Assessing the Stress of Surgeons and Surgical Residents Using a Wearable Smart Device

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Abstract

Although surgeon is one of the most stressful professions, only few studies have attempted to evaluate surgeons' stress using impractical methods. Meanwhile, many wearable devices have been introduced in the health-care market. This study aimed to assess surgeons' stress using a wearable device. Data were collected from 13 participants from June to September 2019. We checked level of stress, heart rate (HR) using Vivosmart4 (Garmin, Schaffhausenm, Switzerland) at rest and perioperatively, and also checked their perioperative self-perceived stress using the short-form State-Trait Anxiety Inventory (STAI). The perioperative stress level and HR significantly increased compared with resting state (stress level: 28.6 ± 18.2 at rest vs. 49.6 ± 25.5 before surgery vs. 55.1 ± 25.5 after surgery, $p < 0.001$; HR: 81.1 ± 6.2 at rest vs. 85.0 ± 11.5 before surgery vs. 85.0 ± 12.2 after surgery, $p = 0.001$). Scores on the short-form STAI significantly decreased after surgery (12.6 ± 4.9 before surgery vs. 11.7 ± 3.6 after surgery, $p = 0.001$). Stress level at rest was significantly higher among fellows and residents compared with professors (fellows: 40.7 ± 15.3 vs. residents: 29.9 ± 12.0 vs. professors: 13.2 ± 7.3, $p < 0.001$). We assessed surgeons' stress using a smart device and demonstrated that surgery significantly increased stress. The level of stress was higher among fellows and residents compared with professors.

Introduction

The surgical profession is one of the most stressful in medical practice; surgeons play key roles in acute care, cancer surgery, trauma surgery, and organ transplantation.[1] In general, surgeons have heavy workloads and long working hours and also face life-and-death situations. Many stressful situations occur in the operating room, such as technical, clinical, equipment, communication, and time pressure issues.[2] Many surgeons, including surgical residents and surgical fellows, perform operations under high pressure and stress.[3,4] Thus, surgeons are continuously exposed to many stressful situations, and such excessive stress could lead to burnout and have a negative impact on their performance and health condition, such as anxiety, depression, substance abuse, and even cardiovascular disease.[4–6] Therefore, monitoring the surgeon's stress could be meaningful for providing interventions and preventing burnout. Several studies have attempted to assess stress in surgeons. A common difficulty is that stress is highly subjective and cannot be monitored directly.[7] Several objective measures, such as heart rate (HR), skin conductance, salivary cortisol, and urine biopyrin, and questionnaire surveys have been introduced but most of them are experimental, complicated, expensive, and time-consuming procedures and thus not practical.[8–12]

Meanwhile, many wearable smart devices have been introduced and applied for checking daily lifestyles and health conditions. Especially, wrist-based devices that employ sensors to measure the electrical activity of the heart have replaced chest-strapped devices owing to their convenience and comfort.[13] In present study, we used wrist-worn wearable smart devices, which were deemed suitable given the busy nature of the operating room, to assess stress in surgeons. This study aimed to measure surgeons' stress using a wearable smart device and identify the risk factors of stress.

Methods

Participants

Attending faculty members, fellows, and residents from the division of colorectal surgery in Seoul St. Mary's Hospital, College of Medicine, The Catholic University of Korea, were recruited for the case-series study participation. Surgeons who had heart medications, cardiovascular or psychiatric disease, cardiac pacemaker, and tattoos around their wrists were excluded. The authors obtained informed consent from all participants. This study received approval from the institutional review board of Seoul St. Mary's Hospital (no. KC19OESI0460). Methods were carried out in accordance with relevant guidelines and regulations.

Materials, Instruments, and Tools

Wrist-worn Wearable Device

We used the wrist-worn wearable device Garmin vivosmart4 (Garmin®, Schaffhausen, Switzerland), which is equipped with a photoplethysmogram to measure HR and pulse oximetry (Fig. 1). This wearable device calculates the stress level based on heart rate variation (HRV), which is shown as a number on the digital display screen. The stress level ranges from 0 to 100, with a higher number indicating a higher level of stress. Our study recorded the stress level, HR, and oxygen saturation (SpO_2) using this wrist-worn wearable device. The collected data were shared to Android or Apple phones via Bluetooth and reviewed via the Garmin Connect app.

Short-form of the State-Trait Anxiety Inventory (STAI)

We used the short version of STAI developed by Marteau and Bekker[14] to assess the stress among surgeons. (Supplementary Table S1) This short-form STAI, modified from the original 40-item version developed by Spilberger at al.,[10] has been substantiated and found as an appropriate questionnaire for checking surgeons' stress level with consideration for the strict time constraints in the operating theater.[9] The short-form STAI consists of six items on a four-point scale from 1 to 4 and estimates anxiety. Total scores range from 6 to 24, with higher scores representing more perceived stress.

Data collection

Data were collected from June to September 2019 and all participants were asked to place the wrist-worn wearable device tightly above their ulnar styloid. The baseline stress level, HR, and SpO_2 were checked via the wrist-worn wearable device after 30 minutes of resting; during the resting period, all participants were asked to sit comfortably and to not perform any physical activity. All participants were also asked to check their stress level, HR, and SpO_2 using the wrist-worn wearable device shortly before and immediately after completing surgical procedure. They were also requested to fill out the questionnaire with the STAI short form before and after operation. Patient demographics were collected retrospectively before data analysis: sex, age, body mass index, underlying disease, and history of previous abdominal surgery to analyze the effect of patient factors on surgeon's stress. Further, we collected data associated with the surgeries, such as types of operation, time of operation, estimated blood loss, operation duration, and surgical complications. The participants also recorded their peritoneal adhesion index (PAI), which is based on the macroscopic appearance of peritoneal adhesions. The PAI score ranges from 0 to 30 and provides an accurate description of intra-abdominal adhesion.[15]

Statistical Analyses

SPSS for Windows (version 21.0, SPSS Inc., Chicago, IL, USA) was used for all statistical analyses. A *p* value of less than 0.05 was considered statistically significant. Descriptive statistics are presented as mean with standard deviation. The normal distribution of data was tested via the Kolmogorov–Smirnov test. Repeated measures analysis of variance (ANOVA) was used to compare values at the three time points of resting state, before surgery and after surgery. One-way ANOVA was used to determine differences in the parameters measured in the different study groups. This method was followed by post-hoc tests corrected by the Bonferroni method. Multiple linear regression analysis was performed to identify the factors independently associated with stress levels. Lastly, we conducted student's *t*-test for the statistical analysis of the variables between two groups.

Results

A total of 269 data were collected from the 13 participants and the 199 patients who underwent operation during study period. Table 1 summarizes the participants' demographic information, including baseline stress, HR, and SpO_2. Three professors and one assistant professor, as attending faculty members, along with four surgical fellows and five residents (9 men and 4 women) participated in this study. Data were collected properly; there were no missing data for the outcome variable. No participant had a history of psychiatric or cardiologic disorders or was taking any medication that could affect their endocrine or autonomic nervous system. All of the participants were non-smokers.

The clinicopathological characteristics of the patients who underwent operation during the study period are given in Table 2. Among the operations, 176 (88.4%) and 23 cases (11.6%) were elective and emergency surgeries, respectively. In terms of schedule, 184 cases (92.5%) were performed during day time (8 am to 6 pm), and 15 cases (7.5%) were performed at night (6 pm to 8 am). The perioperative level of stress and HR significantly increased compared with the resting state (stress level: 28.6 ± 18.2 at resting vs. 49.6 ± 25.5 before surgery vs. 55.1 ± 25.5 after surgery, $p < 0.001$; HR: 81.1 ± 6.2 at resting vs. 85.0 ± 11.5 before surgery vs. 85.0 ± 12.2 after surgery, $p = 0.001$). SpO_2 decreased significantly compared with the resting state (96.4 ± 0.9% at resting vs. 95.3 ± 3.0% before surgery vs. 95.1 ± 3.2% after surgery, $p < 0.001$). The short-form STAI scores significantly decreased after surgery (12.6 ± 4.9 before surgery vs. 11.7 ± 3.6 after surgery, $p = 0.001$) (Table 3, Fig. 2). The perioperative level of stress significantly increased compared with the baseline in all positions (professor, assistant professor, clinical fellow, resident) and all surgical teams (operator, first assistant, second assistant). We observed a significantly higher level of stress at resting state in the fellow group compared with the professor group (40.7 ± 15.3 vs. 13.2 ± 7.3, p <0.001) and in the resident group compared with professor group (29.9 ± 12.0 vs. 13.2 ± 7.3, p <0.001). However, the level of stress after surgery in professors was significantly higher compared with fellows (65.2 ± 20.5 vs. 54.5 ± 26.0, p <0.001) and residents (65.2 ± 20.5 vs. 55.6 ± 26.0, p <0.001). Similarly, baseline stress was significantly higher in the assistant group compared with the operator group, whereas postoperative stress was similar between the groups (Table 4). The years of clinical experience, patient's weight, and PAI were positively associated with the increment in the surgeon's postoperative level of stress (years of clinical experience: standardized coefficients β = 0.535, p <0.001; weight: β = 0.172, p = 0.019; PAI: β = 0.144, p = 0.018) We found no statistical differences in the perioperative stress levels between elective and emergency surgeries and time of operation (Table 5).

Table 1
Characteristics of Surgical Participants

Participants (n= 13)	**Age (Mean)**	**Sex (M/F)**	**Antiarrhythmic medications**	**Baseline stress (Mean)**	**Baseline HR (Mean)**	**Baseline SpO2 (Mean)**
Professor (n=3)	51.7	3/0	None	25.3	78	96.3
Assistant professor (n=1)	38	1/0	None	11	72	96
Clinical fellows (n=4)	34.8	2/2	None	34.5	81.5	97
Residents (n=5)	32.4	3/2	None	27.2	77.4	95.8
M, male; F, female; HR, heart rate;						

Table 2
Clinicopathological characteristics of patients in the department of colorectal surgery

Variables	N = 199
Age, mean ± SD (years)	60.6 ± 16.2
Sex, (M/F)	103/96
BMI, mean ± SD (kg/m^2)	23.6 ± 3.7
Number of underlying diseases, n (%)	
0	79 (39.7)
1	55 (27.6)
2	45 (22.6)
3	13 (6.5)
4	6 (3.0)
5	1 (5)
ASA score, n (%)	
I	34 (17.1)
II	146 (73.4)
III	17 (8.5)
IV	2 (1.0)
Previous abdominal surgery, n (%)	
Yes	79 (39.2)
No	121 (60.8)
Procedure category	
Small bowel	18 (9.0)
Appendix	15 (7.5)
Colon	75 (37.7)
Rectum	40 (20.1)
Anus	8 (4.0)
Inguinal hernia	16 (8.0)
Others	27 (13.6)

Types of surgery, n (%)	
Elective surgery	176 (88.4)
Emergency surgery	23 (11.6)
Approach, n (%)	
Open	51 (25.6)
Laparoscopic	110 (55.3)
Open conversion	4 (2.0)
Robot assisted	16 (8.0)
Not applicable	18 (9.0)
The time of surgery	
8am to 6pm	184 (92.5)
6pm to 8am	15 (7.5)
Use of vasopressors prior to surgery, n (%)	2 (1.0)
Operation time, mean ± SD (min)	132.1 ± 83.2
Estimated blood loss, mean ± SD (ml)	97.4 ± 141.4
pRBC transfusion, n (%)	10 (5.0)
Pathology, n (%)	
Benign disease	74 (37.2)
Malignant disease	125 (62.8)
AJCC stages of colorectal cancer, n (%)	105 (52.8)
0	6 (5.7)
I	23 (21.9)
II	27 (25.7)
III	29 (27.6)
IV	20 (19.0)
M, male; F, Female; SD, standard deviation; BMI, body mass index; AJCC, American Joint Committee on Cancer;	

Table 3
Changes of the level of stress, HR, SpO2 and short STAI

Variables (n = 269)	Baseline	Before surgery	After surgery	*p-value*
Stress	28.6 ± 18.2	49.6 ± 25.5	55.1 ± 25.5	*< 0.001*
HR	81.1 ± 6.2	85.0 ± 11.5	85.0 ± 12.2	*0.001*
SpO_2	96.4 ± 0.9	95.3 ± 3.0	95.1 ± 3.2	*< 0.001*
Short STAI	NA	12.6 ± 4.9	11.7 ± 3.6	*0.001*
HR, Heart rate; STAI, State-Trait Anxiety Inventory.				

Table 4
Changes of the level of stress by the surgeon's position and role.

(A) Changes of the level of stress by the surgeon's position

Variables	Professors (78 cases)	Assistant Professor (33 cases)	Clinical fellows (145 cases)	Residents (13 cases)	*p-value**
Baseline stress	13.2 ± 7.3	11.6 ± 3.3	40.7 ± 15.3	29.9 ± 12.0	*< 0.001*
Stress level: pre-operation	49.0 ± 20.9	22.3 ± 25.3	55.7 ± 24.2	53.3 ± 22.7	*< 0.001*
Stress level: post-operation	65.2 ± 20.5	34.0 ± 23.2	54.5 ± 26.0	55.6 ± 22.5	*< 0.001*
	< 0.001	*< 0.001*	*< 0.001*	0.002	
mean ± SD,					

Table 4
(B) Changes of the level of stress by the surgeon's role.

Variables	Operator (122 cases)	1^{st} assist (132 cases)	Second assist (15 cases)	*p-value**
Baseline stress	14.1 ± 7.7	41.9 ± 15.7	29.6 ± 7.6	*< 0.001*
Stress level: pre-operation	43.2 ± 26.4	54.6 ± 23.6	57.6 ± 22.3	*0.001*
Stress level: post-operation	56.2 ± 25.3	53.0 ± 26.4	65.7 ± 17.2	*0.051*
	< 0.001	*< 0.001*	*< 0.001*	
mean ± SD,				

Table 5
Comparing of the stress level according to the type of surgery

(A) Comparing of the stress level between elective and emergency operation

Variables	**Elective operation (237 cases)**	**Emergency operation (32 cases)**	***p-value****
Baseline stress	29.0 ± 18.7	25.8 ± 14.2	*0.341*
Stress level: pre-operation	49.2 ± 24.8	52.6 ± 30.5	*0.483*
Stress level: post-operation	56.1 ± 25.4	47.6 ± 26.0	*0.077*
mean ± SD,			

Table 5
(B) Comparing of the stress level between Day and Night

Variables	**Day (8am to 6pm) (246 cases)**	**Night (6pm to 8am) (23 cases)**	***p-value****
Baseline stress	28.6 ± 18.5	28.7 ± 15.8	*0.978*
Stress level: pre-operation	49.0 ± 25.1	56.2 ± 29.0	*0.196*
Stress level: post-operation	55.2 ± 25.8	53.9 ± 23.9	*0.813*
mean ± SD,			

Discussion

Studies have used several methods, such as HRV analysis, salivary cortisol estimation, and questionnaire surveys, to assess surgeons’ stress and have reported an association with intraoperative environment, night work, patient factors, and surgeon factors.[8,16,17] However, these previous methods are complicated, experimental, and not practical for checking stress in surgeons. In the present study, we used a commercially available wearable smart device for quantifying the level of surgeons’ stress in the operating theater. Using a novel, non-invasive and lightweight wrist-type wearable smart device was not only convenient and easy but also appropriate for the busy operational situations of surgeons; wearing and removing the wearable smart device and recording the results took less than five minutes.

One of the basic mechanisms for assessing stress in the wrist-worn wearable devices was the measure of HRV, which indicates the periodic variations in the HR and helps in the evaluation of the relative contributions of the sympathetic and parasympathetic nervous system. HRV has been proposed as a reliable biomarker of stress and health.[18] Other studies have reported surgeons' stress through assessing perioperative HRV.[2,4,19]

Our findings revealed that SpO_2 decreased significantly before and after surgery compared with the resting state. Although the pulse oximetry transcutaneously monitors functional SpO_2 of hemoglobin in arterial blood, SpO_2 could be underestimated in the cold temperature of the operation room, which causes vasoconstriction of the peripheral blood vessels of surgeons.[20] Additionally, the usage of surgical masks could have an effect of decreasing SpO_2 in surgeons.[21]

When we designed this study, we hypothesized that surgeons' stress would increase before and decrease after surgery. Our findings showed that stress significantly increased shortly before surgery compared with the baseline level. However, the stress level after surgery remained significantly higher; only the short-form STAI score significantly decreased after surgery. Thus, the surgeons were still under high physical stress even after surgery, whereas the psychological stress tended to be resolved after surgery.

In the present study, we found that the baseline stress was significantly higher in clinical fellows compared with surgical residents and professors. The work hours of surgical residents in South Korea have been capped at 80 hours/week, according to policy imposed in 2017. However, this limitation does not apply to clinical fellows, who continue to have extremely heavy workloads compared with other medical positions. Clinical fellows also play a pivotal role in perioperative care in most tertiary hospitals in South Korea. Thus, they are consistently exposed to stress related to inpatient management, including critical care. This could explain the highest stress level being reported among clinical fellows compared with their colleagues.

Meanwhile, the baseline stress level of professors was significantly lower compared with the other groups, but their postoperative stress level was significantly higher. Professors are responsible for surgeries as the main surgeon. Main surgeons are under environmental, physiological, and psychological pressure, as well as carry the responsibility for patients' prognoses and the possibility of surgical complications. In the present study, the years of surgical experience, patient's weight, and PAI were significantly associated with increments in the stress of surgeons. In general, obesity and PAI are usually associated with surgical difficulties and longer operation time, which could increase the surgeon's stress.

The pre-operative period of emergency operations is especially more stressful for surgeons; their stress level is observed to decrease in the post-operation period.[22] The uncertainty of emergency cases and resuscitation of critically ill patients could be important stress factors for surgeons. However, we found no significant difference between emergency and elective surgeries in terms of the stress level of surgeons. The participants' pre-operative stress level was higher and their post-operative stress level lower in emergency operations, but not to a statistically significant degree. We also observed that night-time surgery did not increase the surgeon's stress significantly compared with day-time surgery. However, considering that night duty could influence the efficiency of the surgeon for the next day's duty, which could be associated with the patient's safety, hospitals should consider giving surgeons the day off after night duty to prevent burnout among surgeons.

This study has several limitations. First, the wrist-worn wearable device could not be worn by surgeons during operations owing to contamination concerns. Therefore, we could not obtain data on the intraoperative changes in surgeons' stress. Several chest-strap type monitors have been introduced, but these cause chest tightness and are uncomfortable for surgeons.[23] Second, the categories of surgery were limited. Finally, we did not consider the experience and learning curves of residents and clinical fellows.

The use of smart devices in the health care industry is progressing in many areas. At present, many studies using wearable smart devices have been conducted on patients and workers in other fields, such as aviation, but rarely among medical professionals. The current work showed that surgeons' stress significantly increased before and after surgery compared with their resting state, and clinical fellows' stress was significantly higher compared with residents and professors. As far as we know, this is the first study to assess the stress level of surgeons, fellows and resident using commercially wearable smart device which gives subjective stress level. Our findings can be used to provide a better working environment for surgeons and help them preventing burnout.

In conclusion, we assessed surgeons' stress using a wearable smart device and demonstrated that surgery significantly increased stress. A wearable smart device could be an intuitive and feasible method to estimate surgeon's stress in the busy nature of the operating room.

Declarations

Data availability

Data are available in supplementary material.

Author contributions statement

The research was conceived and designed by JJK and CSL. The data collection was conducted by WRK and JHB. The data analysis and carried out by SRH, JJK, DSL and IKL, The paper was written by JJK and YSL. Editing was performed by YSL. All authors reviewed the manuscript.

Competing Interests

The authors declare no competing interests,

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Figures

Figure 1

Garmin vivosmart4 (Garmin®, Schaffhausen, Switzerland)

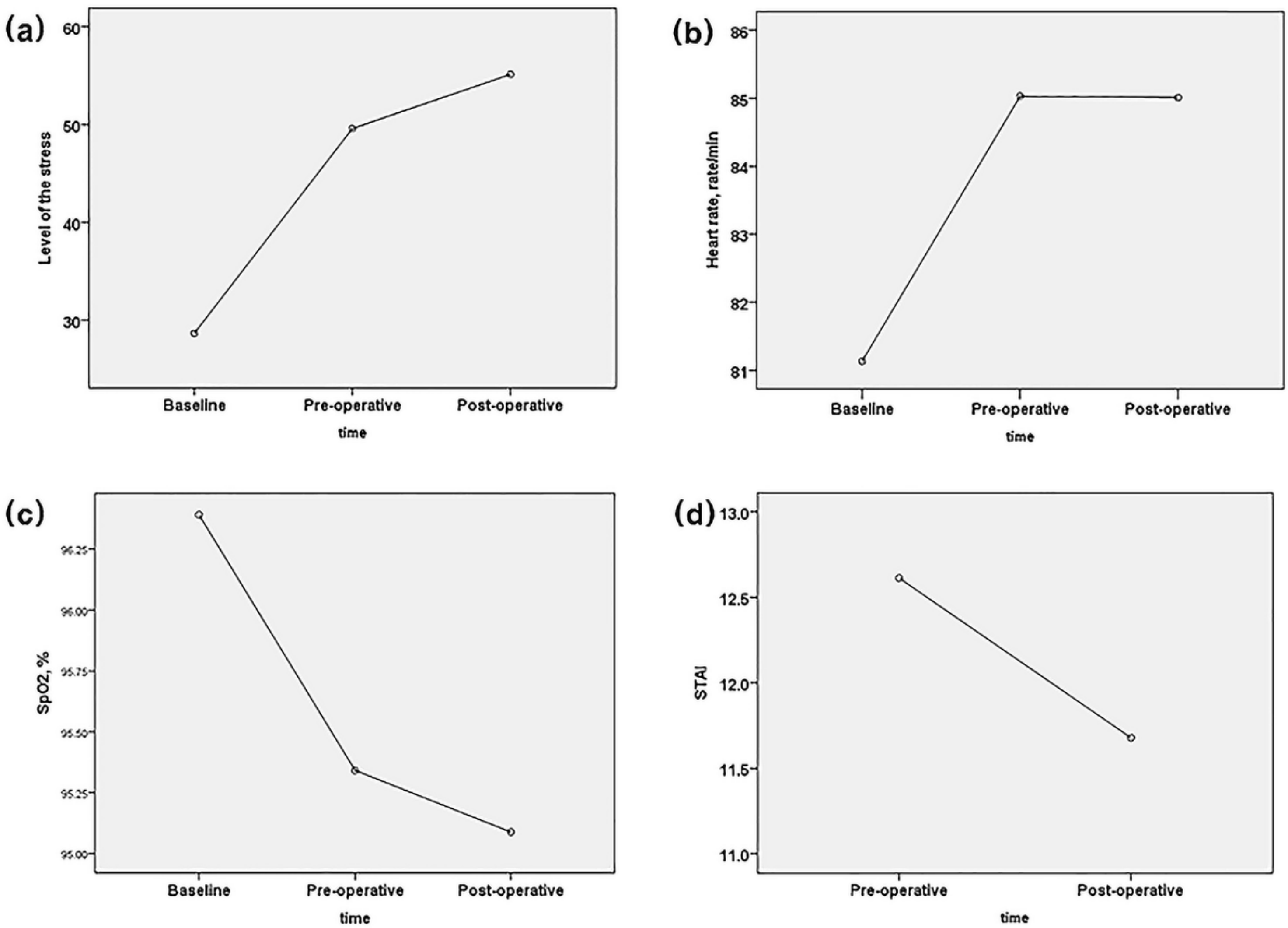

Figure 2

Changes of variables baseline, preoperative and postoperatively. (a) Changes of the level of stress (b) Changes of heart rate, rate/min (c) Changes of SpO2, % (d) Changes of STAI

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryDataset.xlsx
- SupplementaryInfoFile.docx