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Effect of a Facemask on Heart Rate, Oxygen Saturation, and Rate of Perceived Exertion

Auswirkung einer Mund-Nasen-Bedeckung auf Herzfrequenz, Sauerstoffsättigung und subjektives Belastungsempfinden

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Summary

- **The outbreak of the COVID-19 pandemic** has led to severe restrictions and strict behavioral rules for daily life. To minimize the risk of infection, the wearing of facemasks is recommended in public areas, as well as in sports. Many people find this annoying or obstructive.
- **The purpose of this study** was to investigate the physiological effects of wearing a facemask during endurance exercise. A total of 16 male and 22 female subjects each completed two endurance runs of 15 minutes each, once with and once without a facemask, at the same speed. Heart rate and oxygen saturation were measured at the beginning and at the end of the two efforts and a classification of perceived exertion according to Borg was performed.
- **Heart rate and Borg classification** were significantly higher at the end of the exercise with mask (HR without mask: 151.4 ± 17.7 bpm; HR with mask: 156.4 ± 17.4 bpm; $p = 0.009$; Borg with mask: 12.9 ± 1.8; Borg without mask: 14.9 ± 1.6; $p < 0.001$). In contrast, the oxygen saturation shows no significant difference (SaO_2 without mask: 96.9 ± 1.4 %; SaO_2 with mask: 96.9 ± 1.3%; $p = 0.814$).
- **The results suggest** that wearing a facemask during steady-state exercise primarily has a negative effect on the subjective perception of exertion, and slightly on the heart rate. Despite the mask, however, the body is able to ensure uniform oxygen saturation in the blood.

Zusammenfassung

- **Der Ausbruch der COVID-19 Pandemie** hat zu starken Einschränkungen und strengen Verhaltensregeln für das tägliche Leben geführt. Um die Ansteckungsgefahr möglichst niedrig zu halten, wird das Tragen einer Gesichtsmaske in öffentlichen Bereichen, aber auch im Sport empfohlen. Viele Menschen empfinden dies als störend oder hinderlich.
- **Ziel dieser Studie** war es, die physiologischen Auswirkungen des Tragens einer Gesichtsmaske während einer aeroben Ausdauerbelastung zu untersuchen. Insgesamt absolvierten 16 männliche und 22 weibliche Testpersonen je zwei Ausdauerläufe bei gleicher Geschwindigkeit über jeweils 15 min, einmal mit und einmal ohne Gesichtsmaske. Zu Beginn und am Ende der beiden Belastungen wurden Herzfrequenz und Sauerstoffsättigung gemessen und eine Einstufung des subjektiven Belastungsempfindens nach Borg vorgenommen.
- **Die Herzfrequenz und die Einstufung** nach Borg waren am Ende der Belastung mit Maske signifikant höher (Hf ohne Maske: 151,4 ± 17,7 Schläge/min; Hf mit Maske: 156,4 ± 17,4 Schläge/min; $p = 0{,}009$; Borg mit Maske: 12,9 ± 1,8; Borg ohne Maske:14,9 ± 1,6; $p < 0{,}001$), die Sauerstoffsättigung blieb unverändert (SO_2 ohne Maske: 96,9 ± 1,4 %; SO_2 mit Maske: 96,9 ± 1,3 %; $p = 0{,}81$).
- **Die Ergebnisse lassen darauf schließen**, dass sich das Tragen einer Gesichtsmaske während einer gleichmäßigen Dauerbelastung vor allem negativ auf das subjektive Belastungsempfinden auswirkt, geringfügig auch auf die Herzfrequenz. Trotz Maske kann der Körper aber eine gleichmäßige Sauerstoffsättigung im Blut sicherstellen.

KEY WORDS:
Mouth-Nose-Covering, Perception of Exertion, COVID-19 Pandemic, Respiration

SCHLÜSSELWÖRTER:
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Introduction

Since the World Health Organization (WHO) declared the COVID-19 outbreak a global pandemic on March 11, 2020, most countries have been trying to limit its further spread through appropriate regulations. According to Robert-Koch-Institut (18) the primary transmission pathway for SARS-CoV-2 pathogens is inhalation of aerosols, i.e. virus-containing particles produced during breathing, coughing, speaking, singing and sneezing. When exhaling and speaking, very small particles, the aerosols, are expelled. These can remain suspended in the air for a long time and distribute themselves in closed rooms. Coughing and sneezing produce larger droplets that typically cannot traverse more than two meters and remain in the air for a limited time. Therefore, there is an increased risk of infection within a 1-2 m radius around an infected person (14).

Table 1

Anthropometric data of the participants.

ANTHROPOMETRIC DATA	N	AGE [YEARS]	HIGHT [CM]	WEIGHT [KG]
Male	16	22.9 ± 2.6	184.5 ± 3.8	80.0 ± 6.9
Female	22	22.6 ± 1.3	169.2 ± 5.1	61.2 ± 5.3

Table 2

Results for HR, SaO_2 and RPE at the end of exercise, and HR-increase from the beginning to the end of the load, each with and without facemask (mean and standard deviation).

PARTICIPANTS	N	HEART RATE AT THE END OF EXERCISE [BPM]	HEART RATE INCREASE [BPM]	O_2-SATURATION AT THE END OF EXERCISE [%]	RPE
Without mask	38	151.4 ± 17.7	72.7 ± 15.8	96.9 ± 1.4	12.9 ± 1.8
With mask	38	156.4 ± 17.4	79.3 ± 16.6	96.9 ± 1.3	14.9 ± 1.6

SARS-CoV-2 pathogens remain viable and replicable in droplets and aerosols which is problematic in confined room situations with little or no ambient air exchange, or in close contact situations (15).

Therefore, a mandatory use of facemasks in social situations has been established in order to minimize the dispersion of droplets. Surgical masks and N95 respirators are considered to be particularly effective to avoid dispersion of pathogens. However, simple cloth masks have also proven to be effective in significantly reducing the amount of particles emitted via droplets (7, 8, 10). Therefore, a minimum distance of 1.5 m between people and wearing a facemask is considered to be the most important precautions in social situations to avoid further transmission of the pathogens.

Thus, the regulation on mandatory covering of nose and mouth in social situations also applies to the sport context. Here, many people perceive wearing a facemask to be uncomfortable or restrictive during physical exertion which might discourage people from engaging in physical activities. On top, the lockdown of public life itself already leads to a reduced physical activity level and a lack of exercise. Which, in turn, can have a massive impact on the health of individuals. Reduced physical activity increases the risk of most chronic diseases like obesity, cardiovascular disease, diabetes, stroke, depression and other chronic conditions (3). To avoid these long-term impairments, it is imperative to continue encouraging people exercise, even if wearing a facemask during exercise is inevitable.

In order to analyze any potential negative effects of wearing a facemask during physical exertion, three parameters will be assessed in this study: I) The subjective and II) the objective exercise intensity and III) the oxygen supply to the blood.

Although the topic has repeatedly been discussed in public, there is still a lack of scientific research to date. Therefore, the aim of this study is to provide scientific evidence to rule out potential negative effects of wearing a facemask during continuous endurance exercise on the physiological parameters of oxygen saturation (SaO_2), heart rate (HR) and the rate of perceived exertion (RPE).

Methods

Subjects

In the study, 38 sports students volunteered to participate, 16 men and 22 women. Among these, 6 were endurance athletes, 4 strength athletes, and 12 participated in various team sports. 16 participants did not report one specific main sport, but participated in many kinds of sport. At the time of testing, all subjects regularly participated in sport activities and had no current medical conditions, especially no acute respiratory diseases. The anthropometric data can be found in Table 1. The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethical Committee of the Medical Faculty, Technical University of Munich (reference number 53/21 S).

Running Course

All subjects completed two 15-minute endurance runs at a constant speed, one run with and one without covering mouth and nose. The guideline for the test was to run the same course twice at a possible high speed. However, the average running speed had to be the same for both runs, even with perceived impairments from the mask. In addition, care was taken to ensure that the same general conditions prevailed, such as wind, temperature or preload. The required running time was noted. The order of the two runs was randomly assigned by lot. The interval between the two runs was a least 1 hour and a maximum of 4 days.

Face Masks

Participants used either a surgical paper mask according to the standard DIN EN 14683 or a cloth facemask such as the "Face Cover" by Adidas.

Parameters

For the objective observation of the physiological load intensity, the HR is suitable measurand. HR increases with increasing intensity, with the HR-performance-curve flattening out at very high intensities. In the range of intensities of an endurance run, as in this study, the curve rises continuously. A pulse oximeter is used to assess the oxygen supply in arterial blood. SaO_2 is an indicator for the oxygen supply and the loading of hemoglobin with oxygen. In order to determine RPE, the Borg Scale from 6 (minimal effort) to 20 (maximal effort) is recommended (4).

For each run the parameters SaO_2, HR and the RPE were recorded. Arterial oxygen saturation was measured using a battery-operated pulse oximeter from the pulox company, directly before and after exercise. HR was recorded simultaneously with the pulse oximeter and was additionally measured manually at the carotid artery for reference. In any case of discrepancies between the results of the two methods, the measurement was

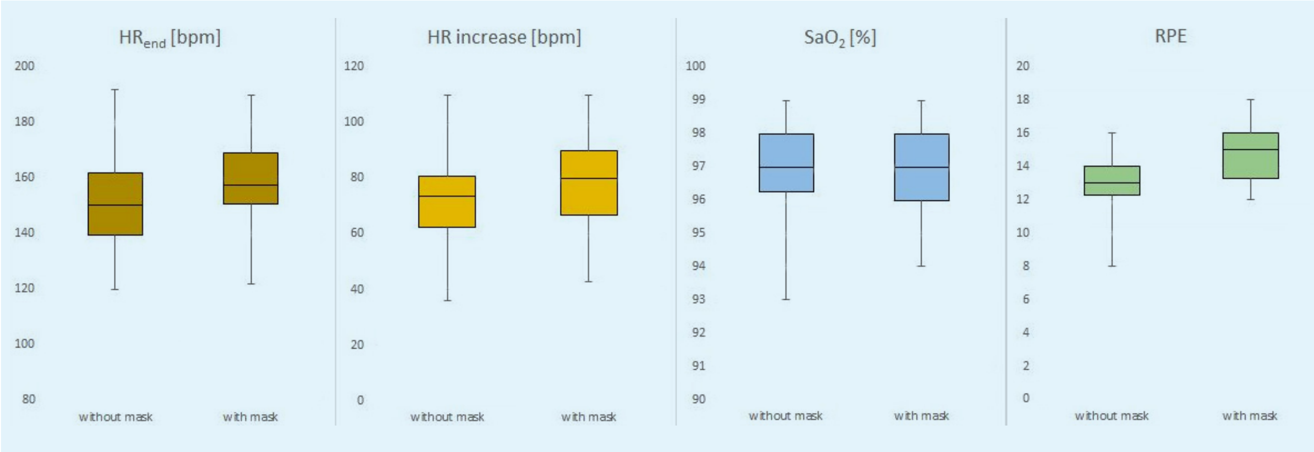

Figure 1

Boxplot of the differences between runs with and without mask for the parameters HR, HR increase, SaO_2, and RPE.

repeated immediately. HR was measured before the exercise, during minute 10 of the exercise, directly after the run, and furthermore in minute 1, 5 and 10 post exercise. Additionally, to account for the fact that some individuals have a naturally higher HR, the heart rate increase (HR increase) during the run was calculated from the difference between post exercise HR values and baseline HR before exercise. Finally, all participants rated their degree of subjective exertion using the Borg scale chart.

Statistical Operations

Descriptive statistics (mean ± standarddeviation) were performed on the participants' characteristics. Kolmogorov-Smirnov test was applied to guarantee for normal distribution of data. To compare variables HR, HR increase, SaO_2, and RPE in the conditions with and without facemask the paired t-test was performed. Differences between surgical and cloth facemask were analysed using the unpaired t-test. For all analyses, the α-error was set at 5 %. The effect size was interpreted according to Cohen (9) with $|d| > 0.2$ small effect, $|d|>0.5$ medium effect, and $|d| > 0.8$ large effect.

Data analysis was performed using the Statistical Package for the Social Sciences (IBM SPSS Statistics for Windows, version 26.0: IBM Corp) and Microsoft Excel (Microsoft Office Professional Plus 2016).

Results

All 38 athletes performed both runs and met the specifications mentioned above. In average, the time between the two runs was 24 hours. 14 of the athletes wore a surgical mask, 24 a cloth facemask. The mean run time was 15.3 ± 1 min, with the first and second run time differing by 0.45 ± 2.5 min on average for each subject. Running intensity, expressed through measured heart rate, ranged from 120 to 192 bpm. Within a run, each athlete was able to maintain a constant intensity. The difference between HR in the 10th min of exercise (151.6 ± 23.2 bpm) and at the end of exercise (153.9 ± 17.6 bpm) was 2.3 ± 15 bpm on average.

From the beginning to the end of the run, SaO_2 decreased slightly, both with (97.6 ± 2.1 % to 96.9 ± 1.3%) and without the mask (97.4 ± 2.9 % to 96.9 ± 1.4 %). A data summary on HR, HR increase, SaO_2, and RPE each with and without mask is presented as mean and standard deviation in Table 2. In addition, the results are visualized in Figure 1.

Wearing a facemask resulted in significantly higher HR values at the end of the run compared to the values of running without a facemask ($t=2.69$, $p=0.009$) and also a significantly higher HR increase ($t=2.50$, $p=0.014$). Likewise, there was a significantly higher Borg classification after exposure to running with a facemask ($t=6.78$, $p < 0.001$). The data on oxygen saturation revealed no significant difference between running with and without a mask ($t=-0.24$, $p=0.814$).

In order to additionally estimate a possible influence of the type of mask, the results were analyzed separately for both types, even though the sample size is very small. This comparison did not reveal any significant differences, all t-values < 1.2 and all p-values > 0.13. The corresponding mean values with standard deviations are summarized in Table 3.

Discussion

Regular exercise of physical endurance is the basis for a healthy lifestyle. Especially during the COVID19 pandemic, people should pay attention to strengthening their immune system and maintaining an intact respiratory and cardiovascular function. Aerobic forms of exercise are particularly suitable for this purpose. The present study shows that endurance training is also possible wearing a facemask. The HR values achieved at the end of exercise between 120 and 192 bpm indicate medium to high exercise intensities. The small difference between the HR in the 10th minute of exercise and the HR at the end of the run supports that the students ran at almost constant speed within a run.

The comparison of the RPE ratings on the Borg scale between wearing a mask and without mask shows that wearing a facemask has a significant influence on the subjective perception of exertion. The values on the scale increased by 2 points from 13 to 15, which corresponds to an increase in intensity from "somewhat hard" to "hard". All runners except one participant perceived the run with facemask as more strenuous.

HR is a suitable parameter for the objective determination of a load intensity. Particularly at medium load intensities, it provides reliable information about the physiological stress on the body. During the run with facemask, the HR was slightly over 5 bpm higher than during the run without facemask. In addition, the significantly higher HR increase of more than 6 bpm during the run with mask is proof for the increased physiological effort. An increase in HR of 5 bpm can be the decisive factor in an individual athlete's inability to sustain a given load intensity. If an athlete is just within the range of the lactate steady state, i.e. the balance between lactate production ›

Table 3

Results for HR, SaO2, RPE at the end of exercise, and HR increase from the beginning to the end of the exercise each with surgical mask and with cloth facemask (mean and standard deviation).

PARTICIPANTS	N	HEART RATE AT THE END OF EXERCISE [BPM]	HEART RATE INCREASE [BPM]	O_2-SATURATION AT THE END OF EXERCISE [%]	RPE
Surgical mask	14	155.5 ± 17.1	83.5 ± 15.4	96.9 ± 1.1	15.3 ± 1.6
Cloth facemask	24	157.0 ± 18.0	82.8 ± 25.6	97.0 ± 1.5	14.6 ± 1.5

and lactate utilization in the body, a minimal increase can lead to an excessive rise in the lactate level and the exercise must be stopped. This limit is very individual, but it is within the range of the load intensities at hand. Thus, if a certain intensity is required during aerobic endurance exercise, the target HR should be adjusted downwards when wearing a facemask. In the present study, it did not matter whether the students chose to run in the medium (HR 120 to 150 bpm) or high intensity range (HR > 150 bpm) as the increase in HR when running with mask was evident to the same extent in both intensity ranges. These findings are consistent with the results of Wong et al. (22) where the HR during 6-min graded treadmill walking in 23 subjects with mask (128,4 ± 13,2 bpm) was significantly higher than without mask (124,4 ± 12,8).

During the continuous endurance exercise performed, no effect on the oxygen saturation in the arterial blood was observed. In terms of breathing, the body seems to adapt to ensure oxygen supply even when wearing a mask. SaO_2 in arterial blood is usually in the range of 94 to 98 % (20). It depends on the partial pressure of oxygen. At a normal arterial partial pressure of 100 mmHg, SaO_2 is 97 %. Thus, SaO_2 is affected by the amount of oxygen and the amount of hemoglobin (16). For the participants in this study, the values for SaO_2 varied between 89 and 99 %. The mean values before and after exercise differ by only 0.5 %. The difference between with and without mask is also not significant and is only 0.1%.

From this study, conclusions can only be drawn on constant aerobic load intensities of young and healthy people. People with a pre-existing condition could be much more affected by wearing a facemask (19). Furthermore, it is conceivable that wearing a facemask at high to very high intensities, such as those found in game sports, has a different effect on the physiological load. Fikenzer (12) found a negative influence of medical masks on cardiopulmonary capacity and also on subjective perception during a step test on a bicycle ergometer. In the study by Epstein et al. (11) however, there were no statistically significant changes in HR, SaO_2, and time to exhaustion using a cycle ergometry ramp protocol. At low exercise intensities, wearing a facemask appears to have even less effect on physiological parameters. Person et al. (17) and Chen et al. (6) investigated the effect of wearing a mask during a short-term walking exercise. Both found that wearing a facemask was associated with increased respiratory muscle effort. In contrast, no differences were found in other parameters, such as HR. A limitation of this study is the inconsistent use of mask type. At the time of implementation of the study, there were no uniform guidelines for wearing an FFP2 mask. Thus, no conclusions can be drawn about the effect of a specific mask type.

Even though the WHO (21) advises against wearing a mask during exercise, this may be necessary due to an increased risk of infection. However, this should by no means lead to a renunciation of sporting activity, instead the load intensity of the exercise should be adjusted. Even in sports halls or fitness studios, endurance training with a mask would be conceivable, although the running or movement speed should be reduced slightly. Shurlock et al. (19) also recommends wearing a mask for indoor exercise. For outdoor training, it is recommended to train without mask, especially for sports where physical distancing is possible and transmission is less likely (19). However, when running or cycling, it should be noted that pathogens spread further behind the person than when standing. Some studies show that when moving at about 4 km/h, small droplets can spread up to 5 m, and at a speed of 14.4 km/h, even 10 m (2). Thus, when training in a group, wearing a facemask could also be important outdoors.

Especially in times when the body is exposed to higher health risks, people should keep fit in order to get through an infection with as few complications as possible. Therefore, it is important to preserve physical performance and organ functions (1). Regular physical activity is considered a protective factor for maintaining physical and mental health (13). Sports training has a positive effect on the immune system. Sport is a temporary stress, which is a kind of training for the immune system. Through this training, the immune system is being stimulated which helps in responding better to new requirements (5). Therefore, sport is necessary! Precisely for health reasons sport can and should be performed even with a facemask.

Conflict of Interest
The authors have no conflict of interest.

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