The Effect of Masks and Respirators on Acoustic Voice Analysis During the COVID-19 Pandemic

Ebru Karakaya Gojayev, Zahide Çiler Büyükatalay, Tuğba Akyüz, Mustafa Rehan, and Gürsel Dursun, *Ankara, Turkey*

SUMMARY: Objectives. World Health Organization declared the coronavirus disease (COVID-19) as a global pandemic on March 11, 2020. The aim of this study was to determine the effectiveness and reliability of voice analysis performed with surgical masks and respirators during the pandemic and to discuss its routine applicability.

Methods. This prospective study included 204 patients who applied to our clinic between the ages of 18 and 55, whose preoperative SARS-Cov-2 PCR tests were negative. Voice analyses were performed on each patient without a mask, with a surgical mask and with a valved face-filtering piece-3 (FFP3) respirator respectively. The F0, shimmer, jitter, s/z ratio, maximum phonation time and harmonic/noise ratio (HNR) values obtained from the voice analyses were compared with each other.

Results. No significant difference was found in terms of F0, Jitter, Shimmer, HNR, s/z and maximum phonation time values in the voice analyses performed without a mask and with a surgical mask. With an FFP3, a significant difference was found in only the Shimmer and HNR values compared to the other analysis values. When we look at the data with sex distinction, in the group of female and male patients, when the data of voice analysis obtained in three situations were compared, different results were obtained from the female and male group.

Conclusion. In conclusion, it should be decided by the physician to perform the voice analysis with a surgical mask or with an FFP3, considering the clinically desired parameters.

KEY WORDS: Acoustic voice analysis−COVID-19−Mask−Level of evidence−Level 3.

INTRODUCTION

Novel coronavirus disease (COVID-19) is a highly contagious infectious respiratory disease that first appeared in Wuhan, China, in December 2019.[1] The World Health Organization (WHO) declared COVID-19 a global pandemic on March 11, 2020, due to reports of its prevalence in many different countries.[2] The highest viral load of SARS-CoV-2, which causes COVID-19, is found in upper respiratory tract secretions and sputum.[3] Otorhinolaryngologists are at a very high risk of exposure to respiratory pathogens due to the nature of their work, which involves the routine evaluation and management of patients.[2] To protect both doctors and patients during the pandemic, the time without a mask during examinations should be kept to a minimum. Voice analysis is performed as a part of the diagnosis and follow-up process for patients who apply to otolaryngology clinics with dysphonia. During voice analysis, patients are required to make sounds of various characteristics and lengths and to read text into a microphone in the analysis room. Using by analysis programme, the voice analysis data is obtained from the collected voice samples. Performing voice analysis without a mask during the pandemic puts both the patient and the physician performing the voice analysis at risk due to potential disease transmission through droplets. The aim of this study was to determine the effectiveness and reliability of voice analysis performed with surgical masks and respirators during the pandemic and to discuss their routine applicability. Current studies related to voice analysis without a mask and with different type of masks has found that there is no statistically significant difference between all of the situations.[4−6] We also hypothesized the acoustic voice analysis parameters would not be affected by wearing mask and the type of the mask worn.

MATERIALS AND METHODS

This prospective study was approved by the ethics committee of our clinic. The study included 204 patients between the ages of 18 and 55 years who applied to our clinic between August 1, 2020, and May 1, 2021. Patients who did not have any complaints or a history related to voice, a condition that might affect the normal voice function, any respiratory infection for the 2 weeks before recording, any previous formal voice training or voice therapy, any laryngeal, mouth, or throat abnormality were selected. Inclusion criterion was to be able to phonate and sustain a vowel for at least 6 seconds. The ritm, fluency, roughness, and strain of the voices were evaluated by the doctors who carried out the analysis. The patients that had a sign related to laryngeal pathology, were not included. They had surgery planned for other reasons, and whose preoperative SARS-CoV-2 polymerase chain reaction test was negative were included in the study. All the patients who participated in the study provided their informed consent in writing.

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From the Department of Otorhinolaryngology, Ankara University, Medical School, Ankara, Turkey.

Address correspondence and reprint requests to Dr. Zahide Çiler Büyükatalay, ALTINDAĞ, Ankara, Turkey. E-mail: cbuyukatalay@gmail.com

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After obtaining the medical history and demographic information of all the patients participating in the study, voice analyses were performed on each patient without a mask, with a surgical mask, and with a valved face-filtering piece-3 (FFP3) respirator.

The study included 204 patients with an average age of 35.49 ± 11.35 years. Among them, 127 (62.3%) were women, and 77 (37.7%) were men. While 42 (20.6%) patients did not have any profession, the percentages of tradesmen (14.2%), officers (11.3%), nurses (10.3%) and students (10.3%) were relatively high in the distribution of the other participants. Among the participants, 41.2% stated that they used cigarettes, and 17.6% used alcohol (Table 1).

The voice recordings of the patients were made by asking them to make an / a / sound for 6 seconds in a modal voice at a distance of 20 cm from the microphone (EM-616 Condenser, Shure, Chicago, IL), and the fundamental frequency (F0; Hz), jitter (%), shimmer (decibels [dB]), s/z ratio, and harmonics-to-noise ratio (HNR; dB) were measured (Vocal Assessment, Dr.Speech Tigers Inc. Seattle, WA). For the maximum phonation time (MPT) analysis, the patients were asked to take a deep breath and make an / a / sound. The duration was noted in seconds. After each patient, the analysis room, microphone, instruments, and room surfaces were disinfected and ventilated. The F0, shimmer, jitter, s/z, MPT, and HNR values obtained from the voice analyses without a mask, with a surgical mask, and with an FFP3 respirator were compared. The surgical masks and FFP3 respirators with valves were selected to comply with the International Organization for Standardization and European Union standards.

TABLE 1.
Participant Characteristics

Variables	n = 204
Age, mean ± SD	35.49 ± 11.35
Gender, n (%)	
Male	77 (37.7)
Female	127 (62.3)
Occupation, n (%)	
None	42 (20.6)
Tradesman	29 (14.2)
Officer	23 (11.3)
Nurse	21 (10.3)
Student	21 (10.3)
Doctor	11 (5.4)
Hospital staff	10 (4.9)
Teacher	9 (4.4)
Secretary	8 (3.9)
Technician	7 (3.4)
Military staff	6 (2.9)
Lawyer	5 (2.5)
Shop Assistant	5 (2.5)
Laborer	5 (2.5)
Dentist	2 (1)
Smoking, n (%)	84 (41.2)
Alcohol, n (%)	36 (17.6)

Abbreviation: SD, Standard deviation.

STATISTICAL ANALYSIS

The descriptive data were presented as mean ± standard deviation, median (range), or n (%), where appropriate. The normality assumptions were controlled by the Shapiro−Wilk test. The differences in the normally distributed data among the study groups were analyzed using repeated measures ANOVA with a post-hoc Bonferroni test. The Friedman test with the post-hoc Bonferroni test, were applied for a nonparametric comparison of the parameters according to the study groups. Two-sided p-values <0.05 were considered statistically significant. All the statistical analyses were conducted using IBM SPSS Statistics for Windows, version 23.0 (IBM Corporation, Armonk, NY).

RESULTS

In this study, no statistically significant difference was found between the voice analyses of the participants without a mask, with a surgical mask, and with an FFP3 respirator in terms of the F0 (P = 0.102), jitter (P = 0.305), MPT (P = 0.416), and s / z (P = 0.295) values (Table 2). In the voice analysis performed with an FFP3 respirator, the measured shimmer values were lower than the values measured with a surgical mask and without a mask (P = 0.019). The HNR values measured in the voice analysis performed with an FFP3 respirator were higher than the values measured with a surgical mask and without a mask (P < 0.001). Given that it may affect the basic parameters in voice analysis, the data for the women and the men were examined separately.

There were no statistically significant differences between the F0 (P = 0.202), jitter (P = 0.052), shimmer (P = 0.143), MPT (P = 0.091), and s/z (P = 0.312) values among the female participants (Table 3). The HNR values measured in the voice analysis performed with an FFP3 respirator were higher than the values measured without a mask (P = 0.010).

There was no statistically significant difference between the F0 (P = 0.307) and s/z (P = 0.350) values among the male participants in the study groups (Table 4). The measured jitter values (mean rank = 1.86) with the use of a surgical mask were lower than the values measured without a mask (mean rank = 2.22; P = 0.045). The shimmer values measured with the use of a surgical mask were higher than the values measured in the voice analysis performed with an FFP3 respirator (P = 0.026). The MPT values measured without a mask were higher than those measured with an FFP3 respirator (P = 0.008). The HNR values measured in the voice analysis performed with an FFP3 respirator were higher than the values measured with a surgical mask and without a mask (P = 0.002).

TABLE 2.
Results of the Acoustic and Aerodynamic Analyses According to the Study Groups

Variables	Without a Mask Median (min-max)	Surgical Mask Median (min-max)	FFP3 Mask Median (min-max)	*P*
F0	202.4 (92.7–290.1)	198.8 (92.6–295.8)	202.1 (95.5–273.8)	0.102
Jitter	0.2 (0.1–1.1)	0.2 (0–3.4)	0.2 (0.1–0.8)	0.305
Shimmer	2.2 (0.8–8.5)^{a}	2.3 (0.9–5.5)^{a}	2 (0.6–11)^{b}	**0.019**
MPT	9.6 (0–29.4)	8.4 (0–29.7)	8.1 (0–32.2)	0.416
HNR	22.1 (0.3–29.6)^{a}	21.5 (0–31.5)^{a}	23.1 (5.4–31.3)^{b}	**<0.001**
s/z	0.6 (0–59)	0.7 (0–8.2)	0.6 (0–10.1)	0.295

Friedman test. ^{a,b} Statistically significant difference between the groups.

TABLE 3.
Results of the Acoustic and Aerodynamic Analyses According to the Study Groups With the Female Participants (n = 127)

Variables	Without a Mask Median (min-max)	Surgical Mask Median (min-max)	FFP3 Mask Median (min-max)	*P*
F0, mean ± SD	221.7 ± 25.2	223.1 ± 26	224 ± 23.8	0.202
Jitter	0.2 (0.1–1.1)	0.2 (0.1–3.4)	0.2 (0.1–0.8)	0.052
Shimmer	2 (0.8–8.5)	2.1 (0.9–5.5)	1.9 (0.6–4.6)	0.143
MPT	7.5 (0–27.2)	7.4 (0–29.7)	7.5 (0–32.2)	0.091
HNR	22.3 (1.9–29.6)^{a}	22.6 (0–31.5)^{a,b}	23.2 (6.4–31.3)^{b}	**0.010**
s/z	0.6 (0–6.2)	0.8 (0–7.8)	0.8 (0–9.6)	0.312

Repeated measures ANOVA, Friedman test. ^{a,b} Statistically significant difference between the groups.

TABLE 4.
Results of the Acoustic and Aerodynamic Analysis According to the Study Groups with the Male Participants (n = 77)

Variables	Without a Mask Median (min-max)	Surgical Mask Median (min-max)	FFP3 Mask Median (min-max)	*P*
F0	123.6 (92.7–161.2)	121 (92.6–187)	122 (95.5–167)	0.307
Jitter	0.2 (0.1–0.5)^{a}	0.2 (0–0.3)^{b}	0.2 (0.1–0.7)^{a,b}	**0.045**
Shimmer	2.3 (1.4–6.2)^{a,b}	2.8 (1.2–4.9)^{a}	2.2 (0.8–11)^{b}	**0.026**
MPT	13.4 (2.7–29.4)^{a}	9.8 (0–21)^{b}	9.8 (0–20.2)^{b}	**0.008**
HNR	21.5 (0.3–27.9)^{a}	21.5 (4.2–27.4)^{a}	22.7 (5.4–29.2)^{b}	**0.002**
s/z	0.5 (0–59)	0.6 (0–8.2)	0.3 (0–10.1)	0.350

Friedman test. ^{a,b} Statistically significant difference between the groups.

DISCUSSION

In the assessment of patients presenting with dysphonia, clinicians frequently use objective and subjective measurements.[7] Acoustic voice analysis is an objective, noninvasive, and easy-to-apply method that enables the evaluation of voice and gives quantitative knowledge on laryngeal function. Fundamental frequency (F0), jitter, shimmer, and HNR are the most frequently used acoustic parameters for voice assessment.[8, 9] These parameters are derived from the acoustic signals produced as a result of laryngeal function and are the markers of the sound production mechanism. Many studies in the literature have shown that F0, shimmer, jitter, and HNR values are important prognostic markers in the diagnosis and follow-up of vocal disorders.[10-13] F0 is the number of cycles per second by vocal folds. It is mainly related to the mass effect, elasticity, compliance, and the length of the membranous vocal folds.[14] Jitter and shimmer are perturbation measurements. They show variations in frequency and amplitude from cycle to cycle in the short term.[15] While there are also changes in frequency and amplitude from cycle to cycle in normal voice, extreme variations are a sign of unhealthy vocal function. Many studies in the literature have shown that perturbation measurements are helpful in distinguishing healthy and pathological voices and in the differential diagnosis of subtypes of pathological voices.[16, 17] HNR is the ratio of discordant energy in the range 1500–4500 Hz to harmonic spectral energy in the range 70–4500 Hz. It is used to determine the amount of noise in the signal. Studies in the literature have revealed that HNR is a quantitative index of hoarseness in the sound.[18, 19]

COVID-19 disease is a viral infection that was declared a global pandemic by the WHO and is transmitted mainly by droplet and contact routes.[20] Respiratory particles can be spread through breathing, talking, coughing, and sneezing.[21] Fluid-resistant surgical face masks are commonly used to protect against these particles. When a COVID-19 positive patient wears a surgical face mask, the rate at which the patient spreads the disease through droplets and contact is significantly reduced. When worn by hospital staff, surgical face masks provide superior protection against droplet transmission if staff maintains a distance of 1−2 meters from patients.[22] It is estimated that the rate of reduction in the risk of spreading the disease between two people if they wear surgical masks is at least 80%.[20] Terms such as FFP2, FFP3, and N95 are used for respirators with high-performance filtering properties. This high-performance filtering capability is achieved by the combination of a polypropylene microfiber mesh and electrostatic charge. The overall filter efficiency of FFP1, FFP2, and FFP3 masks is 80%, 94%, and 99%, respectively.[23]

Because of a lack of adequate awareness and information in the early stages of the pandemic, many healthcare workers were infected with COVID-19. Notably, healthcare workers in certain units dealing with noncommunicable diseases, such as ear-nose-throat (ENT) workers, were infected more frequently than their colleagues in the same hospital.[24-26] ENT specialists are at particularly high risk of exposure to respiratory pathogens due to the nature of their work. During the routine evaluation and management of patients, ENT professionals and staff can come into direct contact with upper respiratory tract secretions, droplets, or blood that can become airborne during accidental sneezing or coughing.[27] Proper use of personal protective equipment titrated to the exposure level and the creation of general patient care strategies can protect ENT specialists from SARS-CoV-2 transmission.[2]

During the COVID-19 pandemic, performing voice analysis without a mask increases the potential for SARS-CoV-2 transmission via droplets and aerosols, putting the patient and the ENT specialist at risk. In this study, we compared the parameters of voice analysis without a mask, with a surgical mask, and with an FFP3 respirator to perform voice analysis with a mask or respirator. The surgical masks used in the study were manufactured using a layer of melted polypropylene placed between two factory-produced non-woven fabrics. The valved FFP3 respirators consisted of multiple layers of nonwoven fabric made of polypropylene and an exhalation valve placed on the fabric.

There are some studies in the literature that have previously investigated this issue. Cavallaro et al performed acoustic voice analysis with and without a surgical mask and compared the basic parameters. The study was carried out on a selected group of 50 healthy subjects. They found no significant difference in F0, shimmer, jitter, and HNR values without a mask and with a surgical mask.[4] Magee et al investigated the impact of wearing a mask on acoustic output and speech perception. They examined how different face mask types (surgical, cloth, and N95), in combination with microphone variations (headset vs tabletop), affect speech recordings and perceived intelligibility. Seven objects were included in the study. They observed significant differences in acoustic power distribution across relevant frequency bands for speech in all three mask conditions compared to no mask for higher frequencies than 3 kHz. But similar to Cavallaro et al, they found no significant differences in F0, shimmer, jitter and HNR values performed without a mask and with different three mask types (surgical, cloth, N95), in combination with headset and tabletop microphone variations. In addition, the masks did not significantly influence listener-perceived intelligibility.[5] Fiorella et al also found that there were no statistically significant differences in F0, shimmer, jitter, HNR, MPT, and vocal intensity when wearing the surgical mask and not wearing the surgical mask. The study was carried out on a group of 60 healthy subjects.[6] Joshi et al investigated the acoustic measures of voice in six mask conditions: no mask, cloth mask, surgical mask, KN95 mask and, surgical mask over a KN95 mask with and without a face shield. Nineteen adults (ten females, nine males) with a normal voice quality performed the tasks for each of these conditions. They observed that individual masks (surgical, cloth, KN95) did not have any significant impact on the cepstral peak prominence, fundamental frequency and first formant frequency recorded at 1 ft. But intensity measures were most variable with additional of face shield.[28] Ribeiro et al studied to analyze the vocal self- perception of individuals who wore the face mask for essential activities and those who wore it for both professional and essential activities during the COVID-19 pandemic in Brazil. 468 individuals were included in the study. The outcome measures tested were self-perception of vocal fatigue, vocal tract discomfort, vocal effort, speech intelligibility, auditory feedback, and coordination between speech and breathing. It was shown that the face mask increased the perception of vocal effort, difficulties in speech intelligibility, auditory feedback, and difficulty in coordinating speech and breathing, regardless of the purpose of use. There was a greater perception of symptoms of vocal fatigue and discomfort, effort, difficulties in speech intelligibility, and coordination of speech and breathing in individuals who use the face masks for professional and essential activities. [29] Lin et al compared the acoustic parameters, including fundamental frequency (F0), sound pressure level (SPL), percentage of jitter (%), percentage of shimmer (%), noise to harmonic ratio (NHR) and cepstral peak prominence, aerodynamic parameter (maximum phonation time, MPT) and formant parameters (formant frequency, F1, F2, F3) without and with wearing medical masks. They further investigated the potential differences in the impact on different sexes and ages (≤45 years old and>45 years old). They concluded that healthy participants showed a significantly higher SPL, a smaller perturbation and an evident decrease in F3 after wearing medical masks. They thought these changes might result from the adjustment of the vocal tract and the filtration function of medical masks, leading to the stability of voices they recorded being overstated. The impacts of medical masks on sex were not evident, while the MPT in the >45-year-old group was influenced more than that in the ≤45-year-old group. [30]

In the present study, acoustic voice analysis was performed without a mask, with a surgical mask, and with a valved FFP3 respirator, and the basic parameters were compared. There was no significant difference in terms of the F0, jitter, shimmer, HNR, s/z, and MPT values in the voice analyses performed without a mask and with a surgical mask. When looking at the analysis data produced with an FFP3 respirator, no significant difference was found in the F0, jitter, s/z, and MPT values compared to the analysis values without a mask and with a surgical mask. However, the detected shimmer values were lower and the HNR values higher than the analysis values without a mask and with a surgical mask. This statistical analysis data led us to the conclusion that the voice analysis parameters that are obtained by a surgical mask are reliable to use in clinical cases. However, when the voice analysis is done by FFP3 respirator, only the F0, jitter, s/z and MPT values were reliable. So FFP3 respirator must be used only in the clinical cases where evaluation of F0, jitter, s/z, and MPT parameters is desired.

Cavallaro et al. and Magee et al. evaluated the voice analysis data without making any distinction between the sexes. Fiorella et al. investigated the data separately according to sex. They found no significant difference in vocal parameters separately in female and male subjects.[6] We also examined the data obtained from men and women separately because sex is the most important factor affecting voice analysis parameters. We think that it is one of the aspects that makes our study valuable. No significant differences were found in the female participants in terms of the F0, jitter, shimmer, MPT, and s/z values for all three conditions. Notwithstanding, in the voice analysis performed with an FFP3 respirator only, the HNR values were significantly higher than the values measured without a mask. For the male participants, no significant differences were observed with respect to the F0 and s/z values measured in all three conditions; however, the jitter values measured with the use of a surgical mask were found to be lower than the values measured without a mask. While the shimmer values measured with the use of a surgical mask were significantly higher than the values measured in the voice analysis performed with an FFP3 respirator, no significant difference was observed with the values measured without a mask. Additionally, the MPT values measured without a mask were higher than the values measured with the use of a surgical mask and an FFP3 respirator, and the HNR values measured in the voice analysis performed with an FFP3 respirator were higher than the values measured with a surgical mask and without a mask.

When the data of the voice analysis with a surgical mask were compared to the data without a mask in the group of female patients, the F0, jitter, shimmer, HNR, MPT, and s/z values were found to be reliable. Furthermore, when the data with an FFP3 respirator were compared to the data without a mask, the F0, jitter, shimmer, MPT, and s/z values were found to be reliable. In the data with a surgical mask for the group of male patients, the F0, shimmer, HNR, and s/z values were found to be reliable in comparison to the data without a mask, while in the data with an FFP3 respirator only, the F0, jitter, and s/z values were found to be reliable compared to the data without a mask. The data showed that, surgical mask for voice analysis can be used for female patients confidently for all parameters. However, the FFP3 respirator can only be used safely in clinical situations where F0, jitter, shimmer, MPT and s/z parameters are required. When looked at the data of the males, it has been seen that the number of the reliable parameters is lower for all situations. While a surgical mask can be used safely in clinical situations where one or more of the F0, shimmer, HNR and s/z parameters are desired to be evaluated, FFP3 can be used safely in clinical situations where one or more of the F0, jitter and s/z values are desired to be evaluated.

LIMITATIONS

Due to the COVID-19 pandemic, the study had to be completed over a longer period of time and with fewer patients. And this study did not use a physical model, so it is possible that the findings can be related to the participants changing effort level during voice analysis.

CONCLUSION

In the present study, when the voice analysis data were examined without a sex distinction, performing a voice analysis with a surgical mask was found to be reliable for all parameters, while performing a voice analysis with an FFP3 respirator was found to be reliable for all parameters except the HNR value. However, when the data obtained from men and women were evaluated separately, the number of reliable parameters obtained with a surgical mask and an FFP3 respirator decreased. In the light of the results obtained in this study, physicians should decide whether to perform voice analyses with a surgical mask or an FFP3 respirator by taking into account the clinically desired parameters. Our study is one of the few study in the literature to investigate voice analysis during the pandemic. Moreover, our study had the largest sample size and it uniquely examined the data obtained from men and women separately due to importance of sex in voice analysis. For this reason, it contributes to the literature and can be a guide for future studies.

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