.

On the other hand, as far as the pulmonary parameters are concerned, the key finding of the study of Epstein et al[15] was the significant increase of $EtCO_2$ during moderate to vigorous exercise with an N95 mask, although the use of surgical masks causes this to a lesser extent, taking into consideration that it is more significant when exercise is intense. This result was reported in previous studies carried out on health care staff with N95 masks, who engaged in 1 h of walking, though they did not experience any notable physiological load. Levels of CO_2 and O_2 in the free space within the N95 mask were, respectively, significantly above and below the environmental standards of the workplace. Moreover, the researchers noted the possibility of finding an increased partial pressure of carbon dioxide (PCO_2), which was probably caused by the exhaled moisture retained by the mask.[41] The rise in the $EtCO_2$ levels could be connected to the expired air because this remains inside the mask and could lead to mild hypercapnia. This statement may mean that more effort is needed to get the air to pass through the mask, and this would result in an increased use of the respiratory muscles. In addition, reduced ventilation due to higher resistance to the airflow produced by the masks is also linked to notable effects, which worsen in N95 masks more than surgical masks, during increasingly intense exercise, in the respiratory values of VO_2, VCO_2, $PetO_2$, $PetCO_2$, VE, RR, FEV1, FVC, and Ti/Te/Ttot analyzed by Mapelli et al[29] and in the physiological values VO_2max, (maximum power output (Pmax), VE, tidal volume (VT), HR, and VA analyzed by Fikenzer et al.[16]

Lee and Wang[23] were the first to demonstrate quantitively and objectively the substantial deterioration in nasal airflow in relation to the resistance in the airways when using N95 masks in healthy humans. Their results showed an average increase of 126% and 122% in the resistance to inspiratory and expiratory flow, as well as an average 37% decrease in the volume of air exchange in the N95 masks. Lässing et al[22] discovered an increase in resistance in the airways (RR, Ti, CO_2, VE, and $avDO_2$) and a decreased level of oxygen with surgical masks during constant exercise. Regarding the type of mask used during exercise and its effects, Smith et al[51] in their review and meta-analysis concluded that significant differences between N95 masks and surgical masks did not exist with regard to risks associated with respiratory tract infection in health care workers. However, the N95 masks have less filter penetration and less leakage around the facial seal compared with the surgical masks, which may explain why the N95 masks have more significant physiological values during exercise compared with their surgical counterparts.[15,16,34] This finding coincides with previous studies where breathing resistance, heat, moisture, tension, and general discomfort are the elements that affect this subjective feeling.[6,25,28]

Oxygen saturation (SpO_2) does not exhibit any marked changes in any of the studies included in the review. Studies on health care workers during their working day using surgical masks and N95 masks for prolonged periods came to the same conclusion: the SpO_2 has a minimal impact and does not have any clinical relevance that should be taken into consideration.[45,52] The use of masks does not appear to markedly decrease the level of muscle oxygenation, which may be connected to sports performance, because, in all the studies reviewed, this is not affected. BP does not show any significant changes within the normal values of exposure to intense bouts of exercise.[15,16,22,29] Last, there is no significant variation in the lactate concentration in the blood when using masks for exercise.[16,22] Moreover, other studies also report this finding.[3]

After examining the use of facemasks when exercising in healthy adults, the results are then compared with other populations. Existing studies covering the use of facemasks in children are scarce; however, they all have the same conclusion, stating that the use of surgical masks and cloth masks do not significantly compromise ventilation and the supply of oxygen in children, making engaging in sports activities both safe and possible.[17,27,50]

In patients with COPD, a decline in physiological variables, in particular respiratory variables, is likely to be significantly higher than in healthy youths. Samannan et al[43] and Kyung et al[21] both concluded that an actual risk only existed for patients with severe COPD using N95 masks, whereas all other patients, despite having increased physiological values, could exercise safely. During a session of training resistance, patients with sarcopenia showed a strength performance and physiological responses similar to those obtained when doing the same exercise without facemasks.[39] Cano-Carrizal and Casanova-Rodríguez[7] and Barbeito-Caamaño et al[2] studied several adults with different conditions (COPD and coronary artery disease). They reported that the use of facemasks did not negatively affect the functional capacity of the patients, not even when performing a stress echocardiography or when carrying out the test with a facemask was feasible, thus avoiding the risk of infection. Finally, Shein et al[48] in their recent study of 50 adult volunteers, 32% of whom had some comorbid condition, documented that the risk of a pathological change in the exchange of gases when using cloth and surgical masks did not exist, or any other kind of physiological deficiency during walking with a facemask.

As far as our findings are concerned and bringing the current literature up to date, recent research has shown negative effects on the performance in exercise, physiological, and perceptual factors in healthy adults when performing a maximal treadmill test using a cloth mask.[13] However, Doherty et al[12] determined that the use of cloth and surgical masks in an increasing maximal test, with moderate intensity, has a minimal impact on cardiopulmonary responses and could only increase dyspnea in the short term. Schulte-Körne et al,[46] in their recent study of children in training, concluded that the use of surgical facemasks during intense aerobic activities affects neither the athletic activities nor the performance. It does, however, produce a significant reduction to the time needed and an increase in the subjective perception of effort. Throughout the analysis of all the literature examined for this study and in that of other authors,[42,44] it has been shown that the use of facemasks during maximal physical exercise, as opposed to other types of moderate or light exercise, should be taken into further consideration.

This systematic review has some additional limitations: (1) the effect of surgical and N95 masks during exercise was not tested on a large number of subjects and the majority were men; (2) a single study analyzed the cloth masks; (3) only the studies that used healthy adults as subjects were analyzed for this review; (4) the effect of mask wearing may vary according to the different physical activities performed in different environments; in most studies the intervention and measurement is carried out with a laboratory test or walk; (5) the incremental tests limit the transferability of the results to everyday resistance exercises; (6) the lack of literature found on the subject; and (7) the effects of the different types of masks are not examined in all the studies.

Future studies should address how the exercise protocol itself, or the same physical test with different facemask, affects different groups (children, adolescent, healthy adults, sedentary groups, adults in training, individuals with medical conditions, etc.) in order to allow a comparison between the different effects caused. In addition, it would be valuable if studies measured the different physiological variables using all the different types of facemasks (cloth, surgical, and N95) to allow more specific conclusions to be drawn. In addition, further studies should be carried out using a larger sample of subjects including all age ranges where the percentage of men and women is more equal, as well as using different training programs to allow us to study the effects according to the type of exercise, activity, and intensity.

CONCLUSION

In conclusion, the use of facemasks by the healthy adult population when engaging in physical exercise only shows minimal effects on the physiological cardiorespiratory responses, and those perceived, the feeling of breathlessness/dyspnea, perceived exertion, and discomfort, do not pose a high risk for doing exercise and furthermore does not have a negative effect on sporting performance or on one's health. As far as global transmission is concerned, new variants of COVID-19 are inevitable and it is still too soon to draw any conclusions about a possible increase in transmissibility; therefore, public health recommendations should be followed in each country, according to their individual situation, when engaging in regular daily exercise to improve general health, reduce stress levels, anxiety, and to minimize the risk of developing different diseases and to improve immune response and protection against COVID-19.

PRACTICAL APPLICATIONS

- In line with the experimental studies done on healthy adults wearing facial masks while performing physical exercise, the practice of physical exercise is possible and safe without affecting the individual's performance or health. However, coaches should adjust exercises that require higher intensity while wearing facemasks, given that in these types of exercises there has been evidence of a significant impact on the physiological response.
- Even though the heart rate, respiratory parameters, and the final respiratory carbon dioxide level can increase during a moderate practice of exercise while wearing a mask, it can only ever cause discomfort, dyspnea, or a higher perception of effort. As professionals in this sector, we must consider these effects, but we should consider that in most cases it presents a minimal risk to the individual's health.

- There is a lack of studies on the topic of face mask usage and its consequences throughout various types of exercises. Future investigations should increase the sample size and provide a more in-depth analysis of the type of exercise conducted. They should also include all the different types of facemasks and compare them while doing the same exercise across different population groups with the aim to be more specific in the findings about the use of facemasks in the physical exercise sector.

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