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ORIGINAL ARTICLE

Decreased Speech Comprehension and Increased Vocal Efforts Among Healthcare Providers Using N95 Mask

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Abstract

Aim: N95 masks are recommended for the healthcare providers (HCPs) taking care of patients with coronavirus disease 2019. However, the use of these masks hampers communication. We aimed to evaluate the effect of N95 masks on speech comprehension among listeners and vocal efforts (VEs) of the HCPs.

Materials and Methods: This prospective study involved 50 HCPs. We used a single observer with normal hearing to assess the difficulty in comprehension, while VE was estimated in HCPs. The speech reception threshold (SRT), speech discrimination score (SDS), and VEs were evaluated initially without using N95 mask and then repeated with HCPs wearing N95 mask.

Results: The use of masks resulted in a statistically significant increase in mean SRT [4.25 (1.65) dB] and VE [2.6 (0.69)], with simultaneous decrease in mean SDS [19.2 (8.77)] (all p-values < 0.0001). Moreover, demographic parameters including age, sex, and profession were not associated with change in SRT, SDS, and VE (all p-values > 0.05).

Conclusion: Though use of N95 masks protects the HCPs against the viral infection, it results in decreased speech comprehension and increased VEs. Moreover, these issues are universal among the HCPs and are applicable to the general public as well.

Keywords Audiometry · N95 masks · Speech comprehension · Speech discrimination scores · Speech reception thresholds · Vocal efforts

Introduction

Declared as a pandemic by World Health Organization in March 2020, coronavirus disease 2019 (COVID-19) has resulted in more than 521 million confirmed cases and more than 6 million deaths globally, till date. 1,2 Severe acute respiratory distress syndrome-coronavirus-2 (SARS-CoV-2) has been identified as an etiologic agent of COVID-19. Though various routes of transmission have been postulated, aerosol transmission is regarded as the main route. 3.

In the initial part of 1900s, surgical face masks were introduced to avoid the infection of surgical wounds due to bacteria originating from the mouth and nose of healthcare providers (HCPs). 4 In the current COVID-19 pandemic, use of masks has been mandated by various countries to halt the transmission of SARS-CoV-2. Face masks together with various other non-pharmacological approaches including social distancing, eye protection, maintaining hand hygiene, and isolation have been universally used and have been proved to curb the spread of COVID-19. 5,6.

To provide complete protection, face masks need to snugly cover the mouth and nose. However, this leads to substantially diminished visual cues as lip reading is not possible and view of facial expressions is hampered. Patients may fail to completely comprehend the instructions of HCPs. Moreover, communication among the HCPs may compel several repetitions and higher strain on both vocal effort (VE) and listening. During a surgical procedure,

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assisting HCPs may not accurately follow the instructions of the operating surgeon. This is likely to result in communication errors which can have serious consequences. 7.

During the COVID-19 pandemic, as in every healthcare set-up, HCPs in our hospital are required to regularly wear N95 masks to curb the spread to infection. In this study, we aimed to quantify the impact of N95 masks on speech comprehension and VE among the HCPs with normal vocal function by evaluating its impact on speech reception thresholds (SRTs), speech discrimination scores (SDSs), and vocal efforts (VEs).

Materials and Methods

This was a prospective, observational study conducted in the out-patient department of ENT of a tertiary care teaching hospital located in the western-part of India. The study was performed over a period of 2 months (from January to February 2021) and commenced after approval of the protocol by the institutional ethics committee and obtaining informed consent of the HCPs.

HCPs with normal vocal function, belonging to age group of 20–50 years, and working in the out-patient department of ENT were enrolled in the study. The HCPs enrolled in the study included resident doctors, interns, and nurses.

To ensure normal uniform hearing, we had a single observer who was subjected to pure tone audiometry (Elkon EDA 3N3 Multi, Mumbai, India), defined as a pure tone average of less than 25 dB at 500, 1000, and 2000 Hz. Normal vocal cord functioning of HCPs was ensured with GRBAS scale (Grade, Roughness, Breathiness, Asthenia, and Strain Scale). 8 HCPs with any hoarseness or change in voice, any proven vocal cord pathology, or change in voice due to old age were excluded.

To determine SRT and SDS, HCPs and observer sat at a distance of 0.6 m, so as to simulate standard conversational distance, and a decibel meter (Mextech SL36 sound level meter, Mumbai, India) was used. The same procedures for speech comprehension and VEs were performed initially with HCPs not wearing the mask and then repeated with the mask. The Venus V-4400 N95 masks were procured from Venus Safety & Health, Navi Mumbai, India.

To test SRT, we used a validated list of 50 spondee words recommended by the American Speech–Language–Hearing Association. 9 These were two-syllable words with same amount of stress on both syllables (e.g., 'birthday', 'play ball', and 'tooth brush'). A volume unit meter was employed to get same amount of syllabic stress. Initially, without wearing the mask, HCPs were asked to read the words with uniform intensity and SRT was estimated as the lowest hearing level (intensity) at which the observer could correctly comprehend and repeat the speech stimuli 50% of the time. The same procedure was repeated with the HCPs wearing mask and SRT with mask was estimated.

To determine SDS, we used a set of monosyllabic phonetically balanced words. Standard word lists included those issued by the Psycho-Acoustic Laboratory and the Central Institute for the Deaf W-22 word list for auditory testing. 10,11 To suit the Indian population, we used an adapted and validated version of this list comprising of phonetically balanced words. Initially, without wearing the mask, HCPs were instructed to read a list of 20 words and observer was asked to hear the words. The number of words that could be correctly heard by the observer were expressed as percentage. The same procedure was repeated with HCPs wearing the mask and SDS was estimated.

To estimate the VE, we used the validated Rainbow Passage. 12 Initially, the HCPs were asked to read the passage at a uniform intensity without mask and rate the effort required with the adapted BORG CR-10 scale. 13 They were asked to repeat the same procedure with mask and read the passage with same intensity as that without the mask, and rate their efforts. BORG CR-10 is a Likert's scale ranging from 0 to 10, with 0 suggesting no VE and 10 suggesting maximum VE.

These procedures were performed to determine the amount of hearing difficulty faced by listeners and the increased VEs that is faced by the HCPs when they wear the mask, thus, mimicking the real-world scenario.

Statistical Analysis

The categorical and continuous data was expressed in terms of frequency (percentage) and mean (standard deviation), respectively. The SRTs, SDSs, and VE with and without mask were compared with paired t-test. While, the change in SRTs, SDSs, and VE with and without mask for the categorical demographic variables were compared with independent sample t-tests. Statistical analysis was performed with SPSS (IBM, Armonk, NY, USA) version 23.0 for Windows. A two-tailed probability value (p-value) of < 0.05 was considered as statistically significant.

Results

Among 50 HCPs, 36 were resident doctors and medical interns, while the remaining were nurses. The age of HCPs ranged from 23 to 50 years, with a mean age of 29.6 (6.33) years. Moreover, 32 HCPs were male.

Without mask, the SRT ranged from 60 dB to 85.5 dB. With mask, the SRT increased and ranged from 64.5 dB to 89 dB. The mean increase in SRT with mask was 4.25

Table 1 Speech reception thresholds, speech discrimination scores, and vocal efforts with and without N95 masks

Parameters	With or without mask	Mean (SD)	p-value
SRT (dB)	Without mask	74.51 (5.09)	< 0.0001
	Mask	78.76 (4.98)	
SDS (%)	Without mask	100 (0)	< 0.0001
	Mask	80.8 (8.77)	
VE	Without mask	0 (0)	< 0.0001
	Mask	2.6 (0.69)	

SRT: Speech reception threshold; SDS: Speech discrimination score; VE: Vocal efforts; SD: standard deviation

(1.65) dB and was found to be statistically significant (p-value < 0.0001) (Table 1).

We observed that, without mask, the SDS of the observer was 100% for all the HCPs. However, with mask, the SDS of the observer decreased and ranged from 70 to 100%. The mean decrease in SDS was 19.2 (8.77) and this decrease was found to be statistically significant (p-value < 0.0001) (Table 1).

Similarly, without mask, all the HCPs had zero VE. However, with mask, an increase in VE was observed and ranged from 1 to 4. The mean increase in VE was 2.6 (0.69) and this increase was found to be statistically significant (p-value < 0.0001) (Table 1).

Finally, the change in SRT, SDS, and VE with and without masks were analysed in terms of age, sex, and profession. We observed no statistically significant difference (all p-value > 0.05) in the change in SRT, SDS, and VE when comparison was made between different age groups (20–35 years versus 36–50 years), sex (male versus female), and profession (doctors versus nurses) (Table 2).

Discussion

Though the masks have been instrumental in curbing the spread of viral infections including SARS-CoV-2, 5,6 their use hinders the propagation of the sound waves because sound energy of some spectral component may be filtered out or attenuated. 14–16 The sound absorbing quality of the material used for making the mask determines the amount of attenuation during transmission. 16 Masks substantially compromises the comprehension of consonants and discrimination of unfamiliar talkers, 14 as well as the intensity and spectral features of the voiceless fricatives. 15.

N95 and surgical masks can attenuate higher-frequency sounds by around 3–12 dB. 17 With N95 masks, the word comprehension decreases by 1–17%.18 In the presence of background noise, their use is associated with a significant decrease in accuracy of speech perception. 19 At longer distances, compared to speaking without a mask, speaking with mask leads to a greater decline in accuracy of speech perception. 20 Moreover, the visual cues that contribute to speech comprehension are obstructed. 15.

The principal findings of our study suggest that use of mask leads to a significant increase in the SRT and VEs, with simultaneous decrease in SDS. The impaired speech comprehension and increased VEs were evident despite the fact that HCPs were evaluated in ideal conditions and with the probability of getting accustomed to words related with repeated testing.

Findings similar to our study were demonstrated by Bandaru et al. 21 They observed that use of N95 mask and face shield results in significantly increased SRT and decreased SDS. Though ideal for HCPs involved in management of patients with COVID-19, their findings cannot be extrapolated to the general public, as both N95 mask and face shield are not used universally. N95 mask alone provides superior protection against micro-organisms; thus, making our findings more pertinent to the public. Hampton et al. 22 reported that use of personal protective equipments, including masks, shields, and gowns, result in significantly impaired speech discrimination in the settings of intensive care units and operating rooms. Thus, use of protective equipments can adversely affect the communication among the HCPs and this has grave implications for patient safety.

To standardize the environment for quantitative assessment, we used acoustically treated room. However, in real world scenario, conversations in the healthcare setup mostly

Table 2 Comparison of changes in speech reception thresholds, speech discrimination scores, and vocal efforts in terms of age, sex, and profession

Outcome measures	Demographic parameters					
	Age (Years)		Sex		Profession	
	20–35 (N = 44)	36–50 (N = 6)	Male (N = 32)	Female (N = 18)	Doctor (N = 36)	Nurse (N = 14)
Change in SRT	4.22 (1.68)	4.50 (1.52)	4.41 (1.91)	3.97 (1.06)	4.08 (0.94)	4.68 (2.76)
p-value	0.697		0.379		0.258	
Change in SDS	19.77 (8.48)	15.08 (10.49)	19.38 (9.14)	18.89 (8.32)	20.56 (8.60)	15.71 (8.52)
p-value	0.214		0.853		0.079	
Change in VE	2.59 (0.69)	2.67 (0.82)	2.63 (0.79)	2.56 (0.51)	2.58 (0.69)	2.64 (0.74)
p-value	0.806		0.740		0.790	

Data expressed as mean (standard deviation); SRT: Speech reception threshold; SDS: Speech discrimination score; VE: Vocal efforts

take place in the presence of substantial ambient noise and this could impair speech comprehension. Bottalico et al. 23 studied the effect of masks on speech comprehension in an acoustically treated room and observed that words were recognized to a significantly better extent in acoustically treated room than the room that was not acoustically treated (34% versus 21%). Moreover, the use of N95 mask was associated with significantly decreased probability of correct recognition of the words, around 47% less than without the mask. In another study, Mendel et al. 24 reported that use of surgical masks was associated with significant difference in the spectral analysis of speech stimuli than without mask. They further reported that use of surgical mask did not result in a significant difference in speech comprehension between individuals with normal hearing and those with impaired hearing; however, the presence of background noise led to reduced comprehension in both groups. Ideally, such studies should be performed in the out-patient setting. However, in such settings, it is not possible to maintain standard ambient noise and presentation level, and obtain reliable results. Thus, we evaluated the HCPs in acoustically treated room.

The relative position of speaker and listener affects the speech comprehension. When a person with mask speaks, the sound transmitted to the sides and behind him are affected to a significantly less extent than that in front. Moreover, if the person is using an additional face shield, then the sound is amplified for the listener behind. Rather than absorbing the sound energy, the mask deflects it to the sides and the maximum attenuation of the sound takes place for the listener in front. 25 Thus, the relative position of HCPs and observer, in our study, could have affected the findings. Alternatively, Llamas et al. 15 evaluated a variety of face coverings and reported that the loss of sound during transmission is negligible except with surgical masks. They suggested that reduced comprehension of sound with the use of mask is primarily due to the auditory consequences of disturbance in speech articulation and/or result of decreased visual characteristics that are accessible to listeners. Thus, with surgical and N95 masks, decreased speech comprehension is a due to both loss of sound energy during transmission and absence of visual cues.

Attenuation of voice by mask results in increased vocal intensity. Moreover, it can affect other aspects of voice generation, produce pneumo-phono-articulatory incoordination, and hampers visualization of articulation. Misuse and abuse of voice is linked to poor vocal adjustments and exaggerated muscle tension may heighten the perception of symptoms, discomfort, and even initiate behavioral dysphonia. 26–29 Similar to our study, Ribeiro et al. 30 reported that mask used for both professional and essential activities was associated with significantly increased VEs. These activities were linked to significantly increased scores of vocal fatigue symptoms, and higher frequency and intensity of vocal tract discomfort. Moreover, when compared to conditions without masks, use of masks was associated with increase in VEs; hardship in speech comprehension, speech coordination, and breathing; and reduced auditory feedback.

We observed that demographic parameters such as age, sex, and profession were not associated with change in SRT, SDS, and VEs. Similar findings are reported by Bandaru et al. 21 Thereby, suggesting that these findings can be generalized across the HCPs.

Our study had certain limitations. First, when determining SRT and SDS, the observer sat in front of the HCPs with mask and maximum attenuation of speech is reported in this setting. Studies needs to be performed with observer sitting at equal distance, on either side of participants with mask. Second, we used a single observer with normal hearing and thus, further research needs to involve multiple observers and analyze the inter-observer difference. Moreover, hearing impaired individuals should be enrolled in the study. Finally, we used single and two-syllable words without considering their effect on the meaning of the whole sentence. It is reported that the use of sentences contributes to the linguistic context, which may permit listeners to correctly comprehend the words that would otherwise be incomprehensible. 31 It is further reported that in fair or poor acoustics conditions, comprehension of sentences can outperform the comprehension of words by around 30%.32 Thus, future studies evaluating the effect of mask on speech comprehension should use sentences rather than the words.

Conclusion

Though the use of N95 masks protects the HCPs against the viral infection, it results in decreased speech comprehension and increased VEs. Although, these issues are universal among the HCPs, they can be applicable to the general public as well. To avoid miscommunication among the HCPs, use of supplementary methods of communication should be encouraged, especially in intensive care units and operating rooms.

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Compliance with Ethical Standards

Conflict of Interest There is no conflicts of interest among the authors.

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Ethical Approval Institutional ethical approval and consent for publication were obtained.

Informed Consent Informed consent was taken from all the participants during the study to include their findings in the study not revealing their identity.

References

1. World Health Organization (WHO). Archived: WHO Timeline - COVID-19. Updated April 27 (2020) https://www.who.int/news/item/27-04-2020-who-timeline---covid-19. (Accessed on May 29, 2021)
2. World Health Organization (WHO) (2022) WHO Coronavirus (COVID-19) Dashboard. https://covid19.who.int/table.
3. Karia R, Gupta I, Khandait H, Yadav A, Yadav A (2020) COVID-19 and its Modes of Transmission. SN Compr Clin Med 1–4. https://doi.org/10.1007/s42399-020-00498-4
4. Belkin NL (1996) A century after their introduction, are surgical masks necessary? AORN J 64(4):602–607. https://doi.org/10.1016/s0001-2092(06)63628-4
5. Rader B, White LF, Burns MR, Chen J, Brilliant J, Cohen J et al. Mask-wearing and control of SARS-CoV-2 transmission in the USA: a cross-sectional study.Lancet Digit Health. 2021Mar; 3(3):e148-e157. https://doi.org/10.1016/S2589-7500(20)30293-4
6. Chu DK, Akl EA, Duda S, Solo K, Yaacoub S, Schünemann HJ(2020) ; study authors. Physical distancing, face masks, and eye protection to prevent person-to-person transmission of SARS-CoV-2 and COVID-19: a systematic review and meta-analysis. Lancet. ;395(10242):1973–1987. https://doi.org/10.1016/S0140-6736(20)31142-9
7. Bakhit M, Krzyzaniak N, Scott AM, Clark J, Glasziou P, Del Mar C (2021) Downsides of face masks and possible mitigation strategies: a systematic review and meta-analysis. BMJ Open 11(2):e044364. https://doi.org/10.1136/bmjopen-2020-044364
8. De Bodt MS, Wuyts FL, Van de Heyning PH, Croux C (1997) Test-retest study of the GRBAS scale: influence of experience and professional background on perceptual rating of voice quality. J Voice 11(1):74–80. https://doi.org/10.1016/s0892-1997(97)80026-4
9. ASHA (1988) Guidelines for determining threshold level for speech. ASHA 30:85–89 PMID: 3155355
10. Hirsh IJ, Davis H, Silverman SR, Reynolds EG, Eldert E, Benson RW (1952) Development of materials for speech audiometry. J Speech Hear Disord 17:321–337. https://doi.org/10.1044/jshd.1703.321
11. EganJP(1948)Articulationtestingmethods.Laryngoscope58:955–991. https://doi.org/10.1288/00005537-194809000-00002
12. The Rainbow Passage. 2nd edition, Grant Fairbanks' Voice and Articulation Drillbook. New York: Harper & Row. pp. 127
13. Ford Baldner E, Doll E, van Mersbergen MR (2015) A review of measures of vocal effort with a preliminary study on the establishment of a vocal effort measure. J Voice 29(5):530–541. https://doi.org/10.1016/j.jvoice.2014.08.017
14. Owren MJ, Cardillo GC (2006) The relative roles of vowels and consonants in discriminating talker identity versus word meaning. J Acoust Soc Am 119:1727–1739. https://doi.org/10.1121/1.2161431
15. Llamas C, Harrison P, Donnelly D et al (2009) Effects of different types of face coverings on speech acoustics and intelligibility. York Papers on Linguistics 9:80–104
16. Nute ME, Slater K (1973) The effect of fabric parameters on sound-transmission loss. J Text Inst 64:652–658. https://doi.org/10.1080/00405007308630315
17. Goldin A, Weinstein BE, Shiman N (2020) How do medical masks degrade speech perception? Hear rev 27(5):8–9
18. Radonovich LJ Jr, Yanke R, Cheng J, Bender B (2010) Diminished speech intelligibility associated with certain types of respirators worn by healthcare workers. J Occup Environ Hyg 7:63–70. https://doi.org/10.1080/15459620903404803
19. Thomas F, Allen C, Butts W, Rhoades C, Brandon C, Handrahanet DL (2011) Does wearing a surgical facemask or N95-respirator impair radio communication? Air Med J 30:97–102. https://doi.org/10.1016/j.amj.2010.12.007
20. Coyne KM, Johnson AT, Yeni-Komshian GH, Dooly CR (1998) Respirator performance ratings for speech intelligibility. Am Ind Hyg Assoc J 59:257–260. https://doi.org/10.1080/15428119891010523
21. Bandaru SV, Augustine AM, Lepcha A, Sebastian S, Gowri M, Philip A, Mammen MD (2020) The effects of N95 mask and face shield on speech perception among healthcare workers in the coronavirus disease 2019 pandemic scenario. J Laryngol Otol 1–4. https://doi.org/10.1017/S0022215120002108
22. Hampton T, Crunkhorn R, Lowe N, Bhat J, Hogg E, Afifi W et al (2020) The negative impact of wearing personal protective equipment on communication during coronavirus disease 2019. J Laryngol Otol 134(7):577–581. https://doi.org/10.1017/S0022215120001437
23. Bottalico P, Murgia S, Puglisi GE, Astolfi A, Kirk KI (2020 Nov) Effect of masks on speech intelligibility in auralized classrooms. J Acoust Soc Am 148(5):2878. https://doi.org/10.1121/10.0002450
24. Mendel LL, Gardino JA, Atcherson SR (2008) Speech understanding using surgical masks: a problem in health care? J Am Acad Audiol 19:686–695. https://doi.org/10.3766/jaaa.19.9.4
25. Corey RM, Jones U, Singer AC (2020) Acoustic effects of medical, cloth, and transparent face masks on speech signals. J Acoust Soc Am 148(4):2371. https://doi.org/10.1121/10.0002279
26. Balata PMM, Silva HJ, Pernambuco LA, Amorim GO, Maior Braga RS, Fernandes da Silva EG et al (2015) Electrical activity of extrinsic laryngeal muscles in subjects with and without dysphonia. J Voice 29(1):129e9–12917. https://doi.org/10.1016/j.jvoice.2014.03.012
27. Redenbaugh MA, Reich AR (1989) Surface EMG and related measures in normal and vocally hiperfunctional speakers. J Speech Hear Disord 54:68–73. https://doi.org/10.1044/jshd.5401.68
28. Hocevar-Boltezar I, Janko M, Zargi M (1998) Role of surface EMG in diagnostics and treatment of muscle tension dysphonia. Acta Otolaryngol 118:739–743. https://doi.org/10.1080/00016489850183287
29. Behlau M, Zambon F, Moreti F, Oliveira G, de Barros Couto E Jr (2017) Voice self-assessment protocols: different trends among organic and behavioral dysphonias. J Voice 31 :112.e13-112.e27. https://doi.org/10.1016/j.jvoice.2016.03.014
30. Ribeiro VV, Dassie-Leite AP, Pereira EC, Santos ADN, Martins P, Irineu RA(2020) Effect of Wearing a Face Mask on Vocal Self-Perception during a Pandemic. J Voice. ;S0892-1997(20)30356-8. https://doi.org/10.1016/j.jvoice.2020.09.006
31. Allison KM, Yunusova Y, Green JR (2019) Shorter sentence length maximizes intelligibility and speech motor performance in persons with dysarthria due to amyotrophic lateral sclerosis. Am J Speech Lang Pat 28(1):96–107. https://doi.org/10.1044/2018_AJSLP-18-0049
32. IEC 60268-16-2003: Sound System Equipment—Part 16: Objective Rating of Speech Intelligibility by Speech Transmission

Index (2003) https://standards.iteh.ai/catalog/standards/clc/b1be26cf-af1f-42d9-a1fa-b187ff9b0239/en-60268-16-2003. (Accessed on August 12, 2021)