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Research

Difficulties Experienced by Surgical Team Members with Operating Room COVID-19 Personal Protective Equipment

Cerrahi Ekip Üyelerinin Ameliyathane COVİD-19 Kişisel Koruyucu Ekipmanlarla Yaşadığı Zorluklar

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ABSTRACT

Objective: During the pandemic, operating theaters were considered high-risk areas because of aerosol-generating procedures and devices. Therefore, the surgical team members had to wear multi-component high-level personal protective equipment to prevent occupational exposure. In the current study, we evaluated the side effects of operating room coronavirus disease-2019 (COVID-19) personal protective equipment.

Methods: A descriptive and cross-sectional study was conducted with 203 participants. Side effects in six thematic areas (respiration, vision, hearing-communication, thermal stress, movement-occupational skills, neurocognitive-psychological) were evaluated using a questionnaire and face-to-face interview.

Results: The mean age was 32.6±8.4; 55.7% were women and 43.8% were doctors. Respiratory, vision, hearing, and communication limitations were determined as 91.6%, 94.1%, 61.6%, and 93.6%, respectively. Those who reported an increase in sweating, warmth, thirst and skin problems were 96.1%, 95.1%, 91.6% and 85.2%, respectively. Restrictions in movements and sense of touch were 88.2% and 80.3%, respectively. Decreased visual quality and psychological tolerance and increased thermal stress and sweating were higher in physicians ($p<0.05$). Hearing limitation was higher in nurses ($p<0.05$).

Conclusion: The results showed that the members of the surgical team experienced serious difficulties while working with the operating room COVID-19 personal protective equipment, and that they were not prepared for strategies to deal with these problems. There must be a balance between the protective effects of this equipment and the user side effects. It is recommended that efforts should be focused on designing and producing new user-friendly and suitable equipment for employee health.

Keywords: Operating room, COVID-19, personal protective equipment, side effects

ÖZ

Amaç: Pandemi döneminde ameliyathaneler, aerosol üreten prosedürler ve cihazlar nedeniyle yüksek riskli alanlar olarak kabul edildi. Bu nedenle, cerrahi ekip üyeleri, mesleki maruziyeti önlemek için çok bileşenli üst düzey kişisel koruyucu ekipman giymek zorunda kaldı. Bu çalışmada, ameliyathane koronavirüs hastalığı-2019 (COVİD-19) kişisel koruyucu ekipmanlarının yan etkilerini değerlendirmeyi amaçladık.

Gereç ve Yöntem: Tanımlayıcı ve kesitsel nitelikteki çalışma, 203 katılımcıyla yürütüldü. Altı tematik alandaki (solunum, görme, işitme-iletişim, termal stres, hareket-mesleki beceriler, nörokognitif-psikolojik) yan etkiler anket ve yüz yüze görüşme yöntemiyle değerlendirildi.

Bulgular: Ortalama yaş 32,6±8,4; %55,7'si kadın, %43,8'i doktordu. Solunum, görme, işitme ve iletişim kısıtlılıkları sırasıyla %91,6, %94,1, %61,6 ve %93,6 olarak belirlendi. Terleme, sıcaklık, susuzluk ve deri problemlerinde artış bildirenlerin oranı sırasıyla %96,1, %95,1, %91,6, %85,2 bulundu. Hareketlerde ve dokunma duyusunda kısıtlamalar %88,2 ve %80,3 idi. Görme kalitesinde azalma, psikolojik toleransta azalma, termal stres ve terlemede artış hekimlerde daha yüksekti ($p<0,05$). Hemşirelerde işitme kısıtlılığı daha fazlaydı ($p<0,05$).

Sonuç: Bu çalışmanın sonuçları, cerrahi ekip üyelerinin ameliyathane COVİD-19 kişisel koruyucu ekipmanları ile çalışırken ciddi zorluklar yaşadıklarını ve bu sorunlarla baş etme stratejilerine hazırlıklı olmadıklarını göstermiştir. Bu ekipmanların koruyucu etkileri ile kullanıcı yan etkileri arasında bir denge olmalıdır. Çalışan sağlığına uygun, kullanıcı dostu yeni ekipmanların tasarlanması ve üretilmesine ağırlık verilmesi önerilir.

Anahtar Kelimeler: Ameliyathane, COVİD-19, kişisel koruyucu ekipman, yan etkiler

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INTRODUCTION

During the coronavirus disease-2019 (COVID-19) pandemic, healthcare workers had to use varying levels of personal protective equipment (PPE) depending on the work area and risk exposure level. The viral transmission routes of severe acute respiratory syndrome coronavirus 2 are respiratory droplets, close contact, and possible splashing (1,2). In this respect, operating rooms are considered high-risk areas due to aerosol-producing procedures and devices and require high-level PPE in the pandemic (1,3,4).

For surgical team members who routinely work with standard PPE such as surgical masks and caps, overshoes, gown, and gloves, and guidelines specific to operating rooms, including COVID-19 PPE donning and doffing instructions have rapidly developed (3,5,6). Components such as N95 masks or air-purifying respirators, a surgical mask on top of the N95, protective coveralls that also cover the head, full face shield, double or triple gloves, and boots were added to the basic operating room PPE (2,3,5-7).

In the process, the tolerability of this PPE by healthcare workers and the side effects caused by it were also tested. It was observed that working with these multilayered PPEs for long periods had many adverse physical, ergonomic, cognitive, and psychological effects on healthcare workers (8-10).

In this study, we primarily aimed to evaluate the adverse effects of COVID-19 PPE in six thematic areas (respiratory, visual, hearing-communication, thermal stress, movement-occupational skills, neurocognitive-psychological) on surgical team members consisting of surgeons, operating room nurses, anesthesiologists, and anesthesia technicians. We also collected information about the employees' levels of knowledge to cope with these adverse effects and their compliance with this PPE. In the future, there will be pandemics or chemical etc. exposures that require the use of PPE. Therefore, it is necessary to develop new PPE with high protective properties, but at the same time user-friendly and with reduced side effects. The study's results may contribute to the side effects that should be focused on when developing such equipment.

METHODS

Study Design

This descriptive and cross-sectional study was conducted in University of Health Sciences Türkiye, İstanbul Bakırköy Dr. Sadi Konuk Training and Research Hospital between November 2021 and February 2022.

Sample and Setting

The study was conducted on surgeons, operating room nurses, anesthesiologists, and anesthesia technicians working in 24 operating rooms of the relevant hospital using a purposive sampling method. Inclusion criteria were as follows: being a surgical team member, having experience participating in surgical interventions with "Operating Room COVID-19 PPE" during the pandemic process, and volunteering to participate in the study. Employees on temporary duty, leave, or reporting during the period when the study data were collected were excluded from the study. The study was conducted with 203 participants.

During the pandemic, the COVID-19 PPE-wearing protocol shown in Figure 1 was applied in the operating rooms of the hospital where the study was conducted. These components were as follows: two-piece operating room uniform + surgical cap + overshoes + N95 mask and surgical mask on top of it + full face shield + coveralls covering the whole body including the head + boots/protective shoes up to the knee over the coveralls + sterile gown + 2 or 3 layers of sterile gloves.

Data Collection Tools

The research data were collected through face-to-face interviews and self-reports using a form consisting of three sections.

The first part included the personal and professional characteristics of the participants. The second part determined the adverse effects of operating room COVID-19 PPE on surgical team members. The researchers created the questions in this section on the basis of the

Operating Room Standard PPE	Operating Room COVID-19 PPE
Two-piece operating room uniform	Two-piece operating room uniform
Surgical cap	Surgical cap
Surgical mask	N95 mask + Surgical mask
Surgical overshoes	Surgical overshoes
Sterile surgical gown	Liquid impermeable protective coverall, covering the whole body including the head
Sterile gloves	Full face shield
	Liquid-proof protective overshoes/boots up to the knee over the coveralls
	Sterile surgical gown
	2 - 3 layers of sterile gloves

Figure 1. Operating room standard and COVID-19 PPE components

COVID-19: Coronavirus disease-2019, PPE: Personal protective equipment

potential risks determined by the literature review and anecdotes of personnel with operation experience with these PPEs (8,11,12). The form consisted of six thematic areas (respiratory, visual, hearing-communication, thermal stress, movement-occupational skills, neurocognitive and psychological) and 23 questions. Impact level was evaluated as "No = It didn't make a change" and "Yes = It had a negative impact." The third section was "Operating Room COVID-19 PPE" related to training, other experiences and opinions. In this section, questions about the knowledge and compliance of the participants regarding the use of PPE, the status of receiving additional training to cope with side effects, and the institutional opportunities provided were included, and the answers were evaluated as yes/no.

Ethical Permissions

For the methodology and data collection form of the study, ethical approval was first obtained from the Ministry of Health COVID-19 Scientific Research Evaluation Commission (08.04.2021/decision no: T16-58-10) and then from Biruni University Non-Interventional Research Ethics Committee (decision no: 2021/51-07, date: 21.05.2021) in accordance with the rules during the pandemic period. Permission was obtained from the institution where the study would be conducted (25.11.2021/decision no: 12). The purpose of the study was explained to the participants, and their informed consent was obtained. This study was conducted in accordance with the principles of the Helsinki Declaration.

Statistical Analysis

Statistical Package for the Social Sciences v.24.0 (SPSS - IBM Corporation, New York, NY, USA) was used for statistical analyses. Frequency, percentage distribution, mean, and minimum-maximum values were analyzed for descriptive analyses. The chi-square test, a parametric method, was used to compare the data according to the groups. The results were evaluated at a 95% confidence interval and $p<0.05$ significance level.

RESULTS

The mean age of the 203 surgical team members who participated in the study was 32.66±8.48 years; 55.7% were female, 43.8% were physicians, and 47.8% of the group had >20 operations with these PPEs (Table 1).

Table 2 shows participant feedback on the effects of N95 + surgical masks on respiratory quality and the effects of visors on visual quality. Those who stated that their respiratory quality was negatively affected were 91.6% (n=186). Regarding symptoms that may develop due to respiratory limitation, 32% of participants reported anxiety, 24.6% reported dizziness, 29.6% reported dyspnea, and 7.4% reported lightheadedness. 94.1% (n=191) of the participants said that their quality of vision had decreased. In this area, 89.2%, 54.7%, and 29.6% reported fogging, light reflection, and visual field narrowing due to full face shields, respectively.

Data on hearing-communication, thermal stress, movement-occupational skills, and neurocognitive-psychological effects of COVID-19 PPE in the operating room are presented in Table 3. 61.6% (n=125) reported a decrease in hearing quality, and 93.6% (n=190) reported problems with communication within the team while working with this equipment. Those reporting increased sweating, warmth, and thirst with these PPE components were 96.1%, 95%, and 91.6%, respectively. Those who reported skin problems due to thermal effects were 85.2%. Those who reported decreased mobility with these PPE were 88.2% (n=179), and those who reported limitations in occupational hand skills such as dissection/instrumentation were 75.9% (n=154). Those who reported decreased tactile sensitivity due to using two or three layers of gloves were 80.3% (n=163). There were 70.0% (n=142) who reported decreased

Table 1. Personal and occupational characteristics of the participants (n=203)

Variables		n (%)
Age	20-35	143 (70.4)
	36-50	52 (25.6)
	>51	8 (3.9)
Gender	Female	113 (55.7)
	Male	90 (44.3)
Occupation	Doctors	89 (43.8)
	Nurses	67 (33.0)
	Anesthesia technicians	47 (23.2)
Operating room experience (years)	0-1	45 (22.2)
	2-4	47 (23.2)
	5-10	48 (23.6)
	>10	63 (31.0)
Operation experience with COVID-19 PPE (number)	<3	27 (13.3)
	4-8	29 (14.3)
	9-14	34 (16.7)
	15-20	16 (7.9)
	>20	97 (47.8)

COVID-19: Coronavirus disease-2019, PPE: Personal protective equipment

reaction speed in performing occupational skills and 79.8% (n=162) who reported that the processes related to tasks are prolonged. 79.3% (n=161) reported decreased physical tolerance. 78.8% (n=160) of participants reported decreased concentration, attention, and perception associated with PPE use, 82.3% (n=167) reported increased headaches, 40.4% (n=82) reported problems with decision-making and forgetfulness, and 85.2% (n=173) reported decreased psychological tolerance (patience).

Complaints of decreased visual quality, increased thermal stress and sweating, and reduced psychological tolerance were higher in physicians than in other occupational groups ($p<0.05$). Hearing limitation was more elevated in nurses than in the other two occupational groups ($p<0.05$) (Table 4, Figure 2). Reports of skin problems and decreased physical and psychological tolerance were higher in men than in women ($p=0.001$, $p<0.05$, $p<0.05$, $p<0.05$, respectively). There was no difference between genders regarding respiratory limitation, thermal stress, increased sweating, and thirst ($p>0.05$). There was no statistically significant difference between the age groups regarding respiratory limitation, fatigue, and physical and psychological tolerance problems experienced by the participants regarding PPE use ($p>0.05$).

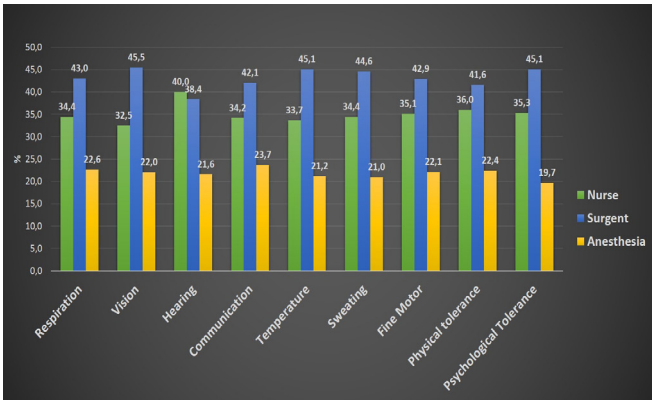

Figure 2. Distribution of operating room COVID-19 PPE-related problems by occupations

COVID-19: Coronavirus disease-2019, PPE: Personal protective equipment

The majority of the participants stated that they did not receive any additional training on breathing with an N95 mask, appropriate head movements to improve vision quality, prevent balance problems, prevent dehydration, and reduce speech-hearing and communication problems (85.2%, 91.6%, 90.6%, 76.8%, respectively). The number of those who stated that they had the opportunity to shower and rest outdoors after an operation with these PPEs was low (13.3% and 9.9%, respectively) (Table 5).

60.1% of the participants reported that the ideal operation time to work efficiently in surgical operations using PPE was less than 2 h. When the level of avoidance of wearing PPE was evaluated depending on the problems they experienced, 59.2% of the participants stated that they showed avoidance behavior (28.1% partially, 31.1% completely).

DISCUSSION

This study examined the difficulties experienced by surgical team members familiar with using standard surgical PPE when working with operating room COVID-19 PPE, which consists of many components and layers. The results of this study, reflecting the subjective experiences of the participants in defined PPE conditions, show that

Table 2. Effects of operating room COVID-19 PPE on respiration and vision (n=203)

Problems with operating room COVID-19 PPE					Yes n (%)	No n (%)
Respiratory limitation (the effects of the N95 mask + surgical mask and shield worn over it on the breathing)	My respiratory quality decreased n (%)	186 (91.6)	Symptoms experienced due to sensation of respiratory limitation associated with PPE components*	Anxiety	65 (32.0)	138 (68.0)
				Dizziness	50 (24.6)	153 (75.4)
	It did not make a difference n (%)	17 (8.4)		Dyspnea	60 (29.6)	143 (70.4)
				Lightheadedness	15 (7.4)	188 (92.6)
Visual limitation (the effects of breathing with masks and of the shields used in the scope of PPE on vision quality)	My quality of vision decreased n (%)	191 (94.1)	Visual effects of masks and shields*	Fogging	181 (89.2)	22 (10.8)
				Light reflection	111 (54.7)	92 (45.3)
	It did not make a difference n (%)	12 (5.9)		Narrowing of the visual field	60 (29.6)	143 (70.4)

*Multiple options. COVID-19: Coronavirus disease-2019, PPE: Personal protective equipment

surgical team members experienced severe difficulties and limitations in the areas of respiration, vision, hearing-communication, thermal stress, mobility-occupational skills, and neurocognitive-psychological impact. They were also unprepared for strategies to reduce these challenges.

Effect of Operating Room COVID-19 PPE on Respiratory Quality

During the pandemic, the use of N95 masks was mandatory to prevent droplet contamination caused by aerosol-generating procedures and surgical smoke. Surgical mask (to prevent N95 mask from blood etc. and prolong its use) and full face shields (to protect eyes) have been added to this combination (5,6). Experimental studies indicate that masks cause CO_2 and moisture to accumulate in the mask, increasing respiratory resistance, making breathing difficult, and reducing air exchange (13-15). In the current study, >90% of the participants stated that they experienced a feeling of limitation in breathing due to this PPE. Symptoms such as anxiety, dizziness, dyspnea, and lightheadedness that may be associated with respiratory limitation were reported at lower rates. Similar to our study results, in a study conducted on surgeons, 67% reported respiratory problems related to prolonged use of the N95 mask, and surgeons reported feeling dyspnea, especially during prolonged operations (12). In a study evaluating the effects of masks on oxygen saturation (SpO_2), a significant decrease in SpO_2 (97.5% vs. 94%) and complaints such as shortness of breath and dizziness were observed in surgeons using N95 masks covered with surgical masks (16). Another study conducted on intensive care healthcare workers showed that the N95 mask caused a significant decrease in SpO_2 and an increase in dyspnea scores (17). In the same study, 60% of the participants reported dyspnea as a side effect of PPE. In another study on dental healthcare workers, the baseline SpO_2 value decreased significantly from 98.6% to 97.0% after 4 h of N95 mask use (18).

Table 3. Effects of operating room COVID-19 PPE on hearing-communication, thermal, movement-occupational skills, and neurocognitive-psychological domains (n=203)

Problems with operating room COVID-19 PPE		Yes n (%)	No n (%)
Limitations in hearing and communication (restriction in hearing and communication due to the use of N95 mask + surgical mask + face shield + coveralls)	Decreased hearing quality	125 (61.6)	78 (38.4)
	Decreased quality of communication within the team	190 (93.6)	13 (6.4)
Thermal problems (thermal effects caused by the combination of upper and lower uniform + coveralls + sterile surgical gown + shoes up to the knee)	Increased sweating	195 (96.1)	8 (3.9)
	Increase in the feeling of warmth	193 (95.1)	10 (4.9)
	Increased sensation of thirst	186 (91.6)	17 (8.4)
	Skin problems	173 (85.2)	30 (14.8)
Movement and occupational skills-related problems (the effects of the combination of upper-lower uniform + coveralls + sterile surgical gown + shoes up to the knee + double/triple gloves on movements)	Decreased mobility	179 (88.2)	24 (11.8)
	Limitation in hand skills (dissection, instrumentation, etc.)-fine motor movements	154 (75.9)	49 (24.1)
	Limitation on tactile sensation-sensitivity (associated with double/triple glove use)	163 (80.3)	40 (19.7)
	Decreased reaction speed in performing professional skills	142 (70.0)	61 (30.0)
	Prolongation of professional tasks and processing times	162 (79.8)	41 (20.2)
	Decreased physical tolerance-loss of strength	161 (79.3)	42 (20.7)
	Feeling an increased level of fatigue	193 (95.1)	10 (4.9)
Neurocognitive-psychological effects (neurocognitive-psychological effects of all PPE components)	Decreased concentration, attention, and perception	160 (78.8)	43 (21.2)
	Increased headache	167 (82.3)	36 (17.7)
	Difficulty in making decisions, forgetfulness	82 (40.4)	121 (59.6)
	Decreased psychological tolerance (endurance, patience)	173 (85.2)	30 (14.8)

COVID-19: Coronavirus disease-2019, PPE: Personal protective equipment

Table 4. Comparison of side effects operating room COVID-19 PPE's between occupational groups (n=203)

PPE related problems		Nurse n (%)	Surgent n (%)	Anesthesia technician n (%)	χ2 p
Limitation of respiration	It didn't make a difference	3 (17.6)	9 (52.9)	5 (29.4	χ2=1.990 p=0.370
	The quality of my breathing has decreased	64 (34.4)	80 (43.0)	42 (22.6)	
Limitation of vision	It didn't make a difference	5 (41.7)	2 (16.6)	5 (41.7)	χ2*=4.553 **p=0.037**
	The quality of my vision has decreased	62 (32.5)	87 (45.5)	42 (22.0)	
Limitation in hearing	It didn't make a difference	17 (21.8)	41 (52.6)	20 (25.6)	χ2*=7.360 **p=0.025**
	The quality of my hearing has decreased	50 (40.0)	48 (38.4)	27 (21.6)	
Communication breakdown	It didn't make a difference	2 (15.4)	9 (68.2)	2 (15.4)	χ2*=3.248 p=0.178
	Our quality of communication within the team has decreased	65 (34.2)	80 (42.1)	45 (23.7)	
Feeling of warmth	It didn't make a difference	2 (20.0)	2 (20.0)	6 (60.0)	χ2*=8.071 **p=0.027**
	My temperature sensation increased	65 (33.7)	87 (45.1)	41 (21.2)	
Sweating	It didn't make a difference	0 (0.0)	2 (25.0)	6 (75.0)	χ2*=10.241 **p=0.002**
	It increased my sweating	67 (34.4)	87 (44.6)	41 (21.0)	
Limitation in occupational hand skills - fine motor movements	It didn't make a difference	13 (26.5)	23 (46.9)	13 (26.5)	χ2=1.280 p=0.527
	Restricted my ocupational hand skills/ movements	54 (35.1)	66 (42.9)	34 (22.1)	
Physical tolerance	It didn't make a difference	9 (21.4)	22 (52.4)	11 (26.2)	χ2=3.242 p=0.198
	I have experienced my power diminishing	58 (36.0)	67 (41.6)	36 (22.4)	
Psychological tolerance	It didn't make a difference	6 (20.0)	11 (36.7)	13 (43.3)	χ2=8.409 **p=0.015**
	My psychological tolerance (endurance, patience) decreased	61 (35.3)	78 (45.1)	34 (19.7)	

χ2= Pearson chi-square, χ2*= Fisher Exact test, p<0.05. COVID-19: Coronavirus disease-2019, PPE: Personal protective equipment

Table 5. Training and precautions to reduce the side effects of operating room COVID-19 PPEs (n=203)

Items	Yes n (%)	No n (%)
Have you received additional training on the problems caused by the N95 mask and how to breathe while using this mask?	30 (14.8)	173 (85.2)
Have you received additional training on appropriate head movements to improve the quality of vision and prevent balance problems?	17 (8.4)	186 (91.6)
Have you received additional training to prevent PPE-related dehydration?	19 (9.4)	184 (90.6)
Has the operating room temperature been decreased to reduce the thermal stress associated with PPE in your operations?	54 (26.6)	149 (73.4)
Have precautions such as speaking face-to-face and slowly, repeating orders, etc., been taken within the team to reduce hearing and communication problems?	47 (23.2)	156 (76.8)
Has your department set a maximum value for the length of stay in operation to reduce the adverse effects of PPE on the staff and established routines such as changing the surgical team at the end of this period?	41 (20.2)	162 (79.8)
After surgical operations using PPE in your department, is rest time and opportunity provided to the personnel in an oxygen-rich area (e.g., open-air), and is it routinely used?	20 (9.9)	183 (90.1)
Does the staff have the opportunity to shower after surgical operations using PPE in your unit?	27 (13.3)	176 (86.7)

COVID-19: Coronavirus disease-2019, PPE: Personal protective equipment

Effect of Operating Room COVID-19 PPE on Visual Quality

Masks and full face shields may lead to decreased quality of vision with effects such as fogging, light reflection, and narrowing of the visual field and may complicate procedures (8). In our study, almost all participants reported deterioration in visual quality due to breathing with masks and using goggles/full-face shields. In this context, the biggest complaint was fogging of the shield surface by exhaled air. The complaint of decreased visual quality was significantly higher among physicians than among nurses and anesthesia technicians. Clear visualization of the surgical field is one of the factors affecting the success of the operation; therefore, it is understandable that surgeons are more sensitive to this issue. In studies conducted on surgeons (11,12,19,20), the adverse effects of PPE on visual quality were reported at varying rates of 58%, 63%, 82%, and 95%, respectively. Some experimental study results indicate that full-face shields narrow the surgical field of view in operations that require a microscope and that the surgical field of view is important for safe surgery (21,22).

Effect of Operating Room COVID-19 PPE on Hearing and Communication

Speech intelligibility and quality communication between healthcare workers are essential to fulfill their duties quickly and safely. The combination of N95 mask + surgical mask + full face shield may impair speech intelligibility by silencing the voice, and cap + suit hood may impair hearing (8). This effect, which impairs hearing and understanding of speech, may be more intense with operating room noise. In our study, most surgical team members stated that their hearing quality decreased, and almost all indicated difficulty in intra-team communication. The problem of hearing limitation was higher in operating room nurses than in physicians and anesthesia technicians. Experimental studies suggest that the mechanical barrier created by masks and shields has a negative effect on speech intelligibility and worsens speech recognition scores (23,24). In a study conducted on surgeons, those who reported impaired communication in relation to PPE were close to our results by 82% (20). However, communication impairment feedback was lower than our results in some previous studies 64%, 54%, 48%, and 46%, respectively) (11,12,18,19).

Thermal Effects of COVID-19 PPE in the Operating Room

A balance between heat gain and loss in the human body is needed to ensure thermal comfort. During the pandemic period in the operating rooms where the study was conducted, a protocol change was made against the risk of contamination, such as wearing a top and bottom uniform + coveralls covering the head and whole body in polyethylene structure + sterile surgical gown + plastic overshoes up to the knee. These multilayered liquid-air impermeable PPE components trap sweat and hot air between the wearer's clothing and body. They may cause thermal stress by preventing heat loss through radiation evaporation convection (2,8). In the current study, almost all surgical team members reported increased sensations of heat, sweating, and thirst, and a significant number of them also reported skin problems. Thermal stress and increased sweating were significantly higher in physicians than in nurses and anesthesia technicians. The fact that they had to perform a surgical operation with these PPEs and under powerful lighting may have had more intense thermal effects on the surgeons. The results confirmed the strong effect of COVID-19 PPE on healthcare workers' perception of thermal stress, which is in line with the results obtained from similar studies (12,25-27). For example, in a study by Saeed et al. (12) on surgeons, heat regulation problems were 67%, and participants reported that increased sweat caused skin irritation. In a study by Tabah et al. (25) on 4879 healthcare workers, 51% reported thermal effects and 47% reported thirst as an adverse effect of PPE. In another study, 78% of healthcare workers reported that they experienced thermal stress perception (26). In the same study, 35.6% described their thermal sensations as hot and 52.4% described them as scalding while working with PPE; thirst was reported by 58% and sweating by 70% (26). In a focus group analysis study, healthcare workers said they sweat much with this PPE, even with minimal effort, and feel like they are on a steamship (27). An experimental study found a significant increase in body temperature (36.40 vs. 37.05) and significant increase in surface temperature measured by thermal imaging (24.5 vs. 26.9 °C) compared with baseline values in healthcare workers performing routine tasks for 1 h in coveralls (28). The researchers concluded that COVID-19 PPE causes significant thermal stress affecting human performance (28).

Effect of Operating Room COVID-19 PPE on Motor Functions

Intraoperative tasks require combined cognitive, visual, and motor skills. Multilayered clothing and gloves may cause effects such as limitation of movement and difficulty in technical skills, and working with these PPEs may lead to a decrease in physical strength with the accumulation of all adverse effects (8). In the study, surgical team members reported high rates of decreased mobility (88%), decreased occupational skill reaction speed (70%), decreased physical tolerance (79%), and increased fatigue (95%) based on their

experience working with COVID-19 PPE. When the results of similar studies were analyzed, the reported increase in physical fatigue was 70% in one study (17). In comparison, the negative effect of PPE on comfort was reported as 92.6% in the study by Alarfaj et al. (20) and 60.7% in the study by Saeed et al. (12). The restriction of movement caused by these PPE components may lead to prolonged task and procedure times. In this study, 79% of the participants reported that it took longer to perform occupational tasks. Supporting this result, a study found that cecal intubation (4.27 vs. 4.88 minutes) and total procedure times (9.08 vs. 11 minutes) were significantly longer with COVID-19 PPE than with standard PPE (29). In this study, 75% of the participants reported limitations in occupational hand skills and 80% in tactile sensation. In an experimental study, double glove use in laparoscopic surgery increased incision errors (20.4 mm^2 vs. 16.9 mm^2) compared with single glove use (30). Unlike our results, in the Yánez Benítez et al. (11) study, 54% of the participants said that their surgical performance was affected, and in the Saeed et al. (12) study, those who stated that the dissection quality was affected were lower, such as 32%. In the study by Alarfaj et al. (20), over half of the surgeons said their instrument use technical skills were unaffected.

Neurocognitive-psychological Effects

Working with these PPEs, especially for prolonged periods, may impair cognitive performance secondary to respiratory, visual, hearing, and thermal effects (8). In the current study, side effects such as decreased concentration, psychological tolerance, and increased headache were reported at high rates. The decrease in tolerance-patience level was significantly higher in physicians than in other surgical team members. This difference was probably related to the fact that the primary responsibility and difficulty in performing a surgical operation was on the surgeons. Supporting our results, a previous study showed that the use of N95 significantly increased headache (59% vs. 15%), attention deficit (50% vs. 15%), and concentration problems (62% vs. 18%) compared with surgical masks (31). In our study, the effect of PPE on decision making/forgetfulness was reported at a low level (40%). In parallel with this result, the effect of PPE on decision making was reported as 48% in one study (11) and 27% in another study (20).

In the study, the participants were also questioned about their training to cope with the problems that may be experienced due to PPE. Most participants stated that they did not receive additional training on strategies to minimize side effects and did not have the opportunity to shower and rest outdoors after surgery. These results suggest that employees were not prepared to reduce the adverse impact of PPE and that the organization could not provide a suitable working environment and rest periods due to the pandemic conditions. Similar to this result, only 50% of the participants reported that they were trained to use this PPE and that training on the appropriate use of this equipment was lacking (19). In the literature, there are suggestions such as consciously controlling the breathing depth rate and focusing on slow-regular breathing to prevent respiratory problems due to masks (8). Users should remember that they should slowly turn their heads right- left/up- down in one axis to reduce the limited field of vision due to all face shields and to prevent dizziness (8). There are suggestions to increase speech intelligibility in the presence of a mask, such as speaking louder, repeating critical commands, reducing simultaneous conversations and additional noise, and using surgical hand signals (8,32). To minimize thermal stress, if there is no risk of hypothermia for the patient, it is recommended to reduce the operating room temperature, use cooling clothing, reduce the time spent working with PPE, or make staff change, adequate fluid intake, and regular measurement of body temperature (8,28). Employees should also be reminded to resist the urge to wipe their sweat.

All these undesirable physical, ergonomic, and cognitive effects may not only decrease the performance of surgical team members but also reduce their compliance with PPE. In this context, it is remarkable that more than half of the participants stated that they avoid wearing these PPEs because of the problems they experienced.

This study is specific in terms of evaluating the side effects of "operating room COVID-19 PPE" on all surgical team members and examining all side effects, not limited to a single effect area. The study's limitations are that it was single-centered, and the results were based on the combination of PPE and the participants' subjective evaluations. In future studies, it is recommended to assess these side effects comparatively in larger sample groups, with physiological parameters, and with different PPEs.

CONCLUSION

PPE, which is used to protect against biological, chemical, thermal, mechanical, and radiological hazards, should have a high protective effect, be easy to put on and take off, and be comfortable. In addition, it should not have side effects that reduce the performance of the users and impair their health.

The results showed that the multi-component, multilayered, heavy, and bulky PPE used in the pandemic is not suitable for intraoperative areas. Operating room COVID-19 PPEs have caused restrictions on many areas such as breathing,

vision, hearing, movement, and technical skills, increased the problems related to thermal stress, and reduced the psychological tolerance levels of the users. It was also found that surgical team members did not know the strategies to cope with these effects and tended to avoid using PPE because of the severity of these adverse effects.

Considering future pandemics, the results of this and similar studies should be taken as a serious warning about areas that require improvement to protect the health and well-being of healthcare workers. studies should be conducted toward designing equipment that will eliminate the identified problems. Therefore, scientists, engineers, and manufacturers must increase their efforts to develop new user-friendly, safe, and effective PPEs using existing technologies. In the design of this new PPE, there is expected to be a balance between the protective effects of this equipment and the serious adverse effects it may have on users.

*This study was produced from the master's thesis of Merve Turgut Eser.

ETHICS

Ethics Committee Approval: Ethical approval was first obtained from the Ministry of Health COVID-19 Scientific Research Evaluation Commission (08.04.2021/decision no: T16-58-10) and then from Biruni University Non-Interventional Research Ethics Committee (decision no: 2021/51-07, date: 21.05.2021) in accordance with the rules during the pandemic period. Permission was obtained from the institution where the study would be conducted (25.11.2021/decision no: 12).

Informed Consent: The purpose of the study was explained to the participants, and their informed consent was obtained.

Authorship Contributions

Concept: M.T.E., M.A., Design: M.T.E., M.A., Data Collection or Processing: M.T.E., M.A., Analysis or Interpretation: M.T.E., M.A., Literature Search: M.T.E., M.A., Writing: M.T.E., M.A.

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