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Cognitive and psychophysiological impact of surgical mask use during university lessons

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ABSTRACT

The aim of the present study was to analyze the impact of surgical mask use in cognitive and psychophysiological response of university students during a lesson. We analyzed 50 volunteers university students (age 20.2 ± 2.9) in two 150 min lessons. i. personal class using a surgical mask and ii. online class with student at home without the mask. Blood oxygen saturation, heart rate and heart rate variability, mental fatigue and reaction time were measured before and immediately after both lectures. We found how both lesson produced an increase in mental fatigue, reaction time and autonomous sympathetic modulation, being heart rate significantly higher (77.7 ± 18.2 vs. 89.3 ± 11.2 bpm, not mask, mask respectively) and blood oxygen saturation significantly lower (98.4 ± 0.5 vs. 96.0 ± 1.8%, mask, not mask respectively) using the surgical mask. The use of surgical mask during a 150 min university lesson produced an increased heart rate and a decrease in blood oxygen saturation, not significantly affecting the mental fatigue perception, reaction time and time, frequency and nonlinear hear rate variability domains of students.

1. Introduction

Since the apparition of the SARS-Cov-2 in the city of Wuhan, (Hubei, China) in December 2019, governments around the world have taken unprecedented actions to respond and contain it [1]. Countries are implementing different community, economic, and public health control measures to flatten the epidemic curve and avoid overload and possible collapse of their health systems. To date, the attenuation of reproduction/infection cases is given via suppression measures. This action aims to lead the R-naught of the virus below R1 with the use of non-pharmaceutical interventions till a vaccine is available, which according to recent data could be likely at least 12–18 months [2]. Among the policies implemented we can highlighted the travel bans, social distancing, stay-at-home orders and general lockdowns, however while the conjunction of these measures have proven their efficacy, it has also shown severe impact and consequence for the economy and society [1, 3].

Since the pandemic seems to be lasting for a long time, governments need to find alternatives to severe measures as strict lockdowns [4]. Given that the main pathway of transmission is via droplets (generally 5–10 μm) that have a short lifetime in the air and infect the upper respiratory tract, or finer aerosols, which may remain in the air for hours, the mandated use of mask seems like an effective non-pharmaceutical intervention to combat COVID-19 lockdowns [5]. However, at the beginning of the pandemic, the World Health Organization did not recommend the use of face mask as a preventive measure [6]. In the middle of the outbreak (May), there were not high-quality controlled trials addressing the question of wearing masks by the general population as a protective measure to contain COVID-19, and analogies were made with the influenza or SARS [7]. Meanwhile, other health agencies as the centre of Disease and Prevention of the US (CDC), recommended the use of face masks, as an effective way to reduce the spread of the virus [8]. In the same line, the European Center of Disease, Control and Prevention (ECDC), also highlighted the importance of its use whereas social distancing cannot be maintained [9].

In general terms, countries are implementing the use of mandatory face mask at all time, independently of the context and situation while staying at public [10]. This has risen a new question while some controversy is still rising about the chronic use of face masks. In this line, while the SARS outbreak, the prolonged use of face mask by healthcare workers, resulted in headaches [11], and adverse skins reactions such as rashes, acne, and itches [12]. So on, recent research suggest that

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prolonged use of masks causes a host of physiologic and psychologic burdens and could decrease work efficiency [13].Indeed, authors stated that chronic use of FPII and surgical mask of healthcare workers in the actual pandemic lead to headaches, breathing difficulty, acne, skin breakdown, rashes, interferes with vision, communication, and thermal equilibrium [13].

Despite most of the professions are subjected to telecommuting (mask-free), some sectors like education, are still face-to-face or combining online classes with traditional personal classes. Therefore, students and professors are a collective subjected to mandatory and chronic use of face mask for over 8 h (average duration of a school day). Yet, there are no studies focusing on this population, addressing the acute and chronic psychophysiological effects of face masks, as well as its impact on cognitive performance. Therefore, we conducted the present research with the aim of to analyze the impact of surgical mask use in cognitive and psychophysiological response of university students during a lesson. The initial hypothesis was that the use of surgical mask would increase the autonomic sympathetic modulation, decreasing cognitive performance and blood oxygen saturation.

2. Materials and methods

2.1. Participants

We analyzed a total of 50 volunteers university students (age 20.2 ± 2.9). From those, 38 were male students (age 21.2 ± 1.6) and 12 female students (age 21.1 ± 1.1). The exclusion criteria were: presence of any medical condition, intake of any dietary supplement, stimulants or other ergogenic aids. Prior to participation, the experimental procedures were explained to all the participants, who gave their voluntary written informed consent in accordance with the Declaration of Helsinki.

2.2. Procedure

To reach the study aim we analyzed the students in two different moments. i. personal face-to-face class in where the use of the mask is mandatory during the entire lecture time. Surgical masks used by students were distributed by the University, therefore all students used the same model with the same face-fit; ii. online class with student at home did not wearing the mask. Both lectures were given at 8:30 A.M and have a duration of 150 min. Both classes were regular magistral classes of biomedical students attending one theorical class. The following variables were measured before and immediately after both lectures.

Blood oxygen saturation by an oximeter OXYM4000 (Quirumed, Madrid), placed in the index finger of the right arm.

Heart Rate (HR) and Heart Rate Variability (HRV) were recorded before and after the lectures by a Polar V800 HR monitor (Kempele, Finland) in a prone position following the procedures of previous research in educational context (Ramírez-Adrados et al.,2020a;2020b). The V800 has a sampling frequency of 1000 Hz being able to register the RR intervals (time interval between R waves of the electrocardiogram) for the analysis of the HRV and the number of beats per minute for the HR analysis. Subsequently, the following parameters of the HRV domains were analysed using the Kubios HRV software program with no factor of correction, since the measures obtained were clean and free of noise (University of Kuopio, Kuopio, Finland):

- Time-Domain (Nonspectral) Analysis. We recorded the Mean RR (ms) and the square root of the mean value of the sum of squared differences of all successive R-R intervals RMSSD (ms).
- Frequency-Domain (Spectral Measures) Analysis. We analysed the low frequency (LF) and high-frequency (HF) power components in normalized units (n.u). The frequency ranges where, HF: 0.15–0.40 Hz and LF: 0.04–0.15 Hz.
- Nonlinear domain analysis. SD1 and SD2 were measured to reflect the fluctuations of the HRV throw a Poincaré chart, physiologically, on the transverse axis. SD1 reflects parasympathetic activity while SD2 reflect the long-term changes of RR intervals and is considered as an inverse indicator of sympathetic activity

Among the HRV analysis, no artifact correction was used, since the sample did not present any noise.

- -Mental fatigue perception. By a scale ranged from 0–100, as in previous research (Redondo-Flórez et al.,2020)
- -Reaction Time. Was measured throw a mobile app. Screen of the phone would be entirely white, randomly it would turn to a color and subject had to immediately react to the change and tap the screen. Participants were previously familiarize with the app, and the evaluations days 3 measures were taken before and after the class. The mean of this three moments would be the final value taken.

2.3. Statistical analysis

The SPSS statistical package (version 21.0; SPSS, Inc., Chicago, Ill.) was used to analyze the data. Normality and homoscedasticity assumptions were checked with a Kolmogorov-Smirnov test. Differences between pre and post samples of the two situations evaluated were analyzed using a MANOVA with samples as a fixed factor and with a Bonferroni post hoc analysis. The Effect Size was tested by the $\eta 2$. Finally, a bivariate correlation analysis between all the study variables was performed using a Pearson correlation analysis. The level of significance for all the comparisons was set at $p \leq 0.05$.

3. Results

Data are presented as mean±sd. The MANOVA results indicate significant differences between the situations analyzed (Wilks lambda=0.256; $F = 5.219$; hypothesis degrees of freedom: 30; error degrees of freedom: 264.844; p=.000; $\eta 2$=0.365). The mental fatigue perception and reaction time significantly increased after both class situation (with and without surgical mask use). By contrary blood oxygen saturation was higher when surgical mask was not used. Regarding HRV parameters there was a decrease in Mean RR, RMSSD and HF after the class, being higher with the surgical mask use (Table 1).

Regarding the correlation analysis we found positive significant correlations between mental fatigue perception and reaction time, LF and SD2, by contrary mental fatigue perception presented a negative significant correlations with the blood oxygen saturation, Mean RR, RMSSD, HF and SD1. The reaction time presented a positive significant correlation with LF and a negative significant correlation with the blood oxygen saturation, RMSSD, HF and SD1 (Table 2).

4. Discussion

The aim of the present study was to analyze the impact of surgical mask use in cognitive and psychophysiological response of university students during a lesson. The initial hypothesis was partially accomplished since the use of surgical mask produced an increased hear rate, and a decrease in blood oxygen saturation, but did not significantly decrease more than non-surgical mask condition the cognitive performance and HRV variables.

We found a significant decrease in the blood oxygen saturation after the class with mask use. It seems how the prolonged use of surgical mask (150 min) negatively affect blood oxygen saturation. This data was in line with previous research conducted in surgeons during 1–4 h surgeons, where the blood oxygen saturation decreased from 98% to 96% [14]. In this studio researcher also reported a significant increase in HR (from 85 to 90 bpm), tendency also measured in the present research where a significant 13 bpm was measured with the use of surgical mask [14]. The inhalation of the exhaled CO2 that mechanically stops the mask would produce physiological modifications to compensate the

Table 1
Study variables modification with and without the surgical mask conditions evaluated.

	Non-Surgical Mask		Surgical Mask		P	η2	Moment Comparison
	Pre (1)	Post (2)	Pre (3)	Post (4)			
Mental fatigue perception	37.2 ± 10.8	48.5 ± 9.4	38.4 ± 13.2	56.3 ± 16.2	*P*<.001	.284	2>1; 2>3; 4>1; 4>3
Reaction time (ms)	.621±.134	.739±.151	.655±.150	.783±.191	.001	.150	2>1; 4>1; 4>3
Blood oxygen saturation (%)	98.2±.0.2	98.4 ± 0.5	98.4 ± 1.1	96.0 ± 1.8	*P*<.001	.390	1>4; 3>4; 2>4
Mean RR (ms)	903.8 ± 135.9	804.4 ± 152.2	965.8 ± 109.1	854.0 ± 143.1	*P*<.001	.166	1>2; 3>2; 3>4
Mean HR (bpm)	71.4 ± 14.6	77.7 ± 18.2	78.6 ± 9.4	89.3 ± 11.2	*P*<.001	.288	1<4; 3<4; 2<4
RMSSD (ms)	75.1 ± 14.1	55.8 ± 18.0	77.6 ± 14.8	53.9 ± 16.9	*P*<.001	.320	1>2; 1>4; 3>2; 3>4
LF (n.u.)	58.5 ± 8.1	63.4 ± 11.0	60.1 ± 8.4	65.4 ± 10.5	.047	.077	
HF (n.u.)	46.4 ± 10.8	37.8 ± 12.7	45.6 ± 10.7	34.5 ± 10.6	*P*<.001	.175	1>2; 1>4; 3>4
SD1 (ms)	48.4 ± 10.9	45.2 ± 12.1	48.8 ± 12.8	42.3 ± 11.5	.171	.049	
SD2 (ms)	84.6 ± 12.4	91.7 ± 13.5	83.7 ± 8.9	91.5 ± 11.3	.019	.095	

Mean RR, RR intervals mean, Mean HR, heart rate mean; RMSSD, root-mean square differences of successive heartbeat intervals; LF: low-frequency band; HF: high-frequency band; SD1, transverse axis; SD2, longitudinal axis; ms, milliseconds; n.u., normalized units.

Table 2
Correlation analysis results.

		Mental Fatigue Perception	Reaction Time	Blood oxygen saturation
Reaction Time	r	.492		
	p	0.000		
Blood oxygen saturation	r	−0.270	−0.253	
	p	0.002	0.005	
Mean RR	r	−0.225	−0.144	−0.033
	p	0.022	0.145	0.740
Mean HR	r	−0.087	−0.045	0.082
	p	0.353	0.632	0.031
RMSSD	r	−0.406	−0.287	.207
	p	0.000	0.002	0.026
LF	r	.435	.440	−0.176
	p	0.000	0.000	0.058
HF	r	−0.331	−0.446	.240
	p	0.000	0.000	0.010
SD1	r	−0.192	−0.304	.274
	p	0.039	0.001	0.003
SD2	r	.273	0.132	−0.092
	p	0.003	0.158	0.328

Mean RR, RR intervals mean, Mean HR, heart rate mean; RMSSD, root-mean square differences of successive heartbeat intervals; LF: low-frequency band; HF: high-frequency band; SD1, transverse axis; SD2, longitudinal axis; ms, milliseconds; n.u., normalized units.

lower O2 inhalation. In this line, blood pressure and aortic and left ventricular pressures increase, leading to an upsurge of cardiac and coronary workload finally increasing the HR [15,16]. The decrease of blood oxygen saturation after the use of surgical mask, even significant, would not be clinical relevant, since the blood oxygen saturation remained in normal range (90–98%) [17], fact also applicated to the HR that was maintained in normal resting values (60–100 bpm) [18]. Only when the use of mask is maintained in time (over 8 h in healthcare professionals) symptoms of hypoxemia such as chest discomfort and tachypnoea are presented [19]. These response could be explained sine CO2 is a respiratory stimulant, and when is accumulated by the mask use increase lung ventilation and respiratory activity, fact that would explain the symptoms of confusion, impaired cognition, and disorientation, experienced by nurses [13]. It would be interesting to analyze present student after the entire university classes day (8 h approx..) to check if the same response of healthcare professionals is presented also by them, but future research may seek this item.

Regarding cognitive performance, we found how the class produced a significant increase in mental fatigue perception of student independently of the use or not of the surgical mask, sowing the mask situation a tendency to be higher than in the non-mask situation. Probably the duration of the lesson was to long, inducing this increased fatigue perception. According to the mental fatigue perception results, the reaction time also increased after the lesson, fact related with a decrease in information processing and cortical arousal, situation related with symptoms of Central Nervous System by previous authors [20,21]. Also, this parameter showed a tendency to be higher than in the non-mask situation. The impact in these cognitive variables could be related with the decrease in the blood oxygen saturation found with the use of surgical mask. In this line, the correlation analysis showed a negative correlation between blood oxygen saturation and mental fatigue perception and reaction time. This result is in line with previous research that found how cognitive performance is associated with cerebral oxygenation and peripheral oxygen saturation [22]. Then could be important to maintain cognitive resources during the entire class make some brakes to try decrease cortical demands and maintain blood oxygen saturation, since the option of live the mask is already not recommended in the actual situation.

Regarding the autonomic modulation of students, we found how the 150 min lecture produced a decrease in Mean RR, RMSSD and HF, modifications related with an increased sympathetic modulation. This increase in the autonomic stress response was also measured in other university context as clinical stays, clinical simulations, clinical practice, final degree dissertations and objective structured clinical examination [23-26], but in these cases the autonomic stress response was higher highlighting how the level of context elicitation have a direct impact in the autonomic response, since in the case of present study students they have a passive interaction in the lessons but in the others research students have an active interaction, in most of the cases interacting with patients and/or with the stress of being evaluated by teachers. Regarding the effect on the autonomic response of the surgical mask use, we only found a tendency to a general decrease in heart rate variability, fact related with a higher sympathetic modulation. Recent studies suggested that the chronic use of face mask result in an increased sympathetic modulation due to the increased hypoxia state, that consequently carries an increased stress, headaches, impaired motor function and cognition (Rosner., 2020). In the present research the low time exposition to the surgical mask use precluded these symptomatology, but it might expect that after the full school day they might arise. In these cases in where the surgical mask must be used for prolonged time, previous authors suggested take off the mask whereas possible and take deep breath for three minutes to quickly release the stress. If the condition does not allow people to take off the mask, wear a mask and take a deep breath for three to five minutes to relieve stress and hypoxia [27].

Finally, the correlation analysis shown the importance of blood oxygen saturation for a correct cognitive function since presented a significant negative correlation with mental fatigue perception and reaction time. In this line the blood oxygen saturation presented a significant negative correlation with sympathetic modulation parameters, and this sympathetic modulation parameters a significant positive correlation with mental fatigue perception and reaction time. It is shown how cognitive functions would be beneficiate by a domain of parasympathetic modulation, as well as a higher blood oxygen saturation.

The importance of blood oxygen saturation in cortical functions was highlighted when an increase in respired oxygen in a group of participants produced an increase in their cognitive performance [28] Then, in educational context, especially when the mask must be used for prolonged time, would be recommend making some break to lead students to decrease their sympathetic modulation as well as to increase their blood oxygen levels.

4.1. Limitation and future practical applications

The first limitation was the low sample size, but the limitations, restrictions, and COVID-19 health protocols precluded to recruit a larger sample. It would be optimal to analyze the cerebral tissue oxygen saturation for better comprehension of the impact of surgical mask in cognitive physiology. Also the control of certain stress hormones such as cortisol or alpha amylase would help into a better understanding on the stress response and HRV results. However, technological, and financial lack precluded its applications. Future research might seek to address these issues. In addition, the study of surgical mask use in professor, as well as the long time use of surgical mask in students and professors are proposed as future research lines.

5. Conclusion

The use of surgical mask during a 150 min university lesson produced an increased heart rate and a decrease in blood oxygen saturation, not significantly affecting the mental fatigue perception, reaction time and time, frequency and non linear hear rate variability domains of students.

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