Wearing face masks during physical activity and selected circulatory and respiratory parameters – a clinical study

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Abstract

Background: Due the COVID-19 pandemic, covering the nose and mouth became mandatory in the light of the epidemiological crisis of the spread of SARS-CoV-2. There are many of doubts in the society regarding the health aspects of long-term wear of protective face masks and their effectiveness in limiting the transmission of the pathogen.

Aims: Assessment of the relationship between wearing face masks and changes in saturation (Sp02), heart rate (HR), and blood pressure (BP), induced by physical activity. Analysis of whether the subjective assessment of exercise intensity is consistent with measured levels of saturation, heart rate and blood pressure.

Material and methods: The study was conducted on 31 healthy adults (16 of these being men) aged 19-67 years. Participants completed the research questionnaire and were subjected to two exercise tests on an ergometer. Only in the first trial a surgical masks were worn. After each trial, breathing quality and fatigue were assessed, and HR, BP and SpO2 were recorded.

Results: The use of face masks during physical activity in healthy participants did not generate clinically significant changes in SpO2, HR, or BP compared to physical activity without the use of face masks. Deterioration in the experience of breathing during physical activity while wearing a face mask is not correlated with changes in the values of SpO2, HR, or BP.

Conclusions: Physical activity while wearing face masks lowers the level of saturation and increases blood pressure, and heart rate when compared to exercising without face masks. The differences, however, are minimal and should not negatively affect patients' health, thus wearing face masks during exercise is considered safe. The subjectively perceived feelings of dyspnea do not result from changes in the examined parameters.

Key words

dyspnoea, saturation, physical effort, COVID-19, face masks

Introduction

In November 2019, information was circulated around the globe about cases of pneumonia of unknown etiology in the Chinese city of Wuhan. It was soon noted that the pathogen responsible for the disease later referred to as the Coronavirus Disease 2019 (COVID-19) was the so far unknown virus SARS-CoV-2. With the spread of COVID-19 and the simultaneous attempts to prevent and limit the transmission of SARS-CoV-2, people's daily lives have changed. Some of the methods of preventing transmission of infections were the WHO recommendations, such as keeping appropriate social distance, isolating people with symptoms indicative of infection, or wearing face masks [1]. In many countries, including Poland, wearing protective face masks became legally regulated. Covering the nose and mouth became mandatory in the light of the epidemiological crisis of the spread of SARS-CoV-2 [2].

The number of conflicting opinions of World Health Organization (WHO) or Centres for Disease Control and Prevention (CDC), and independent scientists, the omnipresence of fake news and the subjective beliefs of mask users raised significant doubts in the society regarding the health aspects of long-term wear of protective face masks and their effectiveness in limiting the transmission of the pathogen [3]. Considering the fact that physiotherapists work not only with relatively healthy individuals with musculoskeletal disorders, but also those with a number of other co-morbid diseases, the concern of physiotherapists about the safety of the use of face masks by patients appeared to be justified.

Aims

The aim of this study was the assessment of the relationship between wearing face masks and selected circulatory and respiratory parameters, such as saturation (SpO2), heart rate (HR), and blood pressure (BP), induced by moderate physical activity. In addition, this study also aimed to analyse whether the subjective assessment of exercise intensity translated into physical parameters, such as saturation, blood pressure, and the number of heart beats per minute.

Material and methods

The study was involved 31 participants between the ages of 19-67 years (M=42.90, SD=13.60) which included 16 males (mean age M=41.88, SD=13.60) and 15 females (mean age M=44, SD= 13.14). In order to ensure the reliability of the results obtained, people with asthma, chronic obstructive pulmonary disease (COPD), hypertension, atrial fibrillation, pneumoconiosis, cystic fibrosis, or severe obesity (BMI > 30) were excluded from the study. The examination was carried out in a bright room with constant artificial lighting to minimise the risk of saturation measurement error and, for the same reason, due to variations in daily blood pressure and heart rate, both tests were performed at the same time of the day for a given subject.

Statistical analysis was performed using Microsoft Excel, where a database was also prepared. Mean values with standard deviation and, in key cases, minimum and maximum values were used to compare results across variables. Pearson's linear correlation coefficient was used to compare the data. The criterion for significance was $p<0.05$.

The participants were exposed to physical exercise in the form of a 6-minute ride on a Kettler model DX1 ergometer using 50 watts as the power unit size. It was reported that the subjects reached a speed that was considered moderate, always around 20 km/h. A total of four measurements of saturation, heart rate, and blood pressure were taken for each subject. There were two measurements in each trial – with a protective mask (WM) and without a protective mask (NM). The first measurement was taken before exercise and the second immediately after 6 minutes of cycling on the ergometer. The first trial was conducted using First® disposable surgical masks of GB/T 32610-2016 standard. A second trial was conducted the following day, at the same time without the protective surgical mask. To measure the saturation, a CE 0123-certified pulse oximeter was used, model: FS20C. Blood pressure and heart rate were measured using a DIAGNOSTIC® electronic manometer, model: DM-300 IHB.

Results

The mean SpO2 value in the measurement before the trial with a mask was 98.0% (SD=1.05). After the trial with a protective mask, mean SpO2 was 97.8% (SD=1.09). The same values in the test without mask were respectively 98.2% (SD=0.79) and 98.3% (SD=0.84). A 0.2% (p=0.6) decrease in saturation was observed in the trial with a protective mask, while in the trial without it, the result increased by 0.1% (p=0.0001) (**Table 1**).

The mean heart rate values (**Table 2**) in the protective mask test were 74.8 bpm (SD=6.91) in the measurement before and 79.9 bpm (SD=9.31) after the test. In the trial without a mask, these values were 73.6 bpm (SD=9.78) and 75.7 bpm (SD=10.29). There was a 5.1 bpm (p=0.0001) increase in heart rate between measurements with the protective mask on when compared to a 2.1 bpm (p=0.0001) difference in the trial without the mask.

Mean blood pressure values (**Table 3**) were higher in the trial with a mask in both measurements than in the trial without a protective mask. The mean blood pressure for both measurements in the trial with a mask increased by 4.1 (p=0.0003) for systolic blood pressure, while it decreased by 0.8 (p=0.00001) for diastolic blood pressure. The same trends were observed for the trial without a mask. With systolic blood pressure increasing by 2.8 mmHg (p=0.00002) and diastolic blood pressure decreasing by 0.7 mmHg (p=0.00001).

Table 1. Saturation (SpO2) values of the entire study group in each measurement.

Values	SpO2 before ZM [%]	SpO2 after ZM [%]	SpO2 before BM [%]	SpO2 after BM [%]
Mean	98.0	97.8	98.2	98.3
Standard Deviation	1.05	1.09	0.79	0.84
Minimum	95.0	95.0	96.0	95.0
Maximum	99.0	99.0	99.0	99.0

Abbreviations: *ZM, with mask; BM, without mask.*

Table 2. Heart rate (HR) values of the entire study group in each measurement.

Values	HR before ZM [bpm]	HR after ZM [bpm]	HR before BM [bpm]	HR after BM [bpm]
Mean	74.81	79.9	73.65	75.68
Standard Deviation	6.91	9.31	9.78	10.29
Minimum	60.0	68.0	55.00	58.00
Maximum	87.0	101.0	95.00	105.00

Abbreviations: *ZM, with mask; BM, without mask.*

Table 3. Blood pressure (BP) values of the entire test group in each of the measurements.

Values	BP1 before ZM [mmHg]	BP2 before ZM [mmHg]	PB1 after ZM [mmHg]	BP2 after ZM [mmHg]	BP1 before BM [mmHg]	BP2 before BM [mmHg]	BP1 after BM [mmHg]	BP2 after BM [mmHg]
Mean	127.61	82.13	131.68	81.29	124.61	79.03	127.35	79.68
Standard Deviation	7.64	7.39	9.69	8.22	9.66	7.33	9.31	7.76
Minimum	108.00	62.00	104.00	61.00	104.00	62.00	105.00	64.00
Maximum	141.00	101.00	145.00	93.00	146.00	90.00	146.00	93.00

Abbreviations: *ZM, with mask; BM, without mask; BP1, systolic blood pressure; DBP, diastolic blood pressure.*

After each trial, the subjects were asked the question "How would you rate the quality of your breathing during the trial...?" with the following possible answers: 'Very Good', 'Good', 'Bad', or 'Very Bad'. 5 subjects (16.1%) rated the quality of breathing in the trial with a mask as 'very good', while in the trial without a mask the quality of breathing was rated as 'very good' by 17 subjects (54.8%). In the trial with a mask, six subjects rated the quality of breathing as 'poor', whereas in the trial without a mask, no one reported a negative rating of the quality of breathing. None of the subjects gave a response of 'Very bad'.

All those who rated the quality of breathing as poor in the trial with a protective mask (6 people), during the next trial without a mask 5 people answered 'Good' and one 'Very good'. A decrease in breathing quality in the trial without a mask was reported by only one person – from a response of 'Very good' in the trial with a mask to 'Good' in the trial without a mask.

The subjects also rated their level of fatigue after the exercise using a four-point scale. The questions 'Do you feel tired after the trial...' were answered with 'Definitely yes', 'Rather yes', 'Rather no', and 'Definitely no'. None of the subjects answered 'Definitely yes'. The answer 'Rather yes' was given 2 times (6%) in the trial without a protective mask and 4 times (13%) in the trial with a mask. The answer 'Rather not' was given 8 times (26%) in the trial without a mask while 13 times (42%) in the trial with a mask. A total of 21 (68%) participants definitely did not experience fatigue in the trial without a protective mask, and 14 (45%) in the trial with a mask (**Figure 1**).

Eight subjects changed their response from 'Rather not' in the trial with a mask to 'Definitely not' in the trial without a mask. Out of the four who answered 'Rather yes' in the trial with a mask, two respondents in the trial without a protective mask answered 'Rather no'. Only one individual's response changed, indicating an increase in fatigue in the no-mask trial - from 'definitely not' to 'rather not'.

Based on the participants' responses, they were divided into two groups. The assessment of the quality of breathing in the trial with a mask was considered crucial, hence the subjects who marked 'Bad' or 'Very Bad' on the questionnaire after the trial were assigned to group one. The second group consisted of those who answered 'Good' or 'Very good'. Based on these responses, the groups were named 'negative respiratory quality assessment' and 'positive respiratory quality assessment' respectively. In the trial with a mask, those with a negative assessment of breathing quality showed an increase in saturation (p=0.5), while those with a positive assessment of breathing quality demonstrated a decrease in saturation levels (p=0.04) (**Figure 2**). At the same time, there was a switch in trends between the groups during exercise without the use of a protective mask. Those who exhibited a negative breathing quality on the first trial, experienced a reduction in SpO2 levels on the second trial (p=0.1). In subjects with a positive respiratory quality during the first trial, a slight increase in SpO2 was observed after exercise in the second trial (p=0.004).

Average heart rate values depending on respiratory quality assessment in the trial without a mask were lower than in the trial with a mask in both groups (**Figure 3**). However, participants rating their breathing quality negatively displayed lower heart rate levels in each measurement (With mask p=0.1; without mask p=0.02) when compared to the other group (p=0.00001 for both trials).

It can be observed that subjects from both groups, irrespective of breathing quality, showed a slight increase in systolic blood pressure both in a mask (p=0.1; p=0.005) and without a mask (p=0.04;

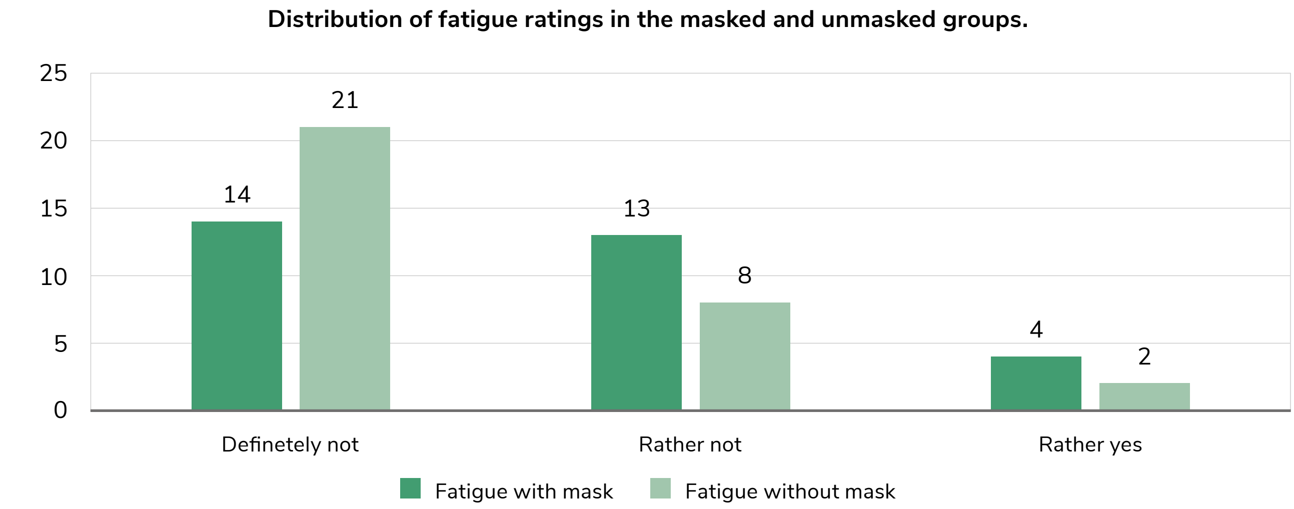

Figure 1. Distribution of fatigue ratings in the masked and unmasked groups.

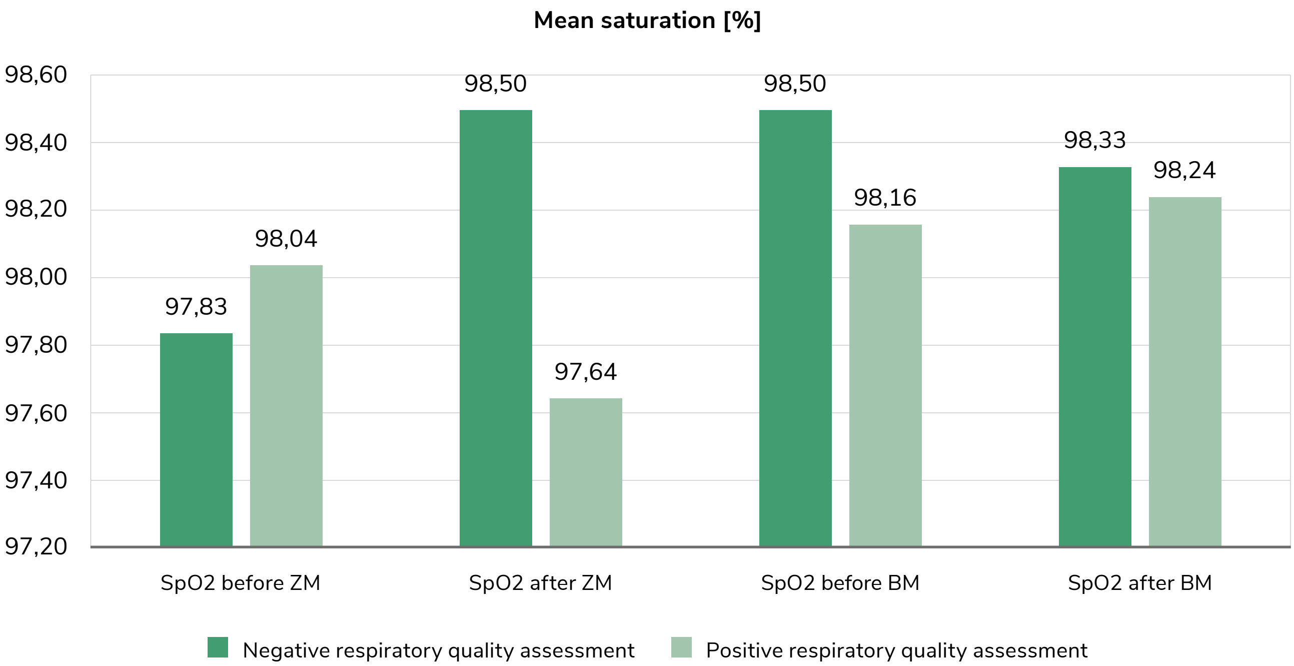

Figure 2. Mean saturation (SpO2) according to respiratory quality assessment.

p=0.002) after physical activity (**Figure 4**). Diastolic blood pressure decreased slightly in both groups in the trial with a mask (p=0.001; p=0.00001), while a slight increase was seen without a mask (p=0.01; p=0.00001).

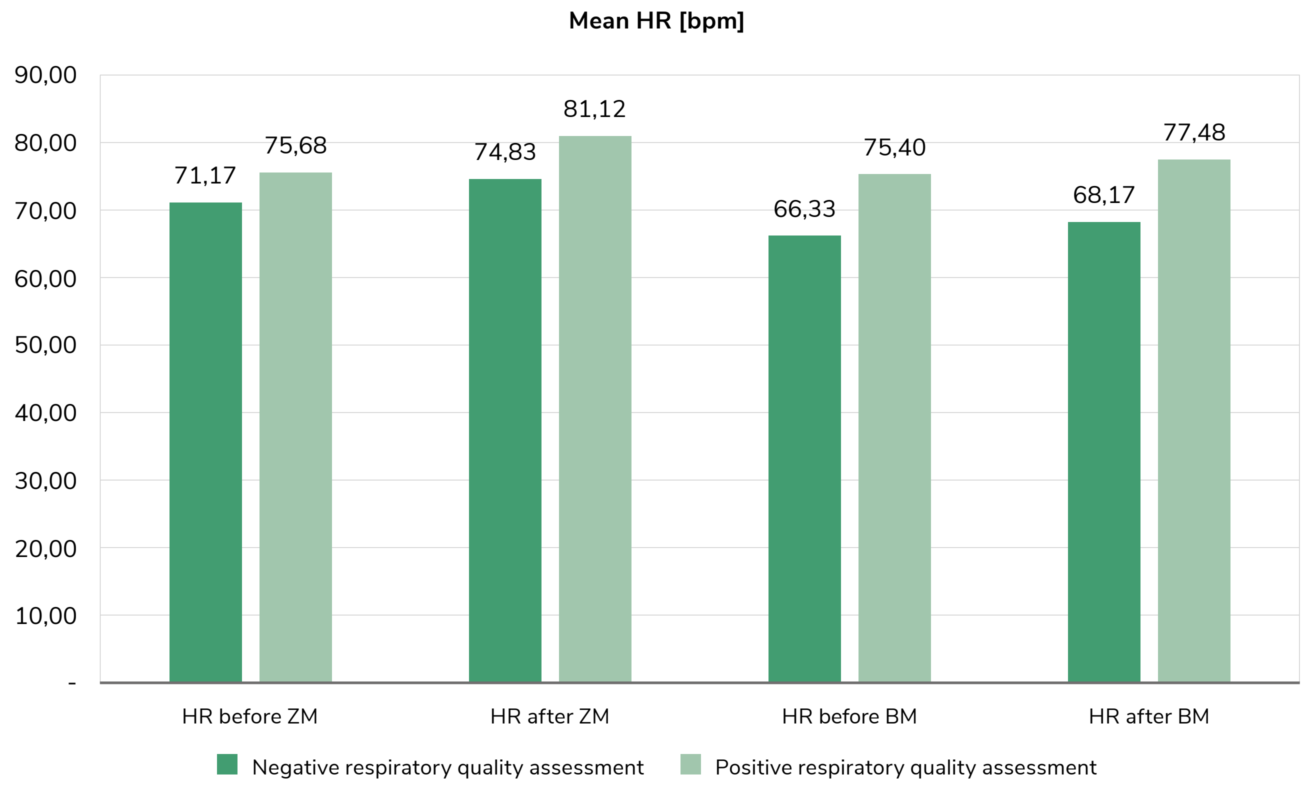

Figure 3. Mean heart rate (HR) values according to breathing quality assessment.

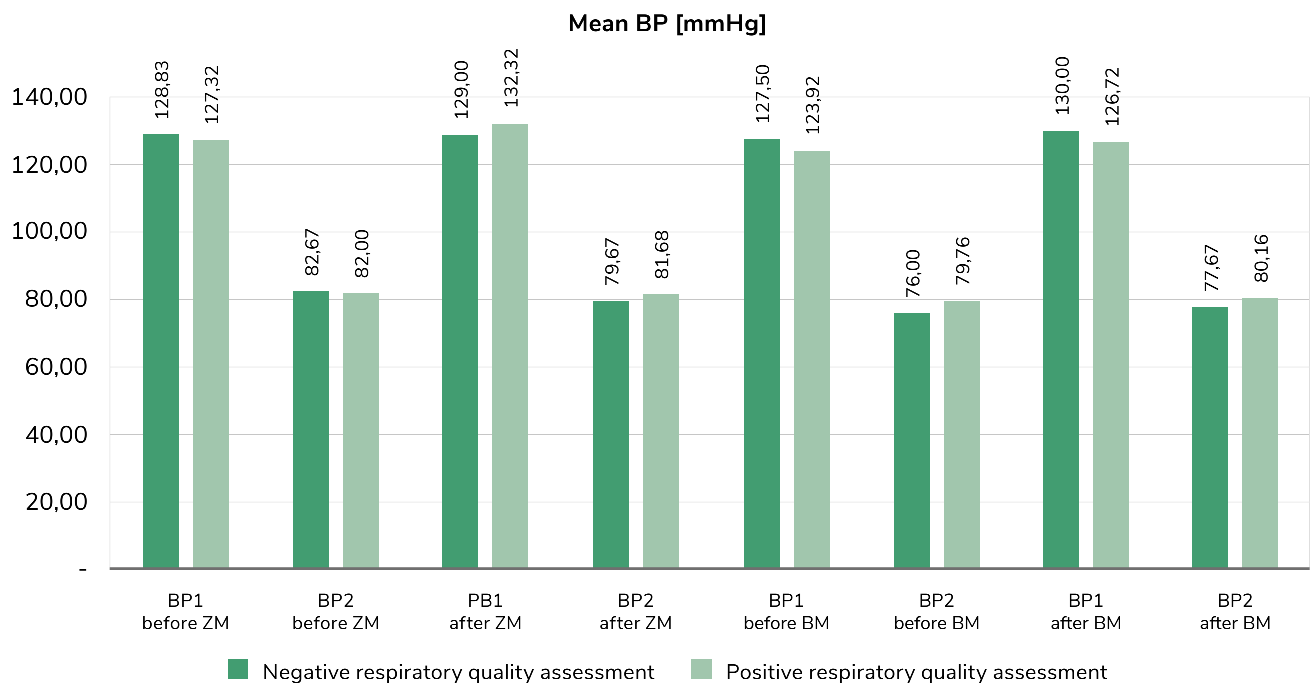

Figure 4. Mean blood pressure (BP) values according to breathing quality assessment.

Discussion

In March 2021, a study was published in the monthly European Respiratory Journal assessing the effects of using different types of masks on cardiopulmonary parameters during rest and maximal exercise. Similarly, to our study, the researchers did not observe a significant difference in saturation levels, while protective masks were associated with a slight worsening of spirometry results, dyspnoea sensation, and cardiorespiratory parameters at rest and at peak exercise. This effect is attributed to reduced ventilation and increased resistance to airflow during inhalation. Despite the observed reduction in respiratory efficiency during exercise while wearing a mask, the differences were small enough that wearing a mask was considered safe even during maximal efforts [4].

Another study that looked at the effects of using a mask on saturation and heart rate is the work of Austrian researchers. Physical activity led to a slight reduction in saturation - by 3% in subjects without a protective mask and by 3.7% in subjects with a mask. It was observed that the reduction in saturation was significantly greater in subjects over 40 years of age, although it did not fall below critical values. Heart rate increased by 31.0 bpm during the trial without a mask and by 33.3 bpm after the activity with a mask [5]. In our study, physical activity did not cause as great of a difference in saturation or heart rate values. This may be due to the intensity and type of exercise to which the subjects were exposed. Despite the differences in the method of the research, the conclusions remained the same - the researchers are convinced that the use of protective masks by healthy adults does not have a significant effect on the oxygen saturation levels in the blood and does not cause additional strain on the heart.

In April 2021, an analysis of 22 studies, available in databases such as SPORTDiscus, PubMed, and Medline, was performed. The analysis investigated the effects of the use of protective masks during physical activity on exercise performance, saturation, end-tidal CO_2 - $EtCO_2$, heart rate, and blood pressure. A total of 1573 participants (620 women and 953 men) were included in the analysis. In research that evaluated saturation, some did not demonstrate a statistically significant decrease in SpO_2. Clinically insignificant reductions in saturation values occurred only with N95 masks or during maximal exercise. While the results of our own study appeared to be consistent with the analysis discussed above in terms of a decrease in saturation levels, no masks other than surgical masks were used in our study. This limits the comparability of our own research with that of other authors. Research analysis indicated that fabric or surgical masks did not cause an increase in heart rate, while N95 masks led to a statistically significant increase in heartbeats per minute. Blood pressure values also did not change significantly with the use of protective masks. However, the use of masks during exercise led to higher ratings of perceived exertion and the occurrence of dyspnoea for each type of masks, according to the results of our study - here again, participants using protective masks rated the quality of breathing worse and experienced more fatigue than without them [6].

However, there are publications suggesting that prolonged use of masks can worsen saturation levels. It is worth mentioning research that evaluated the saturation of maxillofacial surgeons while working in a protective mask. In all 20 participants, a decrease in saturation was observed (from an average of 97.5% before to 94% after surgery) along with an increase in heart rate. A few subjects also reported mild headaches and shallow breathing. It was concluded that the use of FFP2 masks with an additional layer of paper mask led to a reduction in blood oxygen concentration, and although this was not clinically significant, the decrease in SpO_2 in the above study was significantly greater than in our study. This may be due to the type of mask used in the study and the fact that in this case two types of masks were used simultaneously [7].

An extremely valuable study, although limited in the number of participants, is the evaluation of the effects of mask use on gas exchange in patients with COPD. The study examined 15 veterans with chronic obstructive pulmonary disease and 15 healthy medical professionals. The 6-minute walk test (6MWT) was used to load the respiratory system with exercise. After completing the test in the mask, subjects with COPD showed a decrease in saturation, but the researchers did not find it to be significant [8].

The findings of the 2020 study, whose subjects were also individuals with COPD, provide a contrast. A total of 97 participants took part in the study, with 7 failing to complete the exercise test with the N95 type mask. On this basis, the subjects were divided into two groups - those with a successful trial and those with an unsuccessful trial. Subjects that failed the trial showed significant differences in respiratory rate, saturation, and exhaled carbon dioxide levels in relation to the use of N95 masks. Consequently, patients with COPD or other respiratory conditions are advised to be extremely cautious when wearing N95 masks [9].

As the two studies mentioned above demonstrate, physiotherapy management of patients with COPD should take into account the patient's individual capacity and health status. It is also useful to control the type of protective masks used in order to reduce the risk of excessive load on the respiratory and cardiovascular systems, although the results of one study brings us closer to the belief that physical activity in a protective mask does not contraindicate even in patients with respiratory disorders. Patients with, for instance, COPD were excluded from our study because of the difficulty in properly monitoring the subjects' condition. However, the above studies suggest that when further attempts are made to develop our own research, one should not be limited only to the effects of wearing masks on cardiorespiratory parameters in healthy subjects. Especially if the aim is to clearly establish whether their use does not generate harmful side effects.

When evaluating how the use of protective masks affects saturation in older people, it is worth mentioning a study from October 2020. 25 subjects measured SpO2 independently before, during, and after wearing a mask. Some of the participants were individuals with hypertension, asthma, diabetes, and even interstitial lung disease. Non-medical, triple-layered masks and a pulse oximeter were used in the study. Subjects measured SpO2 3 times, 20 minutes apart, for 1 hour before, 1 hour during, and 1 hour after wearing a mask while resting or performing daily activities. Wearing a mask, under the circumstances presented in this study, has not been found to be hazardous in terms of respiratory capacity in older people, during rest or daily activities [10]. In the above study, in contrast to our own study, older people were not subjected to physical exertion other than daily activities, and in our own study the number of people over 60 years of age was significantly lower. Despite that, our own research, according to the reviewed scientific article, confirms that in older people, the use of protective masks does not reduce saturation levels.

Conclusions

Physical activity while wearing face masks leads to reduced levels of saturation and increased blood pressure, and heart rate when compared to exercising without face masks. The differences, however, are minimal and should not negatively affect patients' health, thus wearing face masks during exercise is considered safe. The subjectively perceived reduction in quality of breathing do not translate to changes in parameters such as saturation, blood pressure or heart rate.

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