



# The effect of N95 and surgical masks on mucociliary clearance function and sinonasal complaints

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## Abstract

**Purpose** The aim of this study was to reveal the effect of N95 and surgical masks on mucociliary clearance function and sinonasal complaints.

**Methods** Sixty participants were enrolled in this study, including 30 people in N95 mask group and 30 people in surgical mask group. Two interviews, three days apart, were performed with all participants. The participants were asked not to use any mask before the first interview while they were asked to use the determined mask just before the second interview for 8 h. In both interviews, the mucociliary clearance times (MCTs) were measured and participants were asked to score ten distinct sinonasal complaints using visual analog scale (VAS). Data obtained from first interview were named pre-mask data, data obtained from second interview were called after-mask data. In both groups, pre-mask MCTs and VAS scores were compared with after-mask MCTs and VAS scores.

**Results** After-mask MCTs (mean =  $13.03 \pm 6.05$  min) were significantly longer than pre-mask MCTs (mean =  $10.19 \pm 4.21$  min) in N95 mask group ( $p = 0.002$ ). No significant difference was found between after-mask and pre-mask MCTs (mean =  $12.05 \pm 5.21$  min, mean =  $11.00 \pm 5.44$  min, respectively) in surgical mask group ( $p = 0.234$ ). When after-mask VAS scores were compared with pre-mask VAS scores, it was found that N95 mask use increased nasal blockage and postnasal discharge, surgical mask usage increased nasal blockage.

**Conclusion** While the use of N95 mask leads to nasal blockage and postnasal discharge, surgical mask use results in nasal blockage. N95 masks cause impairment in mucociliary clearance function. But all these effects are mild. Surgical masks have not been found to have any effect on mucociliary clearance function.

**Keywords** N95 mask · Surgical mask · Mucociliary clearance · Sinonasal complaints

## Introduction

N95 and surgical masks are among the personal protective equipment that are commonly used. The importance of these equipment is better appreciated in the COVID-19 pandemic. During this pandemic, healthcare professionals had to wear the N95 and surgical mask for long hours. It is also recommended that the masks be used by the people in public areas due to the pandemic. During the use of these masks, the breathing takes place through the pores on the masks. Since respiration made in this way is not a physiological

respiration, some effects in the body are inevitable. The literature review revealed that there are many studies on how masks affect the systems in the body [1, 2]. On the other hand, there are small number studies on how the various types of masks affect the upper respiratory tract physiology and complaints related to the upper respiratory tract.

Mucociliary clearance function is a crucial defense mechanism of the nose and paranasal sinuses. Disruption of this function causes accumulation of secretions and secondary infections [3]. Temperature, humidity, pH and partial oxygen pressure are factors that affect this function [4]. Furthermore, it has been found that this function is impaired in many pathologies that affect the upper respiratory tract directly or indirectly [5, 6]. During breathing through masks, the humidity, temperature, and resistance of inhaled air are altered [7]. Changes in all these parameters may affect mucociliary clearance function. In addition, breathing

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through these masks for a long time may cause an increase in complaints related to the upper respiratory tract.

In this study, the effect of N95 and surgical masks on mucociliary clearance function and sinonasal complaints was investigated.

## Materials and methods

This study was conducted in the Department of Otorhinolaryngology of XXXXXXXX Yozgat Bozok University after the approval of the local ethics committee. Sixty participants were enrolled in the study, including 30 individuals in N95 mask group and 30 individuals in surgical mask group. Written informed consent was obtained from all participants before enrollment in the study. Those with a diagnosis of nasal polyposis, sinusitis, allergic rhinitis, vasomotor rhinitis, diabetes, kidney failure, smokers, a history of nasal surgery and those younger than 18 and older than 65 years were excluded from the study. Participants were randomly allocated to the groups. Fifteen of the N95 mask group were women and 15 were men. Of the surgical mask group, 16 were women and 14 were men. The mean age of the N95 mask group was  $29.17 \pm 3.98$ , while the average age of the surgical mask group was  $28.03 \pm 4.30$ . There was no difference between the two groups in terms of age and gender (For gender  $p = 0.796$ , for age  $p = 0.294$ ). Two interviews were performed with all participants, three days apart. Before the first interview, the participants were asked not to use any type of mask. Just before the second interview, they were asked to wear the specified mask type (N95 or surgical mask) for 8 h. In both interviews, the mucociliary clearance function of the participants was evaluated and they were asked to score determined sinonasal complaints according to their feelings during the interview using VAS (0 = No complaints, 10 = the worst possible level). The data obtained from the first interview were named pre-mask data, and the data obtained from the second interview were called after-mask data. Mucociliary clearance function was evaluated using the saccharin test. This test was carried out by the same otorhinolaryngologist. The saccharin test was applied from the same nasal passage in both interviews. Participants were asked not to eat or drink within one hour before the test. During the test, the participants were told to stay in an upright position, not to blow their nose or sniff. A 1-mm-wide piece of sodium saccharin was placed on the antero-medial surface of the inferior concha. MCT was accepted as the time from tablet insertion until the sugar was tasted. In addition, the participants were asked to rate their complaints of need to blow nose, nasal blockage, sneezing, runny nose, cough, postnasal discharge, thick nasal discharge, ear fullness, ear pain, facial pain/pressure using VAS, according to what they felt during the first and second interviews. The

mean MCT and the mean VAS score for each complaint in the N95 and surgical mask group at the second interview (after-mask) were compared with those obtained in the first interview (pre-mask). The aim of the study was to reveal the effect of N95 and surgical mask on mucociliary clearance function and sinonasal complaints.

Statistical analyses were performed using the Statistical Package for Social Sciences (SPSS) version 15. The variables were investigated using visual (histograms, probability plots) and analytical methods (Kolmogorov–Smirnov test) to determine whether or not they are normally distributed. Paired samples *t* test/Wilcoxon signed-rank test was run to compare the data at two time points (pre-mask and after-mask) for MCT and VAS scores of sinonasal complaints in N95 mask group and surgical mask group. A *p* value of less than 0.05 was considered to show a statistically significant result.

## Results

In the N95 mask group, pre-mask mean MCT was  $10.19 \pm 4.21$  min. and aftermask mean MCT was  $13.03 \pm 6.05$  min. This difference was statistically significant ( $p = 0.002$ , Table 1). There was no statistically significant difference between the pre-mask mean MCT ( $11.00 \pm 5.44$  min.) and after-mask mean MCT ( $12.05 \pm 5.21$  min.) in the surgical mask group ( $p = 0.234$ , Table 1).

After-mask mean VAS scores of nasal blockage and postnasal discharge complaints ( $3.27 \pm 2.97$ ,  $2.90 \pm 2.88$ , respectively) were higher than pre-mask mean VAS scores ( $1.97 \pm 2.18$ ,  $2.13 \pm 2.44$ , respectively) in the N95 mask group. These differences were also statistically significant ( $p = 0.010$ ,  $p = 0.015$ , respectively, Table 2). Similarly, in the surgical mask group, after-mask mean VAS score of the nasal blockage complaint ( $3.97 \pm 2.48$ ) was statistically significantly higher than pre-mask mean VAS score of this complaint ( $3.67 \pm 2.38$ ,  $p = 0.037$ , Table 2).

**Table 1** Comparison of after-mask mucociliary clearance times with pre-mask mucociliary clearance times in groups

	Mucociliary Clearance time(minutes)		<i>p</i>
	Pre-mask	After-mask	
N95 Mask group	$10.19 \pm 4.21$ min	$13.03 \pm 6.05$ min	0.002 <sup>a*</sup>
Surgical mask group	$11.00 \pm 5.44$ min	$12.05 \pm 5.21$ min	0.234 <sup>b</sup>

<sup>a</sup>Wilcoxon signed-rank test

<sup>b</sup>Paired samples *t* test

\*Statistically significant

**Table 2** Comparison of after-mask sinonasal complaints VAS scores with pre-mask sinonasal complaints VAS scores in groups

Complaints	N95 mask group		<i>p</i>	Surgical mask group		<i>p</i>
	Pre-mask VAS	After-mask VAS		Pre-mask VAS	After-mask VAS	
Need to blow nose	2.43 ± 2.35	2.83 ± 2.60	0.372 <sup>a</sup>	3.13 ± 2.95	2.60 ± 2.94	0.174 <sup>a</sup>
Nasal blockage	1.97 ± 2.18	3.27 ± 2.97	0.010 <sup>a*</sup>	3.67 ± 2.38	3.97 ± 2.48	0.037 <sup>b*</sup>
Sneezing	2.10 ± 2.29	1.53 ± 2.12	0.159 <sup>a</sup>	3.07 ± 2.55	2.67 ± 2.74	0.080 <sup>a</sup>
Runny nose	2.10 ± 2.38	2.77 ± 3.27	0.320 <sup>a</sup>	3.20 ± 2.92	2.43 ± 2.89	0.069 <sup>a</sup>
Cough	0.90 ± 1.42	0.80 ± 1.40	0.377 <sup>a</sup>	1.67 ± 1.98	1.30 ± 1.68	0.252 <sup>a</sup>
Postnasal discharge	2.13 ± 2.44	2.90 ± 2.88	0.015 <sup>a*</sup>	2.27 ± 2.58	1.87 ± 2.50	0.117 <sup>a</sup>
Thick nasal discharge	1.47 ± 2.72	1.50 ± 2.14	0.757 <sup>a</sup>	1.60 ± 2.82	1.43 ± 2.47	0.857 <sup>a</sup>
Ear fullness	0.70 ± 1.91	1.00 ± 2.15	0.750 <sup>a</sup>	2.53 ± 3.48	2.10 ± 3.13	0.204 <sup>a</sup>
Ear pain	0.80 ± 2.45	0.83 ± 1.82	0.673 <sup>a</sup>	1.73 ± 2.70	1.60 ± 2.50	0.631 <sup>a</sup>
Facial pain/pressure	0.90 ± 2.35	1.73 ± 2.82	0.234 <sup>a</sup>	1.77 ± 3.12	2.23 ± 3.20	0.119 <sup>a</sup>

<sup>a</sup>Wilcoxon signed-rank test<sup>b</sup>Paired samples *t* test

\*Statistically significant

In the N95 mask group, there was no statistically significant difference between pre-mask mean VAS scores of need to blow nose, sneezing, runny nose, cough, thick nasal discharge, ear fullness, ear pain, facial pain/pressure and after-mask mean VAS scores of these complaints (Table 2).

There was no statistically significant difference between pre-mask mean VAS scores of need to blow nose, sneezing, runny nose, cough, postnasal discharge, thick nasal discharge, ear fullness, ear pain, facial pain/pressure complaints and after-mask mean VAS scores of these complaints in the surgical mask group (Table 2).

## Discussion

N95 and surgical mask types have multiple overlapping layers of polypropylene [8, 9]. These fiber structures not only provide mechanical filtration, but also contribute to filtration by creating an electrostatic charge [10, 11]. N95 and surgical masks can be used separately or by wearing a surgical mask on the N95 mask to prevent surface contamination [12]. A surgical mask protects the patient and the surgical area from contamination, however, it does not protect the person from infectious aerosols. The N95 mask is designed to protect the person from infectious agents [13]. During the use of masks, air passes through a narrow passage and breathing pressure, breathing resistance and breathing quality are affected [14]. Therefore, besides the filtration capacity, the breathability of the masks is also crucial [15]. It has been suggested that breathability will not be altered if the flow rate of the air passing through the mask is above 85 L/min [16]. Lee et al. performed rhinomanometry and nasal spirometry on 14 participants using N 95 masks in their study and found 126% increase in inspiratory flow resistance

and 122% increase expiratory flow resistance [17]. In the same study, it is also emphasized that there is an average decrease of 37% in air exchange volume due to the use of N95 masks. In their study, Yang et al. used surface EMG signals and respiratory signals to reveal the breathing resistance that occurs due to the N95 mask [18]. All these studies prove that breathing performed through masks differs from physiological respiration.

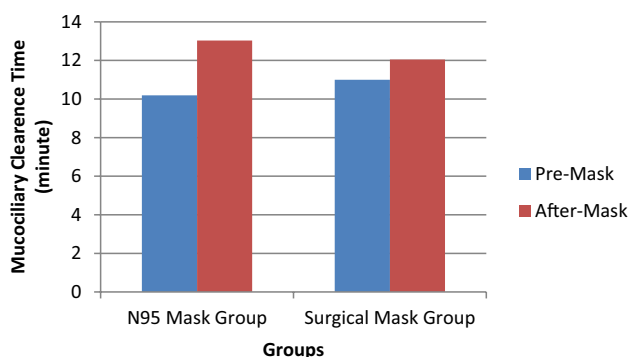
There are various studies investigating the effect of this non-physiological breathing pattern through masks on the body systems. In a study investigating the effects of masks, an increase in perceived exertion, perceived shortness of air, complaints of headache, lightheadedness, difficulty in communicating due to prolonged use of mask was found [19]. It has been shown that the use of N95 mask in patients with chronic obstructive pulmonary disease affects breathing frequency, blood oxygen saturation, and carbon dioxide level in exhaled air [20]. Bharatendu et al. suggested that the use of N95 mask may alter cerebral hemodynamics [21]. It was stated in the literature that using personal protective equipment, including the N95 mask, may cause headache [22]. Headache following the use of N95 mask may be due to changes in cerebral hemodynamics. Lässig et al. evaluated the cardiopulmonary and metabolic responses due to the use of surgical masks with impedance cardiography and ergo-spirometry and found that the use of surgical masks increased airway resistance and heart rate [23]. In another study conducted on healthcare professionals working in intensive care, it was shown that the use of personal protective equipment along with a mask caused changes in heart rate, oxygen saturation and perfusion index [24]. Breathing through masks is not a physiological respiration and this type of respiration affects several systems in the body.

It is inevitable that the masks will affect the physiology of the upper respiratory tract since the masks completely cover the mouth and nose, which constitute the opening to the upper respiratory tract, and the air inhaled through the masks comes into direct contact with the upper respiratory tract. However, there are small numbers of studies in the literature on how mask types affect sinonasal physiology. There are changes in the temperature and humidity of the inhaled air due to the use of face mask [25]. Furthermore, changes in the temperature, humidity, and pH of the inhaled air affect the cilia functions in the upper respiratory tract. Klimek et al. described a new form of irritant rhinitis due to the use of N95 mask [26]. It is suggested that the irritation here may be due to polypropylene fibers seen in the nasal passage due to the use of N95 mask. In addition, in this study, an increase in complaints of sneezing, itching, nasal blockage and rhinorrhea was observed due to the use of the N95 mask. In a study conducted with 87 participants, who used a N95 mask in the first session and a surgical mask in the second session, received acoustic rhinometry and rhinomanometry tests before and after the mask. No difference was found in terms of mean minimum cross-sectional area values obtained before and after the mask in both sessions [27]. However, in this study, the duration of use of masks was three hours. In another study conducted with 250 participants, the effects of the masks were investigated. Excessive sweating around the mouth was found in 67.6% of the participants, difficulty in breathing on exertion at 58.2%, acne in 56.0%, and itchy nose in 52.0% [28]. In our study, a statistically significant prolongation was noted in MCT in the N95 mask group, whereas no statistically significant prolongation was observed in MCT in the surgical mask group (Table 1, Fig. 1). This elongation detected in the N95 mask group may be due to changes in the temperature, humidity, pH of the breathing air or irritant rhinitis. In addition, this type of mask creates higher resistance to inhaled air, which results in negative pressure on the nasal mucosa. This negative pressure may lead to edema of the nasal mucosa, impaired

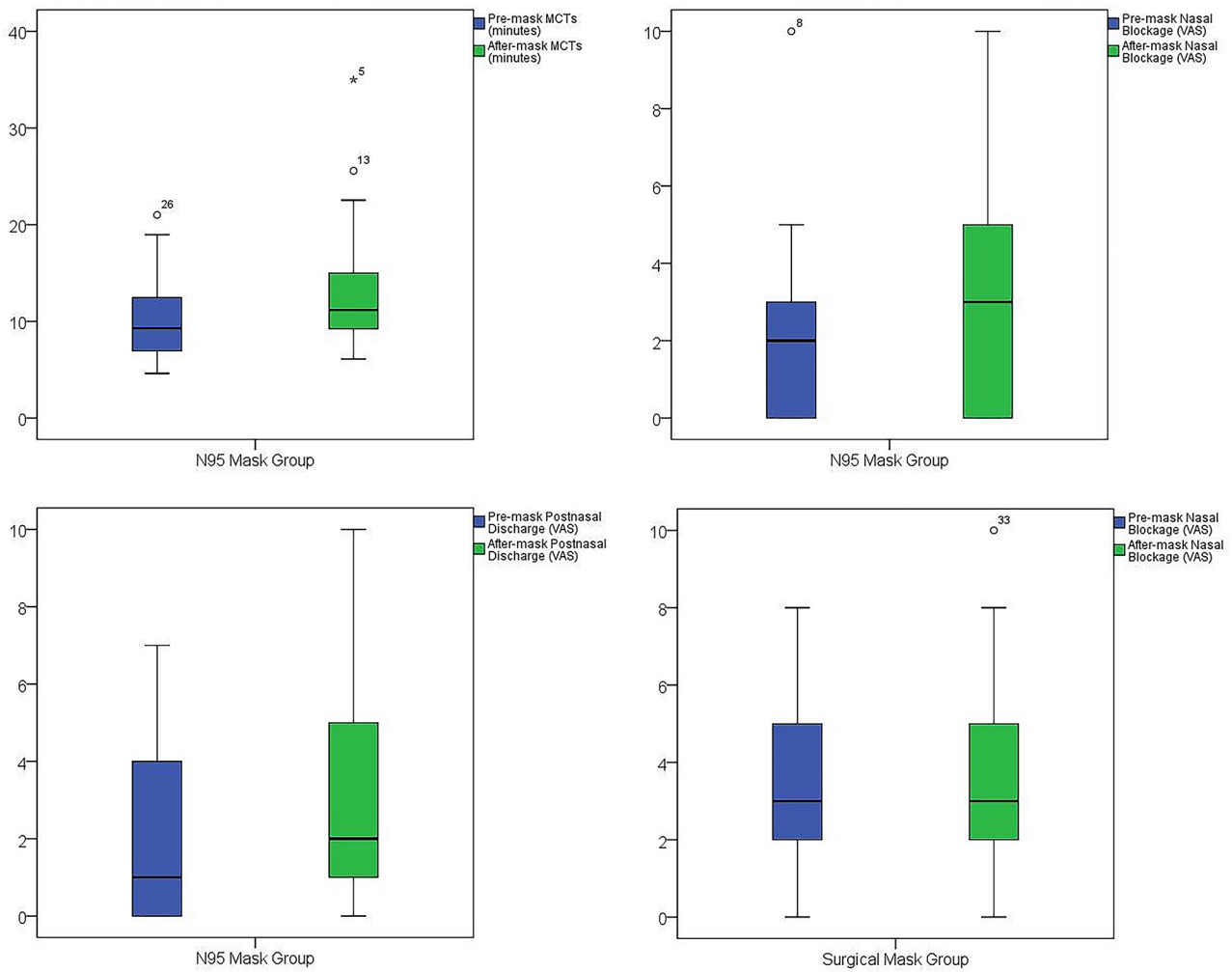
mucociliary clearance function and increased complaints of nasal blockage. Increasing the temperature of the inhaled air may be associated with the thickening of the postnasal discharge and the increased complaints of postnasal discharge. There was no increase in sinonasal complaints other than nasal blockage in the surgical mask group and mucociliary clearance function was not affected (Tables 1, 2). This can be attributed to a more physiological respiration, due to the open edges of the surgical mask.

In the literature, similar to our study, mucociliary clearance function and sinonasal complaints were evaluated in pathologies that directly affect the nasal mucosa, such as acute rhinitis and chronic rhinosinusitis. More significant changes were found in these studies compared to those obtained in our study [29, 30]. This suggests that increases in MCT, nasal blockage and postnasal discharge complaints detected in the N95 mask group and the increase in nasal blockage complaint seen in the surgical mask group were mild. Furthermore, N95 and surgical masks have been frequently used during the COVID-19 pandemic. However, no increase in number of patients with acute rhinosinusitis was noted both in our practice and in the literature review, and these masks are well tolerated by users. Although the increases in the MCT, nasal blockage and postnasal discharge were statistically significant in our study, these differences did not reach clinically significant level. In the N95 mask group, a slight increase in MCT due to the use of the mask was observed in most of the participants (Fig. 2). On the other hand, it was determined that the increase in nasal blockage complaint in the surgical mask group and the increase in nasal blockage and postnasal discharge complaints in the N95 mask group were more common in some participants (Fig. 2). This may be associated with the VAS being more subjective than the saccharine test, or more frequent occurrence of nasal blockage and postnasal discharge complaints due to irritant rhinitis in some participants.

In this study, there was a short period of 3 days between the first and the second interview to prevent the intervention of other factors that may affect mucociliary clearance. Furthermore, pre-mask and after-mask mucociliary clearance measurements were not performed on the same day, as this may affect the results. These are the strengths of this study. On the other hand, in this study, the effects of using the masks for eight hours were investigated. Especially health-care professionals have to use these masks for much longer hours and months. Therefore, further studies are needed to investigate the effects of prolonged mask use.



**Fig. 1** Graphical illustration of pre-mask and after-mask mean mucociliary clearance times in groups



**Fig. 2** Boxplot graphs of significantly changing parameters in groups

### Conclusion

The use of N95 mask causes complaints of nasal blockage and postnasal discharge, while the use of surgical mask causes nasal blockage. N95 masks lead to impairment in mucociliary clearance function. But all these effects are mild and these masks are well tolerated by users. Surgical masks have not been found to have any effect on mucociliary clearance function.

### Declarations

**Conflict of interest** The authors declare that they have no conflict of interest.

**Ethical approval** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee (Yozgat Bozok University Clinical Researches Ethic Committee Ref No: 2017-KAEK-189\_2020.09.16\_02) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

## References

- Fikenzer S, Uhe T, Lavall D, Rudolph U, Falz R, Busse M et al (2020) Effects of surgical and FFP2/N95 face masks on cardiopulmonary exercise capacity. *Clin Res Cardiol* 109(12):1522–1530
- Kim JH, Benson SM, Roberge RJ (2013) Pulmonary and heart rate responses to wearing N95 filtering facepiece respirators. *Am J Infect Control* 41(1):24–27
- Aroor R, Ali ZS, Somayaji KG (2017) Do nasal surgeries affect mucociliary clearance? *Indian J Otolaryngol Head Neck Surg* 69(1):24–28
- Wanner A (1977) Clinical aspects of mucociliary transport. *Am Rev Respir Dis* 116(1):73–125
- Sahin E, Hamamcı M, Kantekin Y (2020) Measurement of mucociliary clearance in the patients with multiple sclerosis. *Eur Arch Otorhinolaryngol* 277(2):469–473
- Mikolajczyk M, Janukowicz K, Majewska E, Baj Z (2019) Impact of allergic rhinitis on Nasal Mucociliary clearance time in children. *Int Arch Allergy Immunol* 179(4):297–303
- Li Y, Tokura H, Guo YP, Wong ASW, Wong T, Chung J et al (2005) Effects of wearing N95 and surgical facemasks on heart rate, thermal stress and subjective sensations. *Int Arch Occup Environ Health* 78(6):501–509
- Huang JT, Huang VJ (2007) Evaluation of the efficiency of medical masks and the creation of new medical masks. *J Int Med Res* 35(2):213–223
- Alenezi H, Cam ME, Edirisinghe M (2021) A novel reusable anti-COVID-19 transparent face respirator with optimized airflow. *Bio-des Manuf* 4(1):1–9
- Azap A, Erdiñç FŞ (2020) Medical mask or N95 respirator: When and how to use? *Turk J Med Sci* 50(1):633–637
- Huang SH, Chen CW, Kuo YM, Lai CY, McKay R, Chen CC (2013) Factors affecting filter penetration and quality factor of particulate respirators. *Aerosol Air Qual Res* 13(1):162–171
- Roberge RJ, Coca A, Williams WJ, Palmiero AJ, Powell JB (2010) Surgical mask placement over N95 filtering facepiece respirators: physiological effects on healthcare workers. *Respirology* 15(3):516–521
- Wen Z, Yu L, Yang W, Hu L, Li N, Wang J et al (2013) Assessment the protection performance of different level personal respiratory protection masks against viral aerosol. *Aerobiologia* 29(3):365–372
- Sinkule EJ, Powell JB, Goss FL (2013) Evaluation of N95 respirator use with a surgical mask cover: effects on breathing resistance and inhaled carbon dioxide. *Ann OccupHyg* 57(3):384–398
- Parlin AF, Stratton SM, Culley TM, Guerra PA (2020) A laboratory-based study examining the properties of silk fabric to evaluate its potential as a protective barrier for personal protective equipment and as a functional material for face coverings during the COVID-19 pandemic. *PLoS One* 15(9):e0239531
- El-Atab N, Qaiser N, Badghaish H, Shaikh SF, Hussain MM (2020) Flexible nanoporous template for the design and development of reusable anti-COVID-19 hydrophobic face masks. *ACS Nano* 14(6):7659–7665
- Lee HP, Wang DY (2011) Objective assessment of increase in breathing resistance of N95 respirators on human subjects. *Ann OccupHyg* 55(8):917–921
- Yang Z, Chen Y, Wang J, Gong H (2017) Recognizing the breathing resistances of wearing respirators from respiratory and sEMG signals with artificial neural networks. *Int J Ind Ergon* 58:47–54
- Rebmann T, Carrico R, Wang J (2013) Physiologic and other effects and compliance with long-term respirator use among medical intensive care unit nurses. *Am J Infect Control* 41(12):1218–1223
- Kyung SY, Kim Y, Hwang H, Park JW, Jeong SH (2020) Risks of N95 face mask use in subjects with COPD. *Respir Care* 65(5):658–664
- Bharatendu C, Ong JJ, Goh Y, Tan BY, Chan AC, Tang JZ et al (2020) Powered Air Purifying Respirator (PAPR) restores the N95 face mask induced cerebral hemodynamic alterations among Healthcare Workers during COVID-19 Outbreak. *J NeurolSci* 417:117078
- Ong JJ, Bharatendu C, Goh Y, Tang JZ, Sooi KW, Tan YL et al (2020) Headaches associated with personal protective equipment—a cross-sectional study among frontline healthcare workers during COVID-19. *Headache J Head Face Pain* 60(5):864–877
- Lässing J, Falz R, Pökel C, Fikenzer S, Laufs U, Schulze A et al (2020) Effects of surgical face masks on cardiopulmonary parameters during steady state exercise. *Sci Rep* 10(1):1–9
- Choudhury A, Singh M, Khurana DK, Mustafi SM, Ganapathy U, Kumar A et al (2020) Physiological effects of N95 FFP and PPE in healthcare workers in COVID intensive care Unit: a prospective cohort study. *Indian J Crit Care Med* 24(12):1169
- Roberge RJ, Kim JH, Benson S (2012) N95 filtering facepiece respirator deadspace temperature and humidity. *J Occup Environ Hyg* 9(3):166–171
- Klimek L, Huppertz T, Alali A, Spielhauer M, Hörmann K, Matthias C et al (2020) A new form of irritant rhinitis to filtering facepiece particle (FFP) masks (FFP2/N95/KN95 respirators) during COVID-19 pandemic. *World Allergy Organ J* 13(10):100474
- Zhu JH, Lee SJ, Wang DY, Lee HP (2014) Effects of long-duration wearing of N95 respirator and surgical facemask: a pilot study. *J Lung PulmResp Res* 1(4):97–100
- Purushothaman PK, Priyanga E, Vaidhyswaran R (2021) Effects of prolonged use of facemask on healthcare workers in Tertiary care hospital during COVID-19 pandemic. *Indian J Otolaryngol Head Neck Surg* 73(1):59–65
- Koparal M, Kurt E, Altuntas EE, Dogan F (2020) Assessment of mucociliary clearance as an indicator of nasal function in patients with COVID-19: a cross-sectional study. *European Archives of Oto-Rhino-Laryngology* 1–6
- Gallo S, Russo F, Mozzanica F, Preti A, Bandi F, Costantino C et al (2020) Prognostic value of the Sinonasal Outcome Test 22 (SNOT-22) in chronic rhinosinusitis. *ActaOtorhinolaryngolItal* 40(2):113–121

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