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Evaluation of respiratory function in healthcare workers wearing face masks during the COVID-19 pandemic

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ABSTRACT

Background: The COVID pandemic, which has caused high mortality rates worldwide, has mainly affected the working environment of healthcare workers. Metabolic and respiratory changes occur in healthcare workers working with surgical masks.
Objective: Our aim is to identify the metabolic and respiratory problems faced by healthcare personnel working with surgical masks and to produce solutions to minimize them.
Methods: The study was conducted among emergency service workers who used surgical masks for at least 8 h in the emergency room between June 2020 and July 2020. Venous blood gas samples were taken from the health personnel participating in the study and their vital signs were checked.
Result: A total of 60 healthcare professionals with a mean age of 28.20 ± 6.30 years were included in the study. The distribution of men and women in the study was balanced with 30 (50.0%) men and 30 (50.0%) women. When the first and last vital signs (blood pressure, pulse, saturation) of the health workers participating in the study were examined, no statistically significant differences were found ($p > 0.05$). While there was no statistically significant difference in the Na, Chlorine, Ca values of metabolic indicators ($p > 0.05$), the first measurements of K (0.017) and Lactate (0.037) values were found to be higher than the last measurements ($p > 0.05$). The first measurements of the respiratory parameters pH (0.002), pCO2 (0.028), sO2 (0.045) and pO2 (0.048) were lower than the last measurements ($p > 0.05$). The first measurement value of pCO2 (0.028) was found to be higher than the last ($p > 0.05$).
Conclusions: Regular and long-term use of surgical masks does not harm the body metabolically and respiratorily.

1. Introduction

Throughout history, pandemics have afflicted humankind. Despite significant advances in microbiology and the development of measures taken to prevent infectious diseases, the COVID-19 pandemic has significantly impacted people across the world [1]. Crises like the COVID-19 pandemic require careful planning to facilitate urgent restructuring.

of many aspects of an ED. The most effective and short-term measure that can be implemented to mitigate to such a crises is to take personal protective measures [2]. The primary protection method involves hand washing or the use of alcohol-based hand antiseptics, following personal hygiene rules, maintaining a distance to avoid contact droplets, physical or social distancing, and wearing face masks to minimize the risk of transmission [3].

In order to avoid the spread of the virus and becoming infected, the use of masks reduces wearers' exposure to infectious droplets [4]. As a result of the coronavirus outbreak, masks have been used in all social areas worldwide. In addition to the advantages of using masks, various difficulties and disadvantages are also experienced such as deterioration in respiratory comfort and the feeling of being increasingly out of breath. It is acknowledged that healthcare professionals and healthy people find it challenging to use masks for a long time [5].

However, a limited number of studies have focused on detecting metabolic and respiratory changes associated with the use of face masks. Therefore, this study aimed to evaluate whether healthcare workers working with masks had impaired gas exchange and metabolic changes.

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2. Methods

2.1. Study population

This prospective study was approved by the Cumhuriyet University Faculty of Medicine institutional review board. Informed written consent was obtained from all participants. The study protocol conformed to the ethical guidelines of the 1975 Declaration of Helsinki as revised in 2000. From June 2020 to July 2020, we enrolled 60 healthy clinical staff (residents in emergency medicine, interns, nurses, and allied health professionals) of our hospital's emergency department (ED). Participants were recruited randomly on a voluntary basis after screening for eligibility. They were asked to use a three-layered surgical mask with a wire covering the mouth and nose during the study period (at least 8 h). They were only allowed to remove the surgical mask when eating or drinking in the hospital. Venous blood was drawn twice by a nurse into a 2.0 mL heparinized syringe at the beginning and end of the working period. The blood test was immediately analyzed with a Radiometer¬Æ ABL 700 series that was available in the ED. Indexes of pH, SpO_2, PaO_2, $PaCO_2$, HCO_3^-, lactate, base excess (BE), and O_2 saturation level were analyzed.

Inclusion and exclusion criteria were as follows:

Inclusion Criteria

- Healthcare worker actively working in the ED,
- Using a three-ply surgical mask with nose wire.

Exclusion Criteria

- Healthcare workers who did not give consent,
- Healthcare workers who did not use a surgical mask regularly during the work period,
- Healthcare workers using another (N95, FFP2, etc.) mask together with a surgical mask,
- Participants who worked <8 h,
- Healthcare workers who were smokers. Smoked during the work period,
- Health care workers having comorbid diseases including asthma, chronic obstructive pulmonary disease, congestive heart failure and/or chronic kidney failure which may cause respiratory and metabolic disorders.

2.2. Statistical analysis

The SPSS Statistics for Windows, version 22.0 (SPSS Inc., Chicago, Ill., USA) was used as the statistical analysis program. Descriptive statistics (mean, standard deviation, frequency, and percentage) were used for the demographic and clinical characteristics. Histograms and the Shapiro-Wilk tests of normality were used to assess the normal distribution of means. The student's *t*-test was used for comparing two groups of continuous data that were both normally distributed. A *p*-value of $p < 0.05$ was considered to be statistically significant. The estimated power is 0.9999 (beta = 0.0001) for $n = 60$, effect size = 0.8 and alpha = 0.05. The Bonferroni correction method was used for multiple test comparisons.

3. Results

A total of 60 participants were included in the study. The mean age of the study population was 28.20 ± 6.30 years, and 50% were female. Table 1 demonstrates that there were no statistically significant differences between the blood pressure, pulse rate, temperature, and saturation values of the participants before and after using a mask for 8 h ($p > 0.05$). Table 2 shows a comparison of the first and last levels of electrolytes. Although the serum K and lactate levels were detected to be significantly higher in the second measurement ($p < 0.05$), when the Bonferroni correction was applied to the values, we found that the difference was not significant ($p > 0.05$). Differences in the levels of serum Na, Cl and Ca were statistically insignificant (p > 0.05).

Table 1
Comparison of participants' clinical features before and after the working hours.

Parameters	n = 60		*P* value
	Before	After	
Blood pressure (mmHg)	115.90 ± 11.14	117.58 ± 11.18	0.182
Pulse rate (/minute)	80.60 ± 4.77	79.95 ± 3.96	0.152
Temperature (°C)	36.8 (36.6–37.0)	36.8 (36.6–37.0)	0.271
Saturation (%)	97.0 (96.0–98.0)	97.0 (97.0–98.0)	0.119

Data are expressed as mean ± standard deviation and median (1st quartile-3rd quartile).

The comparison of the first and last measurement of blood gas levels is shown in Table 3. The differences in the levels of HCO_3^-, p50, MetHb, ABE, SBE, tO_2, and carboxyhemoglobin were statistically insignificant (p > 0.05). However, the differences between the first and second measurements of pH, pCO_2, sO_2, Hct, SBC, pCO_2(T), pH(T), O_2Hb, tHb, pO2, pO_2(T) and RedukteHb were statistically significant ($p < 0.05$). pH, sO_2, SBC, pH(T), O_2Hb, pO_2, and pO_2(T) levels were detected to be significantly lower in the first measurement (p < 0.05). pCO_2, Hct, pCO_2(T), tHb ve ReducedHb were found to be significantly higher in the first measurement (p < 0.05). We identified that only pH, Hct, tHB, reduced Hb difference was significant in the Bonferroni correction we applied to the results in Table 3.

4. Discussion

In this study, the blood gas, blood pressure, pulse rate, saturation and temperature of 60 participants, including ED residents, interns, nurses and allied health personnel using surgical masks, were evaluated before they started work and at the end of their 8-h shift. There were no significant differences in terms of blood pressure, pulse rate, saturation and temperature. We find out that pH was increased after using masks (initial value was 7.36 ± 0.03 and the value at the end of the shift was 7.38 ± 0.02). However this change did not reveal any clinical significance. When Bonferroni correction was made; it was detected that this change was insignificant statistically as well. No significant differences were found in the basic electrolytes such as Na^+, Cl^-, Ca^{+2} in the venous blood gas test.

Healthcare workers in ED exert a certain amount of effort during their shift, which is roughly equivalent to heavy exercise. In a study by Juel et al., the researchers evaluated lactate and K^+ fluxes from muscle to blood during and after intense exercise [6]. They found a wide range of intramuscular lactate concentrations, and 70% of the K^+ ions released from the muscle to the blood accumulated in the plasma. Ahmadi et al. detected the blood lactate accumulation threshold during an incremental exercise test in young athletes and reported that oxygen was inversely proportional to serum lactate levels [7]. Due to their working conditions, the effort exerted by the participants corresponded to heavy exercise. Our study showed no significant difference in serum

Table 2
The comparison of the levels of electrolytes before and after the working hours

Parameters	n = 60		P value	P-Adj.
	Before	After		
K^+ (mmoL/L)	4.02 ± 0.32	3.91 ± 0.33	*0.017*	*0.085*
Na^+ (mmoL/L)	134.17 ± 2.95	133.95 ± 2.71	0.610	0.999
Cl^- (mmoL/L)	107.67 ± 3.72	106.73 ± 3.02	0.098	0.490
Ca^{++} (mmoL/L)	1.9 (1.2–1.2)	1.2 (1.2–1.2)	0.477	0.999
Lactate (mmoL/L)	1.3 (0.9–1.5)	1.0 (0.8–1.4)	*0.037*	*0.185*

Data are expressed as mean ± standard deviation and median (1st quartile-3rd quartile).
p-adj. Bonferroni correction p value.
K^+: Potassium, **Na^+:** Sodium, **Cl^-:** Clor, **Ca^{++}:** Calcium

Table 3
The comparison of the first and last measurement levels of blood gas tests.

Parameters	Measurement of blood gas test (n = 60)		P value	P-Adj.
	Before	After		
pH	7.36 ± 0.03	7.38 ± 0.02	*0.002*	*0.038*
pCO_2 (mm/Hg)	47.58 ± 4.13	46.16 ± 4.56	*0.028*	*0.532*
sO_2 (%)	37.73 ± 18.76	42.83 ± 18.04	*0.045*	*0.855*
HCO_3^- (mmoL/L)	26.42 ± 1.99	26.35 ± 1.84	0.744	0.999
p50	32.92 ± 4.53	32.47 ± 3.90	0.475	0.999
Hct (%)	46.16 ± 4.81	45.16 ± 4.54	*0.001*	*0.019*
SBC	23.75 ± 1.38	24.11 ± 1.17	*0.005*	*0.095*
pCO_2(T)	47.58 ± 4.13	46.16 ± 4.56	*0.028*	*0.532*
pH(T)	7.36 ± 0.03	7.38 ± 0.03	*0.002*	*0.038*
MetHb (%)	0.64 ± 0.12	0.65 ± 0.13	0.484	0.999
O_2Hb (%)	36.72 ± 17.71	41.77 ± 17.16	*0.042*	*0.798*
tHb (mmoL/L)	15.06 ± 1.60	14.73 ± 1.50	*0.001*	*0.019*
pO_2 (mm/Hg)	24.7(22.3/29.2)	27.3 (24.0/33.4)	*0.048*	*0.912*
ABE (mmoL/L)	1.4 (0.5/2.0)	1.3 (0.7/2.1)	0.892	0.999
SBE	1.4 (0.6/2.99)	1.8 (1.0/2.8)	0.904	0.999
tO_2	7.1(4.7/9.4)	8.0(6.2/10.6)	0.057	0.999
pO_2(T)	24.7(22.3/29.2)	27.3(24.0/33.4)	*0.048*	*0.912*
ReducedHb	64.3(54.7/74.3)	59.1(47.9/69.0)	*0.024*	*0.456*
Carboxyhemoglobin(%)	0.8(0.5/1.8)	0.7(0.5/2.0)	0.494	0.999

Data are expressed as mean ± standard deviation and median (1st quartile-3rd quartile).
p-adj. Bonferroni correction p value.
pCO_2: Pressure of carbon dioxide in the blood, **sO_2:** Oxygen saturation in the blood, **HCO3⁻:** Bicarbonate, **p50:** It is the oxygen pressure of the blood in its semi-saturated state., **Hct:** hematocrit, **pCO_2(T):** Total Carbon Dioxide pressure, **pH(T):** total pH, **MetHb:** Methemoglobin, **O_2Hb:** Oxyhemoglobin, **tHb:** Total hemoglobin, **pO_2:** Oxygen pressure in the blood, **ABE:** Actual base excess, **SBE:** Standard Base gap, **tO_2:** Total Oxygen, **pO_2 (T):** Total Oxygen Pressure, **ReducedHB:** The value of reduced hemoglobin.

K+ and lactate levels, indicating that wearing a surgical mask did not impair the participants' ability to extract oxygen from the air.

In the study of Serin et al., it was found that protective masks other than surgical masks used as personal protective equipment increase rescuer fatigue in CPR [8]. In another study by Beder et al., the investigators evaluated whether surgeons' oxygen saturation of hemoglobin was affected by wearing surgical mask using a pulse oximeter pre and post-operatively [9]. They found that the pulse rates of the surgeon's increased and the SpO_2 level decreased after the first hour. However, our results did not support these findings. In our study, no significant change was found in the health workers' pulse rate, and the oxygen pressure levels were found to be high at the end of their shift. A study by Sukul et al. showed that using FFP2 masks reduced arterial oxygen induced hypercarbia in the elderly [10]. In Lin and Orkin's study, the researchers evaluated the arterial blood-gas and pH changes during emergency internal maxillary artery ligation in 9 patients with severe epistaxis, who failed to respond to anterior and posterior nasal packing [11]. They reported arterial hypoxemia and high arterial PO_2 differences without significant changes in $PaCO_2$ and pH; they explained that these findings were due to both the stress during anesthesia and the surgical procedure applied in the nasal passage causing hypoxia. In a similar study conducted by Gupta et al., the effects of complete nasal packing and nasal packing with airways on blood pressure and arterial oxygen saturation were compared [12]. They reported that patients with complete nasal packing without airways had decreased pO_2 and blood pressure levels, nasal obstruction with dry mouth, and dyspnea.

In a study by Wasserman et al., the relationship between lung function and exercise gas exchange in patients with chronic heart failure was investigated. They found an increase in pCO_2 relative to pO_2 resulting from HCO_3^- buffering of lactic acid, approaching the basic values, and decreased arterial pH [13]. Similarly, we detected an increase in pH.

The studies by Wasserman and Sukul et al. included patients with heart disease and elderly individuals respectively. Our cohort does not include either of these populations and further study in these vulnerable populations is warranted.

Taboni et al., in their study on divers, found that when hypoxia develops in such individuals, the CO2 values in blood gases increased while the O2 values decrease [14]. Contrary to their findings, we found that there were no significant differences in CO2 and O2 levels; İn the study by Antonio et al. it was found that wearing an FFP2 covered by a surgical mask induces a reduction in circulating O2 concentrations without clinical relevance among oral surgeons [15].

5. Limitations

Multiple limitations were encountered while conducting this study. Our cohort consists of a small population of young and healthy participants from a single center. It does not include individuals with old age and comorbid chronic diseases. Although individuals who had to use surgical pay attention, they often used them incorrectly or did not fallow to the hygiene rules. Another limitation of the study is the difficulties experienced with collecting blood gas and delivering the samples to the laboratory.

6. Conclusions

The results of our study reveals that using surgical masks does not cause any significant changes in blood pH, pO_2 and pCO_2. As the serious effects of the pandemic emerge, people will pay more attention to the rules of mask use, which will ensure to keep them safer. Despite all these challenges, it was shown that working with a surgical mask does not adversely affect the metabolic processes of the respiratory system in the human body. Knowing that the use of masks has no effect on respiratory function will help people's decision to wear masks in the post-pandemic period.

Prior presentations

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Ethical approval

Study approval was obtained from the clinical ethics committee of Cumhuriyet University Faculty of Medicine.

Authors' contributions

İKC, ED conceived the study. YKT and İK made substantial contributions to conception and design. İKC, ED, İK, YKT supervised data collection and managed the data. ED, YKT provided statistical advice on study design. İKC and ED analyzed the data. ED takes responsibility for the paper as a whole.

CRediT authorship contribution statement

İsmail Kıvanç Cebecioğlu: Writing – review & editing, Writing – original draft, Validation, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Erdal Demirtaş:** Writing – review & editing, Writing – original draft, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Yusuf Kenan Tekin:** Writing – review & editing, Visualization, Supervision, Investigation, Funding acquisition, Formal analysis. **İlhan Korkmaz:** Writing – review & editing, Supervision, Resources, Methodology, Formal analysis.

Declaration of Competing Interest

The authors declare that they have no conflict of interest.

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