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Comparison of Different Face Masks on Physiology and Tolerability

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ABSTRACT

Purpose: There is insufficient data on physiological and psychological alterations that may occur among healthcare workers wearing various face masks uninterruptedly during surgeries or for air-borne infection protection. In this study, we aimed to investigate the physiological effects of various types of face masking and associated discomfort among healthcare workers.

Methods: This prospective study included 33 healthy healthcare workers. Each participant was asked to wear a single surgical mask, double mask, N95 type mask, and surgical mask on N95 type mask for an uninterrupted period of 2 hours. Oxygen saturation, heart pulse, blood pressure, respiratory rate, and step counts were recorded at baseline and every 30 min of 2 hours with a total of five times for each mask type. Self-assessment of fatigue, exhaustion, and headache were also graded. Intra- and inter-group analyses were performed.

Results: There was no significant difference in the oxygen saturation, diastolic blood pressure and respiratory rates among the participants including intra- and inter-groups ($p>0.05$). Systolic blood pressures gradually and significantly increased with a double surgical mask ($p<0.05$). Headache and exhaustion scores increased gradually and significantly over time at every measurement time point with every mask type ($p<0.05$) Fatigue scores also increased in intra-group comparison of mask types without any difference in-between.

Conclusion: Type of face mask affects only subjective parameters such as headache, exhaustion and fatigue without any change in the objective physiological parameters during 2 hours of uninterrupted masking.

Keywords: Face Masking, Personal Protective Equipment, Surgical Mask, N95 mask, Hypo-oxygenation.

ÖZET

Amaç: Ameliyatlar sırasında veya enfeksiyonlardan korunmak için uzun süre aralıksız yüz maskeleri takan sağlık çalışanlarında meydana gelebilecek fizyolojik ve psikolojik değişiklikler hakkında literatürde yeterli veri bulunmamaktadır. Bu çalışmada, sağlık çalışanları arasında çeşitli yüz maskesi türlerinin fizyolojik etkilerini ve verdikleri subjektif rahatsızlık hissini karşılaştırmalı olarak araştırmayı amaçladık.

Yöntemler: Bu prospektif çalışmaya 33 sağlıklı sağlık çalışanı dahil edildi. Her katılımcıdan kesintisiz 2 saatlik bir süre boyunca tek cerrahi maske, çift maske, N95 tipi maske ve N95 tipi maske üzerine cerrahi maske takması istendi. Oksijen satürasyonu, kalp nabzı, kan basıncı, solunum hızı ve adım sayıları başlangıçta ve her 2 saatte içinde 30 dakikada bir, her maske türü için, toplam beş kez kaydedildi. Yorgunluk, bitkinlik ve baş ağrısının öz değerlendirmesi de kaydedilip derecelendirildi. Daha sonra kaydedilen değerlerin grup içi ve gruplar arası analizleri yapıldı.

Bulgular: Gruplar içi ve gruplar arası dahil, oksijen satürasyonu, diyastolik kan basıncı ve solunum hızlarında anlamlı bir fark bulunamadı ($p>0,05$). Sistolik kan basınçları çift cerrahi maske ile kademeli ve anlamlı şekilde artmıştı ($p<0,05$). Baş ağrısı ve bitkinlik skorları her ölçüm zaman noktasında her maske tipinde kademeli ve anlamlı şekilde zamanla arttığı gözlendi ($p<0,05$). Yorgunluk skorları da maske tiplerinin grup içi karşılaştırmasında herhangi bir fark gözlenmeden zaman ilerledikçe arttı.

Sonuç: Tüm yüz maskesi tiplerinin 2 saatlik kesintisiz takılması, objektif fizyolojik parametrelerde önemli bir değişiklik yapmazken maske tipleri arasında da bu parametrelerde anlamlı bir fark gözlenmedi. Uzun kesintisiz maske kullanımının sadece baş ağrısı, bitkinlik ve yorgunluk gibi öznel parametreleri etkilediği görüldü.

Anahtar Kelimeler: Yüz maskesi, Kişisel Koruyucu Ekipman, Cerrahi Maske, N95 maske, Hipooksijenasyon

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A very limited number of studies are found to show the impact of personal protective equipment (PPE) on vital parameters of healthcare workers (HCWs) in the literature. The evaluation of physiological impact of mask wearing seems to be helpful for planning working periods of medical staff and for preventing their possible detrimental effects.

Uninterrupted masking is mostly important at indoor areas such as hospitals in prevention of viral or bacterial transmissions like in pandemics or in epidemics or like in operating rooms during long surgeries. For instance, in recent pandemic, the half-life of the aerosolized Covid-19 virus is between 1.1 and 1.2 hours and the air may contain virus for a long time.[1] Face masks have been scientifically proven to decrease this droplet transmission.[2] However, it is almost certain that to comply with this requirement is not so practical due to the suffocative nature of masking. Regular pauses for face masking can be an important issue in these hard times for HCWs. Long-term use of N95 type masks may cause hypo-oxygenation and increased blood carbon dioxide (CO_2) concentrations, leading to complaints including headache and fatigue and complicating long working hours with masks.[3] This discomfort may cause the workers to wear off the mask for some periods leading to this unprotected period without proper masking to increase the risk of contagion.

In the present study, we aimed to investigate the effects of a single surgical mask, double surgical mask, N95 type mask, and N95 type with a surgical mask on vital parameters such as oxygen saturation, heart pulse, blood pressure, and respiratory rate among HCWs. In the light of the results of this study, our objective was to identify the optimal uninterrupted masking time with proper break times and working schedules in HCWs.

Materials and Methods

Study Design and Study Population

This prospective study was conducted at the polyclinics of a tertiary care hospital between July and September,2023. With 5% Margin of Error (95% confidence interval), 80% Power and Standard Effect Size was determined as 0.72. It was decided to include at least n = 30 cases in the study. All participants were informed about the nature of the study and a written informed consent was obtained. The study protocol was approved by the Acibadem Mehmet Ali Aydinlar University, Medical School, Board of Ethics (No: 2020-13/8). The study was conducted in accordance with the principles of the Declaration of Helsinki.

A total of 33 HCWs including physicians, nurses, administration officers, front desk staff, receptionists, and cleaning staff were included. The presence of acute or chronic systemic diseases such as diabetes (type I or II), heart diseases (congenital or acquired), lung diseases (asthma, chronic obstructive pulmonary disease, bronchitis) for any continuous medication for any medical reason or known vitamin deficiency, cigarette smoking, pregnancy, and any history of infection for the past two weeks were excluded from the study. Complete blood count analysis was performed for every participant to rule out anemia. Those having chronic headaches were also excluded.

Each participant was asked to wear the same type of a single surgical mask (triple-layered surgical mask, certified by the International Organization for Standardization (ISO; 13485; EN-10993-1,5,10, and EN-14683 approved), double mask (identical masks to single surgical mask types were used , but worn in a double layered manner, one over the other), N95 type mask (3M Corp., St. Paul, MN, USA), and surgical mask on N95 type mask for an uninterrupted period of 2 hours in the same time period during working hours between 08:00 AM and 13:00 PM. Mask size was selected according to the participant's facial dimensions to ensure a full coverage without any gaps. Completion of the study for each participant lasted for four days, as only one type of masking was tested during one day at the same duration of the day.

Data Collection and Instruments

Body height and weight of study participants were noted. Data including oxygen saturation, heart pulse, blood pressure, respiratory rate, and step counts were recorded using a follow-up sheet at baseline and every 30 min of 2 hours with a total of five times for each mask type. Pulse oximetry measurement was performed by an experienced nurse who was unblinded to the study, and a standardized measurement was done using a PC-66B hand-held pulse oximeter (Shenzhen Creative Industry Co. Ltd., Shenzhen P.R. of China) device. Temperature of the hospital environment was always set at 22 to 24°C through a constant running air-conditioning system of the facility. None of the female participants had nail polishes due to the institutional rules, which may interfere with the pulse oximetry measurements.

Self-assessment of fatigue and exhaustion were also graded with Fatigue Numeric Rating Scale (NRS). The score ranges from 0 to 5 (0-Energetic, no fatigue, 5-worst possible fatigue or exhaustion at all, and 5- completely exhausted) Headache was assessed using the Visual Analog Scale (VAS). The scores are ranked on a 10-cm line from no pain to the worst pain.[4]

For step counts, the participants were asked to download a validated Runtastic Pedometer© (Adidas, Germany) application on their Android or IOS mobile phones and record the step counts obtained from this program for standardization. They were also told to carry their phones in their pants' pockets during face masking. Each participant was followed by an auditing staff every 15 min to ensure the proper use of masks and compliance with the study protocol.

Statistical Analysis

Statistical analysis was performed using the SPSS version 26.0 software (IBM Corp., Armonk, NY, USA). Descriptive data were expressed in mean ± standard deviation (SD), median (min-max) or number and frequency. Distribution of the variables was analyzed using the Kolmogorov-Smirnov test. Regression analysis of dependent variables was carried out using the Friedman and Wilcoxon tests. Intra- and inter-group analyses were performed using the Friedman test (Wilcoxon test). A *p* value of <0.05 was considered statistically significant.

Results

Baseline demographic characteristics of the participants are shown in **Table 1.** The increase in the step counts was comparable in the intra- and inter-group analyses (p>0.05)

Table 1: Baseline demographic characteristics of the participants

		Minimum-Maximum	Median	Mean±SD /n-% †
Age		23.0-35.0	27.0	28.0±4.3
Gender	**Female**			24-72.7%
	Male			9-27.3%
Height (cm)		150.0-187.0	166.0	165.6±8.6
Weight (kg)		45.0-88.0	57.0	61.2±11.3
Body Mass Index		18.7-30.5	22.1	22.2±2.7

†: Mean ± Standart Deviation/ Number -Percentage

There was no significant difference in the oxygen saturations, respiratory rates and diastolic blood pressures in the intra- and inter-group comparisons according to the timepoints (0, 30, 60, 90, and 120 min) (p>0.05). However, there was a more decrease with the surgical mask on N95 type masking type at oxygen saturations compared to other masking types and intra-group values at 120 min, although no statistically significant difference was found (p=0.51 and p=0.54) (**Table 2**).

Table 2: Oxygen saturation levels in the intra- and inter-group comparisons according to the timepoints.

Single Surgical Mask		**Oxygen Saturation**				***Inter-group Variance-p values***
		Double Surgical Mask	**N95 Mask**	**SM+N95 Mask†**		
Baseline	Mean±SD§	98.3±1.2	97.8±1.6	98.2±1.4	98.0±1.4	0.383‡
	Median	99.0	98.0	98.0	98.0	
30.Minute	Mean±SD§	97.8±1.4	97.8±1.6	97.8±1.5	97.9±1.5	0.948‡
	Median	98.0	98.0	98.0	98.0	
60.Minute	Mean±SD	97.8±1.3	97.4±1.5	97.7±1.8	97.5±2.0	0.292‡
	Median	98.0	97.0	98.0	98.0	
90.Minute	Mean±SD§	97.8±1.5	97.6±1.4	97.5±1.7	97.6±1.6	0.779‡
	Median	98.0	97.0	98.0	98.0	
120.Minute	Mean±SD§	97.8±1.6	97.5±2.2	97.7±1.8	97.1±2.7	0.051‡
	Median	98.0	98.0	98.0	97.0	
In-group Variance -p values		0.125‡	0.327‡	0.604‡	0.054‡	

†: Single Surgical Mask with N95 ‡: Friedman test §: Mean ± Standard Deviation

Table 3: Pulse rates in the intra- and inter-group comparisons according to the timepoints.

Single Surgical Mask		Pulse Rates				*Inter-group Variance-p value*
		Double Surgical Mask	N95 Mask	SM+N95Mask†		
Baseline	Mean±SD§	80.8±12.9	81.4±12.0	80.9±11.6	81.8±13.9	0.370‡
	Median	80.0	78.0	80.0	82.0	
30.Minute	Mean±SD§	79.3±9.4	78.7±10.6	79.2±10.1	81.3±10.7	0.109‡
	Median	80.0	77.0	78.0	82.0	
60.Minute	Mean±SD§	77.5±10.8	77.9±12.0	79.4±9.6	81.6±9.3	***0.012***‡,*
	Median	76.0	77.0	78.0	82.0	
90.Minute	Mean±SD§	78.2±12.6	76.8±10.6	80.0±11.0	79.2±11.4	0.118‡
	Median	75.0	77.0	80.0	80.0	
120.Minute	Mean±SD§	77.4±12.1	75.3±10.5	78.7±13.6	80.7±12.6	0.052‡
	Median	76.0	74.0	77.0	80.0	
In-group Variance p value		0.156‡	***0.017***‡,*	0.901‡	0.151‡	

*†: Single Surgical Mask with N95 ‡: Friedman test (Wilcoxon test) §: Mean ± Standard Deviation *: p<0.05*

Table 4: Systolic pressure levels in the intra- and inter-group comparisons according to the timepoints.

Single Surgical Mask		Systolic Pressure				*Inter-group Variance- p value*
		Double Surgical Mask	N95 Mask	SM+N95Mask †		
Baseline	Mean±SD§	113.3±14.2	111.1±12.6	110.7±10.2	114.9±12.8	0.051‡
	Median	110.0	110.0	110.0	115.0	
30.Minute	Mean±SD§	112.9±13.0	115.2±13.5	111.4±12.6	112.9±10.7	0.237‡
	Median	110.0	110.0	110.0	115.0	
60.Minute	Mean±SD§	109.2±10.5	112.3±11.5	113.0±13.5	112.1±11.2	0.055‡
	Median	110.0	110.0	110.0	115.0	
90.Minute	Mean±SD§	111.0±11.1	114.7±12.1	109.7±11.4	113.7±13.8	0.051‡
	Median	110.0	115.0	110.0	111.0	
120.Minute	Mean±SD§	111.1±10.1	115.6±11.0	112.0±11.1	113.3±12.2	0.084‡
	Median	110.0	118.0	110.0	112.0	
In-group Variance-p Value		0.115‡	***0.002*** ‡,*	0.577	0.424‡	

*†: Single Surgical Mask with N95 ‡: Friedman test (Wilcoxon test) §: Mean ± Standard Deviation *: p<0.05*

As for pulse rates and systolic blood pressures, there was a gradual decrease in the former, and gradual increase in the latter with only the double surgical mask over time, indicating statistical significance (p<0.05). Systolic blood pressures indicated no statistically significant difference among the other masking groups (p>0.05) The pulse rates were also not significantly different between the measurement timepoints and between the groups (p>0.05), with an exception that pulse rates with the single surgical mask were significantly lower than the other types of masking at only 60 min (p<0.05) (**Table 3** and **Table 4**).

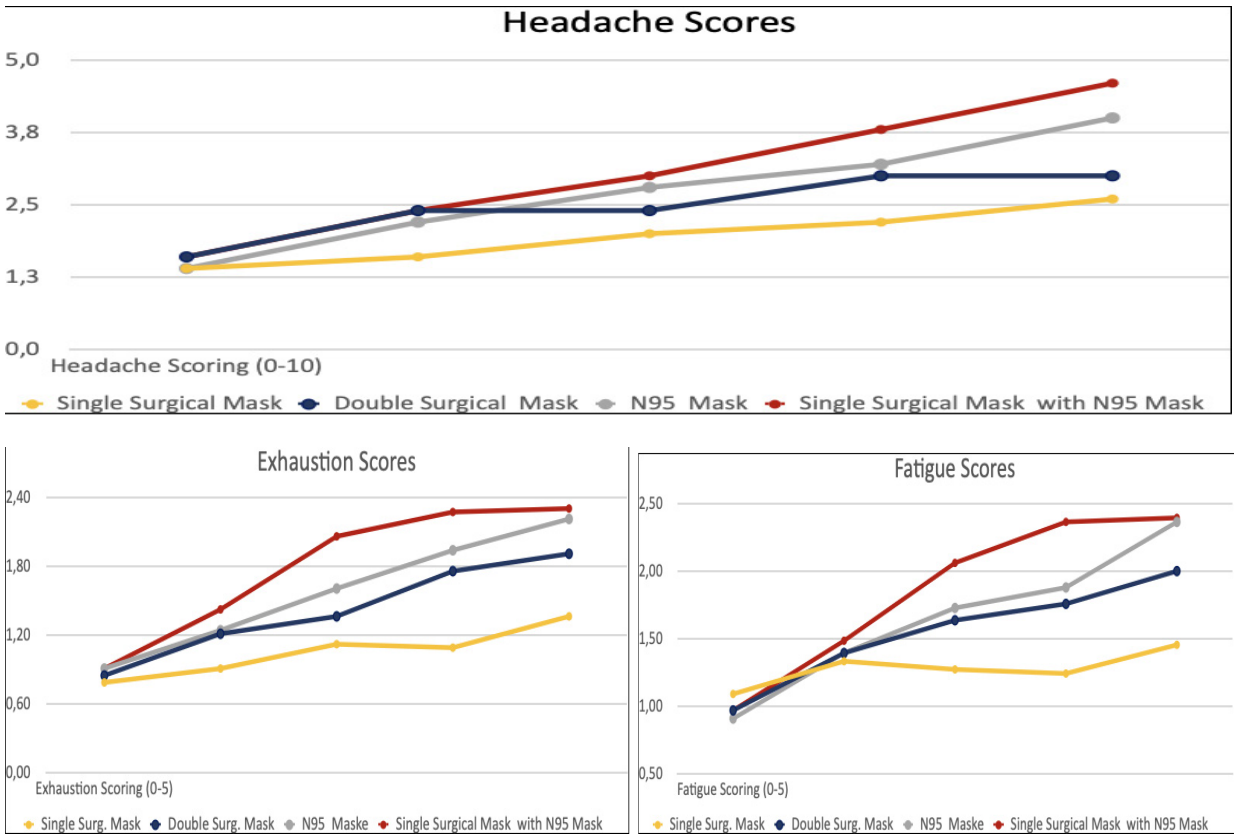

Figure 1: Headache, fatigue and exhaustion scores with 4 types of masking by time.

Headache and exhaustion scores gradually increased over time at every measurement within every mask type, indicating a statistically significant difference among the mask types ($p<0.05$). Fatigue scores did only significantly differ from headache and exhaustion scores at 30 min of measurement in which there was no significant difference of scores among the mask types ($p>0.05$); however, a gradual and statistically significant increase was observed in the intra- group analysis ($p<0.05$) (**Figure 1**).

Discussion

Surgical mask, double surgical mask, N95 type mask, and surgical mask on a N95 type mask are the types of facial masking which have been proved to prevent viral transmissions.[5-9] When face masking is necessary or mandatory in the healthcare setting, selection of the mask type to be used is related to the governmental or institutional regulations, to the departments of the hospitals (e.g., intensive care unit, operating rooms), to the availability of the mask types and, rarely, to the individual preferences. However, wearing an uninterrupted face mask for a long time may be troublesome for HCWs, for every type of face masking described above. Dyspnea, commonly referred to as shortness of breath, may be caused psychologically and it is one of the symptoms of anxiety.[10,11] Shortness of breath symptom may occur due to prolonged masking caused by a feeling of suffocating which causes anxiety and this anxiety may lead to interrupt face masking to catch the air even for a short time with panic. This behavioral act was a common observation of this study's authors and was also one of the main drives to start this study. We believe that the awareness including objective parameters not altered during various face masking types for a distinct period of time may cause a relaxation leading to decrease in anxiety and to cease these interruptions.

To the best of our knowledge, there is no study comparing four types of facial masking described above in terms of discomfort and mask-related symptoms. As expected, hypo-oxygenation and hypercarbia are the main side effects of facial masking. Other symptoms such as tachycardia, tachypnea, and elevated blood pressure can be compensatory mechanisms of this low oxygen level. Therefore, in the present study, we evaluated the pulse rate, blood pressure, and respiratory rate and assessed the related changes and consequences of hypoxemia, thereby, preventing us from failing to notice low oxygen delivery of the face mask types, even if measurement of the oxygen saturation was normal.

As a standard of clinical care, pulse oximetry can measure arterial oxygen saturation with clinically acceptable accuracy. Motion artifact, nail polish, hypotension carboxy-hemoglobinemia, presence of intravascular dyes, change in systemic vascular resistance, vasoconstriction, and anemia may decrease the performance of pulse oximetry.[12,13] However, age, sex, body weight, body temperature, hemoglobin concentration, and pulse pressure have little effects on the accuracy of pulse oximeters in detecting hypoxemia, with an absolute mean error of less than 1.0%, compared to *in vitro* saturation measurements.[14-16] Therefore, we believe that hypoxia assessment of facial masking in our study can be done with the oxygen saturation levels as measured by pulse oximetry. Constant room temperature and humidity inside the hospital building and the absence of anemia were the other factors which increase the accuracy of these measurements.

In this study, each participant used four types of masking, which makes our study more valuable, since tolerance to hypo-oxygenation was able to be measured and compared in the same participant. The BMI was also included in the study to standardize lung capacities of the participants, as those with high BMI values demonstrated reduced lung volumes and capacities compared to those with normal BMI values in the literature.[17] In our study, the mean BMI values were within the normal range. The age of the participants was also restricted (younger than 35 years), as one study performed among surgeons showed that age-related decrease of oxygen levels due to facial surgical masks was more prominent after 35 years old.[18] Thus, as the number of participants is limited in this study, additional contribution of BMI and aging on measured masking effects would be a difficult factor for the discriminant statistical analysis, and this limitation led us to apply this age exclusion criterion to form a homogeneous population along with the normal mean BMI.

For the evaluation of the step count, we used a free Runtastic Pedometer application which can be downloaded on both android and IOS mobile phones, and which has a proven reliability in measuring step counts.[19] In our study, we attempted to find the proportion or increase of the step counts during 2 hours of masking, rather than the exact number to eliminate motion artifacts in measurements. The results of step counts did not significantly differ among the mask types. We believe that these considerations prevented the measurements from being affected by the factors unrelated to face masks.

In the current study, the duration of uninterrupted masking was 2 hours. In a study, Lim et al.[3] assessed headaches caused by N95 masks among HCWs for 4 hours of uninterrupted masking, as this duration was the actual daily working hours without any break for the participants of this study. The authors concluded that headaches following the use of the N95 face masks could develop in HCWs and shorter duration of face mask wear could reduce the frequency and severity of these headaches. Nonetheless, these aforementioned authors recommended that durations less than 4 hours of masking should be also investigated for mask-related headache. Again, Kao et al.[20] evaluated physiological effects, mainly oxygenation, in patients with end-stage renal disease during hemodialysis, a 4-hour procedure, and found a decrease in the oxygen saturation caused by N95 type mask. However, in a controlled clinical study in pregnant HCWs, the impacts of N95 type masks on respiratory functions were examined for a total of 50 min including a 15-min light-intensity exercise.[21] Wearing N95 masks were found to complicate gaseous exchange and posed an additional workload on the metabolic system of pregnant HCWs. In this study, mask wearing for longer periods was unable to be evaluated due to ethical concerns. In our hospital, HCWs have an 8-hour working schedule with 2-hour breaks daily designated by the hospital regulations and additional breaks must be used in separate times, usually arranged as 2-hour working time and 15- or 30-min breaks, all of which are compatible with the Labour Act of Republic of Turkey.[22] We believe that 2-hour time frame could be adequate to compare four types of mask, as there is no consensus on optimal duration of face masking to be used in researches in the literature. However, a more decrease with the surgical mask on N95 type masking type at oxygen saturations was observed compared to other masking types and intra-group values

at 120 min without a statistically significant difference. Therefore, 2 hours of timeframe could be a cut-off limit for this type of masking and could be a target for future studies.

We observed a gradual, but statistically significant decrease in the pulse rate over time with only double surgical masking. This decline would not seem to cause clinically important changes. On the other hand, pulse rates were comparable among the measurements at prespecified time points and in-group mask types, with an exception that pulse rates with single surgical masking were significantly lower than the other types of masking at 60 min. Additionally, although there was a statistically significant increase in the systolic pressure with a double surgical mask only, we believe that this level of increase is also not of clinical relevance in the young population.

Fatigue, exhaustion, and headache are known symptoms of hypo-oxygenation. However, headaches may have a variety of subtypes according to the International Headache Society recommendations.[23] We, therefore, evaluated headache symptoms in detail, while fatigue and exhaustion feelings were also asked using a self-administered questionnaire with a score ranging from 0 to 5. The use of face masks may lead to headaches and previous studies have demonstrated that masking duration of more than 4 hours and pre-existing headaches may trigger headache.[3,24] As in fatigue and exhaustion, we believe that the increased severity of headache with masking for less than 4 hours may be related to psychological or emotional stress in an individual having no pre-existing headache.

Limitations

The sample size is limited, but it is not easy to accomplish a study with a large number of participants, since strict study rules and auditing would put more stress on HCWs, when they are already working under a heavy workload.

Conclusıon

In conclusion, we attempted to evaluate four types of masking objectively and subjectively with prespecified parameters that yielded two results. First, during 2 hours of working period, face mask types affected only subjective parameters such as headache, exhaustion, and fatigue without any detrimental clinically significant changes in objective parameters such as oxygen saturation, blood pressures, pulse and respiratory rates among HCWs. Second, comparison of face mask types with these parameters also revealed no significant difference between each other. But, further larger scale, well-designed, prospective studies are needed to confirm these findings and to draw a firm conclusion.

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