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Effect of medical mask on voice in patients with dysphonia

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Abstract

Objective: Medical masks have been shown to significantly influence speech communication in healthy people. The effect of mask-wearing on phonatory capability and daily communication exchanges in patients with voice disorders remains unclear. To evaluate the effect of the medical mask on acoustic parameters in patients with a voice disorder, we measured the voice frequency, quality, and intensity.

Methods: Thirty-three healthy and 44 voice disorder patients were involved in this study, including 27 patients with vocal-fold lesions and 17 with primary functional dysphonia. Perceptual evaluation and acoustic parameters, including F0 (fundamental frequency), jitter, shimmer, and maximum vocal intensity, were analyzed without and with medical masks.

Results: With medical mask-wearing, the maximum vocal intensity significantly decreased in all patients with voice disorders ($p < 0.05$), especially in patients with lesions of vocal folds ($p < 0.05$) and functional dysphonia ($p < 0.05$). The perceptual evaluation roughness scales also increased in patients with lesions of vocal folds ($p < 0.05$) and functional dysphonia ($p < 0.05$) with mask-wearing. There were no significant effects of mask-wearing on acoustic parameters for healthy participants.

Conclusions: The intensity was influenced when wearing medical masks in patients with disordered voices. The voice perceptual roughness scales also significantly increased compared to those without medical masks.

KEYWORDS

acoustic, dysphonia, medical mask wearing, perceptual, perturbation, voice intensity

INTRODUCTION

Many industrialized countries wear face masks indoors and outdoors to reduce infection and the spreading of respiratory viruses, such as COVID-19. The community wears two main types of medical masks. Fluid-resistant medical masks (medical masks) fit loosely on the face and are designed to reduce the spread of large droplets, and the filtering facepiece (FFP) mask can filter the small particles to reduce the concentration of the hazardous substance.[1] The masks significantly influence speech communication, such as speech intelligibility

Jing Kang and Jing-Lin Su contributed equally to this study.

(SI), listening effort, singing voice, and online talking display in healthy people.[2–8] If mask-wearing influences the assessment of voice, it may affect clinical diagnosis in patients with voice disorders. Furthermore, the effect of mask-wearing on phonatory capability and daily communication exchanges in patients with voice disorders still has been unclear.

For assessment of phonatory capabilities, acoustic parameters are now applied routinely in both laboratories and clinics, such as jitter, shimmer, harmonic-to-noise ratio, voice intensity, and F0. Mostly, mask-wearing did not influence healthy people's acoustic measurements and phonatory capability. Several studies demonstrated no significant difference in voice pitch, harmonic-to-noiseratio (HNR), jitter, shimmer, and intensity between wearing a medical mask and not wearing a medical mask in healthy people.[9–11] On the other hand, few studies analyzed the effect of masks on acoustic parameters in patients with vocal pathology. Lin detected the acoustic parameters and perceptual evaluation in patients with vocal lesions and insufficient glottic closure and revealed that the pitch, jitter, and sound pressure level (SPL) increased significantly with medical masks, and G scales of the vocal-fold benign lesion decreased, they did not measure the voice in patients with the primary functional vocal disorders.[12,13]

In this study, we aim to detect and analyze the potential effects of medical masks on acoustic assessment and perceptual evaluation in patients with different kinds of voice disorders, including primary functional dysphonia and vocal lesions. The study may help us figure out the applications of acoustic parameters and perceptual evaluation in assessing different kinds of voice disorders with or without medical wear.

METHODS

The protection of the privacy of research participants has been ensured. The adequate level of confidentiality of the research data has been ensured.

Participants

This study was conducted in Department of Otolarynogology and Head and Neck Surgery, Guangdong Provincial People's Hospital, from December 2021 to January 2023. All participants who agreed to participate in the study signed an informed consent form previously approved by the hospital ethics committee (Approval number: KY-Q-2022-032-01). The inclusion criteria of patients were as follows: (a) age older than 18 years, (b) patients with disordered voices for at least 4 weeks, (c) those with perpetual voice disorders, and (d) voice disorders diagnosed by two experienced laryngologists. The exclusion criteria of patients were as follows: (a) patients with an acute respiratory infection, (b) those with hearing impairment, and (c) those with a recent vocal training history.

Mouth-and-nose covering medical mask

This study assessed the influence of the nose-and-mouth covering respiratory protective medical mask (Winner Medical Company) on acoustic and perceptual measurement of voice. The medical mask was chosen because it is commonly used to prevent the COVID-19 pandemic in China. The mask met the YY 0469-2011 medical mask standard by the General Administration of Quality Supervision.

Voice recordings

All participants were trained to voice the vocal sample before measurement. For voice pitch, quality assessments, and habitual vocal intensity, every participant was asked to phonate a sustained vowel/a/for at least 4 s three times at a habitual comfortable pitch and intensity. The recordings were made in a quiet clinical room where the background level was under 35 dB. The participant sat in front of a microphone (Shure SM81, SuZhou Shure Ltd) positioned approximately 10 cm from the left corner of the mouth. The voice signal coupled with Roland Edirol UST Audio interface (UA-25, Roland Ltd) with a sampling rate of 44 kHz and 16-bit accuracy. The signal was stored in a computer system after collecting sustained vowels. For the maximum vocal intensity assessment, every participant was asked to take a deep breath and then to phonate a sustained vowel/a/in the maximum vocal intensity for at least 4 s. We used a sound level meter (Tes 1350 A) to measure and record the maximum vocal intensity three times. The sound level meter is positioned as the microphone above. We directly took the raw SPL values from the SPL meter. For acoustic parameters measurement with masks, the participants were instructed to wear masks and repeat the procedure above. All participants performed the task with and without the mask. The order of measurements without and with mask-wearing was randomly performed and followed by a break of 30 s to avoid vocal fatigue.

Acoustic assessments

The voice signals were analyzed using PRAAT software (version 5.3.56, Phonetic Sciences). The stable phase of the voice sample was extracted for analysis. A 3000 ms segment at the midpoint of each sample was isolated for subsequent analyses. The 3000-ms sample was analyzed for acoustic parameters. The acoustic parameters include F0 (fundamental frequency), percentage of jitter (%), percentage of shimmer (%), harmonic to noise ratio (HNR), and intensity. All parameters were calculated on the average value.

Perceptual ratings

Perceptual ratings of roughness, breathiness, and hoarseness in sustained vowels were made on a four equal-point scale with 0 being normal, 1 mild, 2 moderate, 3 severe, which were used to evaluate disorder and normal voice.[14] Two listeners judge 438 samples assembled in random order. The listeners were two experienced speech-language pathologists who were familiar with voice disorders and were blinded to the identity of the patients. Interlistener reliability was evaluated by comparing scaling values from two listeners for all samples.

Statistical analysis

Data were managed and analyzed using IBM SPSS Statistics v.24.0 (IBM Corp, 2018). The *t*-test and Wilcoxon analysis were used to compare data between two conditions (with and without medical masks) on acoustic measures and perceptual scales. One-way analysis of variance (ANOVA) analysis was used to compare the means of voice outcome measures within the different diseases of masked patients and sex. Before analyses, the normal distribution of the data was examined using Kolmogorov–Smirnov tests and post hoc analysis. Spearman analysis was computed to measure the correlation between roughness, breathiness, hoarseness (RBH) ratings and acoustic measures. Correlations were also assessed for sub-components of the RBH scale. A significance level of 0.05 was used.

RESULTS

Participants

The study was carried out on two selected groups of healthy subjects (13 men and 19 women, mean age 33.3 years, and range 20–66) and patients with voice disorders (20 men and 24 women, mean age 39.8 years, and range 19–70) recruited among hospital staff and clinic patients of the ENT department of our hospital. The vocal lesions were visualized and diagnosed with the help of fiber optic laryngeal stroboscopy. Out of 27 vocal lesions, 7(24.1%) patients had vocal polyps, 6(20.7%) patients had vocal nodules, 7(24.1%) patients had vocal sulcus, and 5(17.2%) patients had vocal paralysis. Vocal cysts and scars were present in 2(6%) patients each. Of 17 primary functional dysphonia, 13(76,5%) patients had vocal muscle tension dysphonia, 3(17.6%) patients had spasmodic dysphonia, and one had puberty dysphonia.

Acoustic analysis

Voice quality parameters, including jitter, shimmer, and HNR, and fundamental frequency did not change while wearing the medical mask in healthy participants. The maximum vocal intensity also did not significantly change while wearing the medical mask (Table 1). There are no significant differences between participants with voice disorders without and with medical masks in voice F0, jitter, shimmer, and HNR. However, the maximum vocal intensity became lower while wearing the mask ($p < 0.001$) in the participants with voice disorders, including vocal lesions group ($p = 0.007$) and functional dysphonia ($p = 0.002$). The voice quality parameters, including jitter, shimmer, and HNR, did not change significantly in all participants with voice disorders while wearing the medical mask. F0 also did not significantly change while wearing the medical mask (Table 2).

Perceptual evaluation

Interjudge reliability was analyzed for the perceptual ratings of roughness, breathiness, and hoarseness in sustained vowels. The α value of reliability is 0.988 in roughness (R), 0.995 in breathiness (B), and 0.984 in hoarseness (H).

There was a significant difference between voice disorder patients and controls with mask-wearing in roughness ($p < 0.001$), breathiness ($p < 0.001$), hoarseness ($p = 0.001$), also significant difference without mask-wearing in roughness ($p = 0.001$), breathiness ($p < 0.001$), hoarseness ($p = 0.002$). Table 3 shows the results of the rating scores for the three perceptual parameters: roughness, breathiness, and hoarseness of sustained vowels in voice disorder patients with and without mask-wearing. The roughness scales of perceptual evaluation became higher while wearing the mask in the participants with voice disorders ($p = 0.003$), including vocal lesions group ($p = 0.025$) and functional dysphonia ($p = 0.046$).

TABLE 1 Acoustic parameters of healthy participants without and with surgical masks ($\bar{x} \pm s$).

	Healthy ($n = 32$)			Male ($n = 13$)			Female ($n = 19$)		
Parameters	Without	With	*p* Value	Without	With	*p* Value	Without	With	*p* Value
F_0 (Hz)	237.1 ± 73.1	233.7 ± 75.2	0.155	163.2 ± 6.0	160.7 ± 5.2	0.305	294.7 ± 54.3	290.8 ± 48.4	0.318
jitter (%)	0.3 ± 0.2	0.2 ± 0.1	0.143	0.3 ± 0.2	0.3 ± 0.1	0.617	0.3 ± 1.3	0.2 ± 0.1	0.144
shimmer (%)	2.5 ± 1.6	2.7 ± 1.3	0.622	3.5 ± 2.7	3.2 ± 1.7	0.464	2.1 ± 0.7	2.5 ± 1.4	0.313
HNR (dB)	23.4 ± 4.4	23.4 ± 4.3	0.999	21.9 ± 4.9	21.6 ± 4.3	0.624	24.2 ± 4.0	24.6 ± 4.0	0.699
Maximum intensity (dB)	95.2 ± 10.8	94.7 ± 7.8	0.629	97.8 ± 9.6	96.4 ± 7.6	0.200	93.5 ± 11.4	93.6 ± 7.9	0.984

Abbreviation: HNR, harmonic to noise ratio.

TABLE 2 Acoustic parameters of patients without and with surgical masks across different voice disorders ($\bar{x} \pm s$).

Parameters	Voice disorders ($n = 44$)			Vocal-fold lesions ($n = 27$)			Functional dysphonia ($n = 17$)		
	Without	With	p Value	Without	With	p Value	Without	With	p Value
F_0 (Hz)	230.0 ± 47.3	234.9 ± 53.0	0.458	226.0 ± 45.4	249.7 ± 52.5	0.081	224.3 ± 28.6	218.8 ± 34.1	0.067
jitter (%)	1.2 ± 4.2	0.5 ± 0.5	0.300	0.6 ± 0.6	0.5 ± 0.4	0.238	2.1 ± 6.8	0.5 ± 0.7	0.352
shimmer (%)	6.2 ± 4.6	5.4 ± 4.5	0.122	6.1 ± 4.2	5.4 ± 2.6	0.443	5.7 ± 5.2	5.4 ± 6.0	0.782
HNR (dB)	19.4 ± 6.3	20.4 ± 6.2	0.057	18.5 ± 6.5	19.5 ± 5.4	0.284	21.1 ± 6.8	21.5 ± 7.5	0.667
Maximum intensity (dB)	90.9 ± 7.6	88.8 ± 7.6	<0.001*	91.1 ± 6.1	88.7 ± 6.8	0.007*	90.9 ± 9.4	88.4 ± 8.9	0.002*

Abbreviation: HNR, harmonic to noise ratio.

*Parameters different significantly between with and without medical masks wearing, $p < 0.05$.

TABLE 3 Perceptual evaluation results of patients without and with surgical masks across different voice disorders.

Parameters	Voice disorders (average scale) ($n = 44$)			Vocal-fold lesions (average scale) ($n = 27$)			Functional dysphonia (average scale) ($n = 17$)		
	With	Without	p Value	With	Without	p Value	With	Without	p Value
R (roughness)	1.34	1.23	0.003*	1.56	1.46	0.025*	0.97	0.84	0.046*
B (breathiness)	0.43	0.42	0.317	0.50	0.50	1.000	0.31	0.28	0.317
H (Hoarseness)	1.76	1.69	0.058	1.91	1.83	0.157	1.50	1.44	0.157

*RBH value different significantly between with and without medical masks wearing, $p < 0.05$.

Correlations between ratings and acoustic measures

Numerous acoustic measures were significantly correlated with RBH ratings. Table 4 contains p-values and r-values for correlations. The high r values for the roughness scale of voice quality were observed for jitter ($r = 0.50$, p), shimmer ($r = 0.39$, $p = 0.010$), and HNR ($r = -0.42$, $p = 0.014$) in patients with lesions of vocal folds without wearing the mask. For wearing the mask, the high r values for the roughness scale of perceptual rating were observed for jitter ($r = 0.32$, $p = 0.040$). The breathiness and hoarseness scales were significantly correlation with jitter, shimmer, and HNR in patients with voice disorders with and without wearing masks. RBH scale had a higher correlation with jitter, shimmer, and HNR in patients with vocal-fold lesions while wearing the mask and without wearing the mask (Table 4).

DISCUSSION

Mask use was reported as negatively and widely affecting communication exchanges in the community, workplace, and household members in the COVID-19 era.[15] Medical masks have evolved to prevent infection in patients with viruses such as COVID-19.[1] We used acoustic analysis and perceptual evaluation to investigate the possible reasons for whether medical masks influence communication exchanges in patients with voice disorders.

Acoustic analysis plays a vital role in voice assessment. F0, jitter, shimmer, and HNR are often used to evaluate pitch and voice quality in healthy people and patients with voice disorders.[16,17] Both our and Cavallaro and Fiorella's studies demonstrated that the difference in acoustic voice analysis detected between wearing a surgical mask and not wearing a surgical mask was not statistically significant in healthy people, including F0, jitter, shimmer, HNR, and intensity.[9–11,18]

A few studies analyzed the effect of masks on acoustic parameters in patients with vocal pathology. Furthermore, patients with voice disorders were required to wear medical masks to perform an acoustic measurement against virus infection in many hospitals, especially during the respiratory virus incidence peak period. Lin reported that voice pitch, quality, and intensity were influenced by wearing the mask in patients with a voice disorder. Our study differed from their work on Lin' study, including disease patterns and acoustic parameters. The err and trk values are usually used to quantify the noise from the voice. Type 1–2 voices produced low err and trk and were suitable for F0 measurement and perturbation analysis, but type 3 and type 4 voices produced high err and trk values to worsen voice evaluation.[19] Most glottic carcinoma voices are type 3–4 signals, which may cause the inaccuracy of voice quality measurement. The early-stage glottic carcinoma involved Lin's study.[13,20] To avoid type 3–4 voice signals, glottic carcinoma was excluded from our study.

On the other hand, Lin's study also did not measure patients with primary functional dysphonia, who were many patients with voice disorders.[12] In avoidance of compensatory vocal effort behavior in response to the voice attenuation from mask-wearing, we measured maximum vocal intensity in this study.[21,22] In our study, we measured maximum vocal intensity instead of habitual vocal intensity, which was measured in Lin's study. In our study, the maximum vocal intensity decreased significantly in all patients with mask-wearing,

TABLE 4 Correlations between RBH and voice acoustic measures.

Voice measures	Voice disorders (average scale) (n = 44)						Vocal-fold lesions (average scale) (n = 27)						Functional dysphonia (average scale) (n = 17)					
	Roughness		Breathiness		Hoarseness		Roughness		Breathiness		Hoarseness		Roughness		Breathiness		Hoarseness	
Acoustics	r	p Value	r	p Value	r	p Value	r	p Value	r	p Value	r	p Value	r	p Value	r	p Value	r	p Value
Jitter with	0.32	0.04*	0.39	0.01*	0.33	0.03*	0.40	0.04*	0.50	0.01*	0.38	0.05	0.02	0.95	0.18	0.51	0.18	0.51
Shimmer with	0.19	0.22	0.45	0.00*	0.33	0.03*	0.31	0.11	0.58	<0.01*	0.402	0.04*	0.23	0.40	0.11	0.68	−0.04	0.88
HNR with	−0.22	0.15	−0.47	0.00*	−0.37	0.02*	−0.37	0.06	−0.63	<0.01	−0.47	0.01*	0.07	0.79	−0.15	0.58	−0.12	0.67
Jitter without	0.50	<0.01	0.40	0.01*	0.49	<0.01	0.69	<0.01	0.68	<0.01	0.65	<0.01	0.09	0.74	0.05	0.87	0.15	0.58
Shimmer without	0.39	0.01*	0.59	<0.01	0.35	0.02*	0.49	0.01*	0.75	<0.01	0.41	0.04*	0.14	0.60	0.25	0.36	0.14	0.62
HNR without	−0.42	0.01*	−0.60	0.00*	−0.44	<0.01	−0.47	0.01*	−0.75	<0.01	−0.48	0.01*	−0.25	0.36	−0.28	0.29	−0.29	0.28

Abbreviation: HNR, harmonic to noise ratio.

*Indicates significant association, significance level at 0.05 jitter, shimmer, HNR.

either female or male. The voice intensity also decreased significantly in patients with lesions of vocal folds and functional dysphonia ($p < 0.05$). Deng employs a body-cover model of the vocal folds to investigate the effects of mask-wearing on acoustic assessments. They found that wearing masks reduces the sound intensity.[22] Lin reported that SPL in patients with a vocal-fold lesion group increased significantly with medical masks. Lin believed that the Lombard effect on voice compensation behavior might cause an intensity increase.[13] To reduce the distortion of measurement from vocal hyperfunction for compensatory behavior, the maximum vocal intensity was measured in the patient with the vocal disease in our study. There was intensity attenuation from mask-wearing when measuring the maximum vocal intensity and no compensatory behavior, which may result from weak vocal compensatory ability in patients with vocal pathology.

In Lin's study, F0 significantly increased while mask-wearing in patients with lesions of vocal folds and insufficient glottic closure.[13] Our study showed no difference in fundamental frequency between patients with mask-wearing and those without mask-wearing. The fundamental frequency is independent of vocal intensity with vowel phonation for healthy people.[23] Even though compensatory behavior happens in healthy people with mask-wearing to increase vocal intensity, the F0 remains invariable. Mallol-Ragolta used machine-learning techniques to investigate the effect of face masks on speech sample frequencies. Porschmann used a dummy head and mouth simulator wearing face masks to measure and analyze sound radiation. They both claimed that face masks mainly attenuate frequencies above 1 or 2 kHz, not the frequency range of F0 in the speech sample.[24,25]

In this study, there was no significant change in the voice quality acoustic parameters of patients with lesions of vocal folds and functional dysphonia. Berry believed that the conditions of pressure-stiffness mismatch cause irregular or chaotic vocal fold vibration, which reduces voice quality.[26] The vocal fold approximation only slightly affects the glottal closure quotient and noise production within the normal range of glottic closure configuration.[27] For the patients with insufficient glottal closure, Zhang' study demonstrated that glottal insufficiency leads to increased noise production and can be compensated by bilateral vocal fold approximation using the physic phonation model in patients with insufficient glottal closure. Patients with insufficient glottic closure sustaining target sound intensity levels may necessitate increased vocal fold compensatory collision behavior while wearing the medical mask.[22,28] Lin demonstrated that the jitter in the insufficient glottic closure group increased significantly with the medical mask but not in the shimmer, cepstral peak prominence, and noise to harmonic ratio (NHR). The parameters of voice quality did not change in patients with benign vocal fold lesions while wearing the medical mask in Lin's study. Robert reported that GRBAS ratings were significantly correlated with voice quality acoustic measures (jitter%, shimmer%, NHR) in voice disorder.[29] However, Lin found that the G and R scales of perceptual scales significantly decreased in the patients with vocal-fold benign lesions while wearing medical masking.[13] In our study, the voice acoustic perturbation did not change in patients with vocal fold lesions and functional dysphonia while wearing the mask. However, the perceptual R scale significantly increased in patients with voice disorders, including vocal-fold lesions and functional dysphonia. There is a significant correlation between the voice perceptual R scale and the quality perturbation parameters in patients with vocal fold lesions wearing or not wearing a mask. This finding corroborates that of Robert, who reported that the GRBAS rating was correlated with jitter and shimmer in voice disorder.[29]

For healthy people, our study and other studies showed that F0 did not significantly change in male or female people with the medical mask when compared with no mask scenarios.[11,30,31] When wearing medical masks, the maximum vocal intensity of healthy people did not change in our study. The aforementioned studies and our study unraveled that the effects of mask-wearing on the pitch, intensity-related measures, and perturbation-related measures were insignificant in healthy people. Lin's study found that voice intensity significantly increased, and jitter and shimmer significantly decreased while wearing medical masks in healthy people.[12] Their results differed from other studies and did not discuss them.[9–12] Future research will explore the effects of pitch and intensity on the perturbation of patients with mask-wearing.

CONCLUSIONS

Medical mask-wearing significantly decreased maximal vocal intensity, but there was no difference in F0, jitter, shimmer, or HNR in patients with vocal pathology, especially with lesions of vocal folds and functional dysphonia. There was also increased roughness on the perceptual R scale in patients with voice disorders, including vocal lesions and functional dysphonia. For healthy participants, mask-wearing had no significant effects on fundamental frequency, maximum vocal intensity, and perturbation.

AUTHOR CONTRIBUTIONS

Jing-Lin Su: methodology, data collection, draft writing; **Jing Kang**: methodology, data collection, draft writing, revision, formal analysis; **Qin-Yi Ren and Zhi-Xian Zhu**: data collection; **Si-Yi Zhang**: review writing and revision; **Ping-Jiang Ge**: methodology, idea formulation, data collection, editing the final draft, and final revision.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

All of the data analyzed during this study are included in this article. Further enquiries can be directed to the corresponding author.

ETHICS STATEMENT

The study was approved by the Ethics Committee of Guangdong Provincial People's Hospital (Approval number: KY-Q-2022-032-01).

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