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Association of Face Mask Use With Nasal Symptoms And Mucociliary Clearance

ABSTRACT

Background: Masks may have negative impacts on health; thus, it is important to investigate mask-related symptoms and the effects of masks on mucociliary clearance. We conducted our investigation using 4 study groups to determine the long-term health effects of both surgical and respiratory masks.

Methods: We studied 139 people aged 18-65 years. Participants were divided into 4 groups: single surgical mask, double surgical mask, N95 or equivalent mask alone, and surgical mask in combination with N95 or equivalent mask. The saccharin test was used to measure the mucociliary clearance times. We performed the saccharin test with a 1 × 1 × 1 mm piece of saccharin (Hermesetas®) and sterile-appropriate technique.

Results: In this study, no significant difference was found between the groups in terms of saccharin transition time. Prolongation of mask wearing time was positively correlated with headache symptom, with the correlation coefficient of 0.26 ($P = .002$). It was also found that not wearing an N95 mask reduced the symptom of earache 0.35 times ($P = .025$).

Conclusion: In this study, no severe symptoms were detected that would limit the use of masks. It was demonstrated by the saccharin test that the use of masks did not affect nasal physiology.

Keywords: surgical mask, N95, N99, saccharin test, mucociliary clearance

INTRODUCTION

Infections caused by respiratory tract viruses are effective in various periods without losing their importance. Viral infections are transmitted directly or indirectly through respiratory droplets.[1] Transmission is possible by direct respiration of aerosols (inhalation after an infected individual coughs or sneezes), transmission of established aerosols (the sources may include mechanical ventilation, bronchoscopy, flexible nasopharyngoscopy), or direct contact with infected or contaminated persons or their secretions.[2,3]

The importance of personal protective equipment for health-care has been demonstrated in various studies.[4] Most health-care professionals use 2 types of masks:

- Surgical masks: These masks are generally used by health-care professionals who are not exposed to high droplet risks. The surgical masks standardized by ASTM International (previously known as the American Society for Testing and Materials) or the European Standards Organizations (EN) are preferred—usually 3-layer surgical masks. They are not tight-fitting masks, so they serve only to protect the wearer from large droplets during routine health-care procedures in which the wearer is further than 1 meter from the patient. They have been shown to be more than 90% successful in holding particles larger than 3.0 microns.[4,5]
- Respiratory Masks (N95, filtering face piece (FFP2), FFP3, and their equivalents): These masks are standardized by the EN in Europe and the Food and Drug Administration (FDA) and the National Institute for Occupational Safety and Health (NIOSH) in the United States. The US standard is N95 or N99 masks, and the European standard is FFP2 or FFP3 masks.

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> Respiratory masks are masks that fit tightly to the face and have the capacity to hold viruses and similar small substances (particles larger than 0.3 µm) with an over 95% or 99% success rate. They are subjected to various tests for effectiveness before being put into use.[4,5]

It is widely known that health-care professionals wear at least 1 mask, and the amount and type are usually determined by their working conditions and personal preferences. It is also known that the use of masks can be challenging because of their negative impact on personal comfort and user health.

Nasal mucociliary clearance is an important defense mechanism of the respiratory tract against various microorganisms and particles found in the inhaled air.[6] After the respiratory air is filtered in the nose, the particles held in the mucus layer are swept into the nasopharynx by ciliated cells in the nasal mucosa. This process is called mucociliary clearance. Many factors may affect mucociliary clearance, including ambient air, upper respiratory tract infections, or systemic disorders that affect cilia functions.[6,7]

In our study, we investigated mask wearing by health-care professionals (the types of masks and the duration of wear) in relation to the expressed symptoms. We also investigated the effect of mask wearing on nasal mucociliary clearance, and hence nasal physiology, using the saccharin test.

MATERIAL AND METHODS

The study was initiated after approval by the local ethics committee (No. E1-20-1346). We included health-care workers aged 18-65 years, working in Ankara City Hospital, and who had been wearing surgical or respiratory masks regularly for at least 1 year. We excluded individuals who smoked, had an upper respiratory tract infection in the previous 2 weeks, were on regular medications, had a history of nasal or paranasal surgery, or had significant nasal septum deviation, nasal polyps, or any nasal mass from the study.

We confirmed that the participants wore masks that were standardized by the FDA, NIOSH, or EN. We asked each person which type of mask they wore and for how many hours they wore it without taking long rest breaks. The individuals included in the study changed their masks after a maximum of 8 hours and wore the masks by covering their noses, mouths, and chins. We formed groups based on the responses we received. The mask brands were the same regardless of the type because the people included in the study worked in the same hospital. Initially, we created the following 4 main groups:

- N95 mask wearers
- Single surgical mask wearers
- N95 and surgical mask wearers
- Double surgical mask wearers

We compared the groups for any differences in mask-related symptoms and saccharin transit times.

The individuals we accepted into the study included 44 male and 95 female individuals between the ages of 22 and 64. First, we administered a questionnaire to the 139 participants. We asked them to rate the severity of their symptoms (cough, smelling disorder, headache, cough, dry mouth, skin problems, concentration problems, earache, frequent sinusitis attacks) as mild (1), moderate (2), or severe (3). Informed consent was obtained from all patients.

Saccharin Test

We performed the saccharin test after a subject had worn a mask for at least 4 hours. A 1 × 1 × 1 mm piece of saccharin (Hermesetas®) was prepared in a sterile container with sterile instruments. The saccharin was then placed on the anterior end of the inferior turbinate with the help of sterile forceps by the same otolaryngologist physician. During the test, the individuals were asked to swallow every 30 seconds, and the time between the administration of saccharin and the report of a sweet taste was recorded. The individuals were observed for at least 30 minutes after the test. None of them had any allergic reactions or respiratory problems.

Statistical Analysis

We presented the descriptive statistics of the demographic and clinical characteristics of the participants as numbers, percentages, and means (or medians if the normal distribution is not satisfied). The means of the numerical data—such as age, duration of mask use, symptoms, and saccharin transit time—were compared between the groups using the independent *t*-test if the data were normally distributed and the number of subjects was sufficient ($n \geq 30$), and the medians of the data were compared with the Mann–Whitney *U*-test if the normal distribution hypothesis was not met or the number of subjects was not sufficient. We compared the numerical data such as age and saccharin transit time among more than 2 groups with the Kruskal–Wallis *H* test. We compared proportional data such as gender, presence of smelling disorder, and presence of headache among the study groups with the Pearson's chi-square test and Fisher's exact test. Since the variables of interest are categorical, e.g., presence of headache, earache, smelling disorder, etc., our main methodology relies on a logistic regression setup. We used a binary multiple logistic regression to analyze the saccharin test and the variables that may increase the odds of exposure to health problems resulting from mask wearing. We checked the compliance of numerical data with normal distribution with kurtosis and skewness values (±1.5). The significance level for all analyses was determined to be $P < .050$. We tested the pairwise comparison of clinical characteristics in relation to the mask type using chi-square test. We used IBM Statistical Package for the Social Sciences Statistics 22.0 (IBM SPSS Corp.; Armonk, NY, USA) software to conduct the analyses.

MAIN POINTS

- Increase in mask wearing time is associated with headaches.
- Wearing non-N95 masks increases the odds of exposure to earache.
- Nasal physiology is not adversely affected as shown by tests that provide indirect results about mucociliary clearance and nasal physiology.

RESULTS

Of the 139 health-care workers included in the study, 44 (31.6%) were male and 95 (68.4%) were female. The median age of the patients was 28, between a minimum of 22 and a maximum of 64 years.

We divided the patients into 4 groups according to the masks they wore: group 1 consisted of 27 individuals wearing N95 masks, group 2 consisted of 63 individuals wearing surgical masks, group 3 consisted of 31 individuals wearing N95 and surgical masks, and group 4 consisted of 18 individuals wearing double surgical masks. We also recorded the amount of time per day that each individual spent wearing a mask. The information is presented in Table 1.

When we questioned the patients regarding their symptoms, the most common symptom was difficulty smelling (81.3%, n=113). Other common symptoms were skin problems (63.3%, n=88) and nasal congestion (53.9%, n=75). The distribution of the symptoms is presented in Table 1.

We compared the saccharin transit times of the individuals with and without symptoms separately for every symptom. We observed that the saccharin transit time was shorter in those who had headaches and difficulty smelling compared to those who did not have these symptoms (P =.031 for headache, P =.039 for smelling disorder). The results of the statistical analyses are presented in Table 1. We also determined that the mean saccharin transit time of the participants with smelling difficulty was statistically significantly shorter than the participants without any smelling difficulty (P =.039). The mean saccharin transit time was shorter in the participants with headache compared to those without (P =.031). These mean saccharin transit times can also be viewed in Table 1.

Table 1. The Comparison of Mean Saccharin Transit Times with the Mask-Related Symptoms

		n	Analysis	*P*
Smelling disorder	Absent	113	***r*=−2.06***	**.039**
	Present	26		
Nasal obstruction	Absent	64	*r*=−0.36	.716
	Present	75		
Headache	Absent	69	***r* = −2.16***	**.031**
	Present	70		
Cough	Absent	106	*r* = −1.63	.103
	Present	33		
Dry mouth	Absent	81	*r* = −0.51	.611
	Present	58		
Skin problem	Absent	51	*r* = −1.87	.062
	Present	88		
Concentration problems	Absent	84	*r* = −0.60	.549
	Present	55		
Earache	Absent	72	*r* = −0.63	.531
	Present	67		
Frequent sinusitis attacks	Absent	129	*r* = −1.23	.218
	Present	10		

*P<.05

Conversely, the saccharin transit time was not significantly correlated with the duration per day that the mask was worn in any of the groups (r=0.21, P =.253 for N95; r=0.06, P =.509 for 1 surgical mask; r = −0.03, P =.806 for N95 and surgical mask; and r=0.18, P =.392 for double surgical masks) (Table 2). We compared the rate of difficulty smelling among participants with heavy use of N95 and surgical masks to those with heavy use of surgical masks, using Pearson's chi-square analysis. Difficulty smelling occurred at a statistically significantly higher rate in the group using N95 and surgical masks (P =.030).

Pearson's chi-square analysis further revealed that cough and concentration problems were statistically significantly higher in participants with heavy use of N95 masks compared to those with heavy use of double surgical masks (P =.022 and P =.041 in order; Table 3).

Binary multiple logistic regression analysis showed that an increase in the maximum duration of mask wearing increased the odds of exposure to headache 1.07 times (CI: 1.00-1.15; P =.005) and that the absence of N95 masks reduced the odds of exposure to earache 0.35 times (CI: 0.14-0.87; P =.025) (Table 4).

When we analyzed the effects of mask use on saccharin transit time, smelling disorder, nasal congestion, cough, and dry mouth, we found that not wearing an N95 mask increased the odds of exposure to a longer saccharin transit time 2.45 times (CI: 1.03-5.82; P =.041) (Table 5).

DISCUSSION

One of the most prevalent issues during the pandemic has been mask wearing. There have been several discussions about and investigations into the protection provided by surgical and respiratory masks, mask-related problems, and factors limiting their use. A number of studies reported that mask wearers complained of skin problems (particularly oily skin and a tendency for acne), smelling problems, and earaches caused by long-term

Table 2. Correlation coefficient, p-value and frequency

		Saccharin Transit Time (Minutes)
Age	*r*	0.11
	P	.195
	n	139
N95 mask wearing (h/day)	*r*	0.21
	P	.253
	n	31
Surgical mask wearing (h/day)	*r*	0.06
	P	.509
	n	118
N95 + surgical mask wearing (h/day)	*r*	−0.03
	P	.806
	n	67
Double surgical mask wearing (h/day)	*r*	0.18
	P	.392
	n	24

*P<.05

Table 3. Comparison of Clinical Characteristics in Relation to the Mask Type

		N95 (I)		Surgical Mask (II)		N95 + Surgical Mask (III)		Double Surgical Mask (IV)			Pairwise Comparison *P*				
		Freq.	Perc.	Freq.	Perc.	Freq.	Perc.	Freq.	Perc.	χ^2	I-II	I-III	I-IV	II-III	III-IV
Smelling disorder	Absent	17	81.0	54	87.1	25	67.6	17	89.5	6.80[b]	.419	.393	.453	**.030***	.115
	Present	4	19.0	8	12.9	12	32.4	2	10.5						
Nasal obstruction	Absent	9	42.9	26	41.9	17	45.9	12	63.2	2.75[b]	.748	.789	.105	.973	.120
	Present	12	57.1	36	58.1	20	54.1	7	36.8						
Headache	Absent	11	52.4	28	45.2	19	51.4	11	57.9	1.12[b]	.664	.842	.408	.424	.460
	Present	10	47.6	34	54.8	18	48.6	8	42.1						
Cough	Absent	12	57.1	48	77.4	29	78.4	17	89.5	6.21[b]	.491	.301	**.022***	.600	.106
	Present	9	42.9	14	22.6	8	21.6	2	10.5						
Dry mouth	Absent	14	66.7	39	62.9	16	43.2	12	63.2	4.78[b]	.920	.472	.584	.400	.190
	Present	7	33.3	23	37.1	21	56.8	7	36.8						
Skin problems	Absent	5	23.8	23	37.1	16	43.2	7	36.8	2.19[b]	.409	.68	.423	.141	.351
	Present	16	76.2	39	62.9	21	56.8	12	63.2						
Concentration problems	Absent	10	47.6	39	62.9	20	54.1	15	78.9	4.95[b]	.351	.998	**.041***	.249	.073
	Present	11	52.4	23	37.1	17	45.9	4	21.1						
Earache	Absent	8	38.1	36	58.1	18	48.6	10	52.6	2.71[b]	.084	.491	.152	.224	.343
	Present	13	61.9	26	41.9	19	51.4	9	47.4						
Frequent sinusitis attacks	Absent	18	85.7	59	95.2	33	89.2	19	100.0	3.97[c]	.391	.673	.157	.109	.088
	Present	3	14.3	3	4.8	4	10.8	0	0.0						
Saccharin risk (>15)	Absent	17	81.0	33	53.2	26	70.3	13	68.4	6.54[b]	**.038***	.520	.408	.074	.768
	Present	4	19.0	29	46.8	11	29.7	6	31.6						

	N95 (I)		Surgical Mask (II)		N95 + Surgical Mask (III)		Double Surgical Mask (IV)			Pairwise Comparison *P*				
	Mean	Median	Mean	Median	Mean	Median	Mean	Median	χ^2	I-II	I-III	I-IV	II-III	III-IV
Saccharin transit time (minutes)	14.95	10.00	17.65	15.00	15.38	12.00	17.53	12.00	4.99[a]	.779	.357	.520	.440	.281

[a]Kruskal–Wallis *H* test.
[b]Pearson's chi-square analysis.
[c]Fisher's exact chi-square analysis.
*$P<.05$

Table 4. The Results of Binary Multiple Logistic Regression Analysis for Mask-Related Complaints

	Headache (Present) OR (95% CI)	Concentration Problems (Present) OR (95% CI)	Earache (Present) OR (95% CI)	Skin Problems (Present) OR (95% CI)
Mask wearing (days/week) (3-4)	0.81 (0.33-2.04) (.667)	0.63 (0.19-1.14) (.199)	1.50 (0.53-3.25) (.571)	0.85 (0.62-1.15) (.280)
Minimum mask wearing (h/day)	1.03 (0.96-1.14) (.294)	1.03 (0.95-1.13) (.422)	1.03 (0.98-1.17) (.153)	1.01 (0.92-1.10) (.849)
Maximum mask wearing (h/day)	**1.07**** **(1.00-1.15)** **(.005)**	1.02 (0.96-1.07) (.602)	1.05 (0.99-1.24) (.090)	1.08 (0.96-1.19) (.196)
N95 wearing (absent)	0.81 (0.68-1.04) (.110)	0.41 (0.11-1.03) (.062)	**0.35*** **(0.14-0.87)** **(.025)**	0.24 (0.09-1.11) (.088)
Surgical mask wearing (absent)	0.38 (0.13-1.45) (.180)	1.32 (0.31-3.98) (.863)	0.42 (0.17-1.65) (.271)	0.70 (0.15-1.67) (.263)
N95 + surgical mask wearing (absent)	1.25 (0.70-3.10) (.304)	0.98 (0.48-2.15) (.973)	0.70 (0.34-1.49) (.376)	1.38 (0.63-3.05) (.413)
Double surgical mask wearing (absent)	0.80 (0.23-2.52) (.669)	3.943 (0.92-15.23) (.065)	0.86 (0.31-3.24) (.978)	1.32 (0.33-3.92) (.832)

First parentheses for the CIs and the second for the corresponding *P*-values.
OR, odds ratio.
**<.01.
**P*<.05

mask usage.[8,9] In our study, we had opportunity for a wider comparison because we included a large number of individuals using surgical masks, double surgical masks, N95 masks, and N95s with surgical masks. This allowed us to investigate not only the effects of wearing masks, but also the effects that different masks have.

We found that smelling disorder was more frequent in the group wearing N95 and surgical masks compared to the group wearing surgical masks alone. Regardless of the type of the mask, we determined that an increase in mask wearing time increased headache. Supporting our results, Lim et al[10] and Zhang et al[5] have shown that the use of masks, particularly N95 masks, may cause headaches.

The authors of several studies reported that ear pain and ulceration wounds on the face occur as complications of tight-fitting masks. In our study, we determined that ear pain was a more common symptom in non-N95 mask wearers, supporting the literature data.

Cough was more common in the group using only N95 masks and its equivalents when compared to the group using double surgical masks. Other researchers have also reported that cough may occur with the use of masks;[11] however, in our study, we observed that the cough symptom was not severe and did not limit mask wearing in any of our study groups.

Our analysis of saccharin transit times in our study showed that none of the mask types affected the saccharin transit time directly. The saccharin transit time was shorter in the individuals who complained of headaches and smelling difficulty. Intergroup comparisons revealed that the odds of exposure to a longer saccharin transit time was 2.45 times higher in the non-N95 mask wearers. Cengiz et al[12] compared the N95 and surgical mask use of 60 individuals and observed that there was no significant difference in mucociliary clearance between the 2. In another study evaluating mucociliary clearance, Rajan et al[13] studied 48 individuals who wore N95 masks at least 4 hours per day and reported that wearing N95 masks prolonged the mucociliary clearance time. In our study, comparison of groups wearing surgical masks and those wearing N95 or equivalent masks revealed a shorter saccharin transit time in the group wearing N95 or equivalent masks. Mucus structure and cilia number are the main factors that determine mucociliary clearance. Oliveira et al[14] showed an increase in the number of cilia and mucociliary clearance in patients using nasal continuous positive airway pressure in the early period. This information may explain the faster mucociliary clearance in the group wearing the N95 and N99 mask equivalents, where nasal airflow decreases more. However, this theory was not supported by other symptoms such as nasal congestion and frequent sinusitis attacks, which could also provide information about mucociliary clearance. These results show that the use of surgical masks, respiratory masks, or their combination does not significantly affect nasal physiology. In a randomized controlled study by Che et al,[15] the researchers compared groups wearing N95 and surgical masks. They also evaluated physiological parameters and detected no abnormality in physiological parameters in either group. This

Table 5. The Results of Binary Multiple Logistic Regression Analysis for the Odds of Smelling Disorder and Its Related Complaints

	Saccharin Transit Time (>15.00) OR (95% CI)	Smelling Disorder (Present) OR (95% CI)	Nasal Obstruction (Present) OR (95% CI)	Cough (Present) OR (95% CI)	Dry Mouth (Present) OR (95% CI)
Age	1.03 (0.98-1.08) (.275)	0.99 (0.92-1.06) (.780)	1.00 (0.94-1.04) (.650)	1.00 (0.95-1.05) (.977)	**0.94* (0.88-0.99) (.027)**
Gender (male)	0.75 (0.33-1.69) (.489)	0.87 (0.32-2.31) (.756)	**0.45* (0.21-0.98) (.040)**	0.75 (0.28-1.77) (.455)	0.52 (0.24-1.24) (.145)
Mask wearing (days/week) (3-4)	1.10 (0.41-3.16) (.799)	1.40 (0.41-5.10) (.569)	1.55 (0.46-3.88) (.582)	0.27 (0.06-1.39) (.120)	1.48 (0.45-4.11) (.576)
Minimum mask wearing (h/day)	1.02 (0.91-1.11) (.834)	1.04 (0.93-1.16) (.498)	1.00 (0.89-1.09) (.848)	1.01 (0.89-1.13) (.946)	0.97 (0.89-1.08) (.709)
Maximum mask wearing (h/day)	1.00 (0.94-1.07) (.947)	1.01 (0.93-1.09) (.891)	1.06 (0.99-1.12) (.125)	1.05 (0.97-1.12) (.255)	1.06 (0.99-1.14) (.081)
N95 wearing (absent)	2.38 (0.90-6.37) (.081)	0.69 (0.23-2.20) (.548)	0.72 (0.29-1.89) (.540)	0.44 (0.18-1.19) (.108)	1.24 (0.47-3.05) (.713)
Surgical mask wearing (absent)	1.10 (0.30-3.78) (.932)	0.50 (0.08-2.72) (.395)	1.21 (0.33-3.85) (.831)	0.58 (0.12-2.57) (.453)	0.99 (0.35-4.07) (.779)
N95 + surgical mask wearing (absent)	**2.45* (1.03-5.82) (.041)**	0.40 (0.13-1.17) (.093)	0.84 (0.32-1.82) (.561)	1.90 (0.71-4.76) (.210)	0.58 (0.26-1.38) (.230)
Double surgical mask wearing (absent)	2.25 (0.56-7.49) (.277)	1.57 (0.24-8.64) (.682)	3.25 (0.89-12.04) (.73)	2.36 (0.46-10.85) (.313)	1.45 (0.46-6.15) (.429)

First parentheses for the CIs and the second for the corresponding *P*-values.
OR, odds ratio.
*$P<.05$.

study supports our findings. Therefore, the results of this study are important for health-care professionals who have concerns about the use of masks.

The mask, which is obviously protective against upper respiratory tract viruses, creates various usage difficulties. For this reason, it is important to determine whether the different symptoms explored constitute objective data. In our study, we observed that an increase in mask wearing time is associated with headaches, and that wearing non-N95 masks increases the odds of exposure to earache. Although standardized masks may be worn in various ways and mask wearers experience different symptoms, we have shown that nasal physiology is not adversely affected by tests that provide indirect results about mucociliary clearance and nasal physiology, such as the saccharin test.

Because we conducted our study on health-care workers, it does not include a group that does not use masks regularly. We believe that further information on the effects of surgical and respiratory mask wearing may be obtained through studies on larger groups that use more comprehensive tests.

Ethics Committee Approval: This study was approved by Ethics Committee of Ankara City Hospital (Approval No:No. E1-20-1346, Date: 2021).

Informed Consent: Written informed consent was obtained from the patients who agreed to take part in the study.

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