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Review article

Implications of face mask use in diverse populations: Physiological, psychological, and functional perspectives

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Abstract

This review critically examines the effect of prolonged face mask use across diverse populations, which is a crucial aspect of global health strategies during infectious disease outbreaks, particularly the coronavirus disease 2019 (COVID-19) pandemic. The synthesis of research findings highlights the physical, psychological, and social implications of face mask use among healthcare workers, individuals with preexisting health conditions, the older adults, children, and people with disabilities. Healthcare workers, using masks for a long term, report symptoms including headaches, skin irritation, and diminished quality of life. Individuals with respiratory conditions such as chronic obstructive pulmonary disease (COPD) or asthma experience intensified difficulties, underlining the need for tailored mask guidelines for such groups. For older adults, masks increase exertional discomfort after physical activity, whereas in children, particularly those with special needs, mask-wearing poses unique behavioral challenges. The psychological dimension, including "mask fatigue" has emerges as a significant concern, affecting mental well-being and adherence to mask protocols. In addition, the review addresses sociocultural challenges, particularly for those with hearing impairments, emphasizing the necessity for inclusive mask designs. This comprehensive analysis underscores the need for healthcare professionals to recognize and address the varied challenges posed by face mask use. This review advocates for evidence-based, inclusive public health guidelines and the development of masks that cater to diverse needs. This study highlights the importance of continued research in optimizing mask design and usage policies, balancing infection control efficacy with minimal adverse effects on different population segments.

Keywords: Face mask implications, respiratory health, viral transmission.

This review explores the effect of face mask use during the coronavirus disease 2019 (COVID-19) pandemic across different groups of people. We comprehensively searched databases such as PubMed, Scopus, and Web of Science, focusing on terms such as "face mask usage," "COVID-19," and "respiratory effects." The goal is to gather studies for a clear understanding. The review focused on the side effects of wearing N95 masks, sush as dizziness and headaches, due to conditions called respiratory alkalosis and hypocarbia.[1] How long-term mask wearing affects healthcare workers' quality of life[2] and leads to 'mask fatigue,' a tiredness felt by both healthcare workers and the general public, was also examined [3] Regarding exercise, we examined the risks of using face masks, particularly N95 types, which may limit oxygen (O_2) and worsen chronic health problems.[4] For older adults, this review shows that wearing masks can make them feel more tired during physical activities, such as in the 6 minute walk test (6MWT), although it does not greatly affect their breathing or heart health.[5] Pregnant women are another important group. Wearing N95 masks can make their bodies work harder, suggesting a need for careful use. [6] For children, the review emphasizes the importance of using safe and comfortable pediatric N95 masks.[7] The review also focused on people with chronic obstructive pulmonary disease (COPD), a lung condition that makes breathing difficult. This review examine how wearing masks can be challenging for them.[8] Similarly, for people with asthma, a condition that inflames the airways, masks can worsen their breathing problems.[9] Finally, the review considers people with hearing loss, highlighting how masks make communication difficult and affect their daily lives. [10, 11]

This review provides a clear overview of how face mask use affects different groups, including healthcare workers, older adults, pregnant women,

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children, and people with conditions such as COPD and asthma. The information presented helps healthcare professionals make well-informed recommendations that consider the specific needs and challenges of each group.

Healthy populations

The adoption of face masks by healthy individuals has become vital in combating respiratory infections, notably severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Masks serve as barriers by limiting the spread of potentially infected droplets and enhancing existing hygiene measures. This practice not only protects the wearer but also others, particularly those with increased vulnerability to illness, thereby supporting broader public health objectives. However, the potential health effects of face mask use must also be considered, even for those in good health **(Table 1).**

Table 1. Side effects, precautions and recommendations in healthy populations.

Group	Side effects	Precautions	Recommendations
Adults	Respiratory alkalosis, hypocarbia[1]; headaches, discomfort[12 - 14]	Monitor for symptoms during prolonged use[1, 12 - 14]	Use with caution, consider breaks[1, 12 - 14]
Elderly adults	Ased perceived exertion post-exercise[5]; respiratory and cardio parameters stable[5, 15]	Monitor for exertion, respiratory status[5, 15]	Safe for use, with monitoring[5, 15]
Pregnant individuals	Decreased oxygen saturation[16]; respiratory burden with N95[6]	Use N95 with caution, monitor oxygen levels[6, 16]	Balance between protection and respiratory comfort[6, 16]
Children	Increased $ETCO_2$, $FICO_2$; discomfort[7]; respiratory difficulties in asthmatic children[9,17]	Monitor respiratory parameters, comfort [7, 9, 17]	Prefer masks with ventilators for tolerance[7, 9, 17]
Healthcare workers	Headaches, exacerbation of conditions[12,13]; skin reactions[18]; breathing difficulties[13 - 15, 19]	Frequent breaks, ergonomic designs[12 - 15, 19]	Use masks with better fit and comfort[12 - 15, 19]
Exercise and physical activity	Reduced oxygen, hypercapnic hypoxia[4, 14, 20, 21]; no major cardiorespiratory impact[20, 21]	Avoid strenuous exercise with masks[4, 14, 20, 21]	Promote social distancing over mask use during exercise[4, 14, 20, 21]

$ETCO_2$, End-tidal carbon dioxide; $FICO_2$, Fractional concentration of inspired carbon dioxide

1) Adults: Adults using N95 masks may experience respiratory alkalosis and hypocarbia, which may lead to headaches and discomfort.[1] In addition, prolonged face mask use is associated with increased reports of headaches and physical discomfort.[12-14] Thus, adults must be aware of these potential side effects, particularly during extended wear, and to consider using ergonomically designed masks or taking breaks as needed; 2) Older adults: Older adults do not exhibit significant changes in cardiorespiratory parameters with face mask use but may experience increased perceived exertion, particularly after physical activities. [5, 15] This finding suggests that while masks are generally safe for older individuals, monitoring for signs of discomfort or exertion is advisable during and after exercise; 3) Pregnant individuals: Pregnant women face specific challenges with face mask use, including decreased O_2 saturation with double masks and additional respiratory burden when using N95 masks.[6, 16] Caution and regular monitoring of O_2 levels are recommended, particularly when using masks that offer higher levels of protection such as N95s; 4) Children: Children, particularly those with asthma, may experience increased end-tidal CO_2 and fractional concentration of inspired carbon dioxide (CO_2) levels when wearing masks, which could lead to discomfort.[7, 9, 17] Pediatic masks should ideally include ventilation features, and their use should be closely monitored, particularly in those with asthma. 5) Healthcare Workers: Healthcare workers are susceptible to various side effects of prolonged face mask use, including headaches, skin reactions, and breathing difficulties.[12, 13-15, 18, 19] Implementing ergonomic mask designs and scheduled breaks could help mitigate these issues, improving comfort and reducing the risk of exacerbation of pre-existing conditions; and 6) Exercise and physical activity: Engaging in physical activity while wearing masks, particularly N95, can lead to reduced O_2 availability and hypercapnic hypoxia.[4, 14, 20, 21] However, not all studies have show significant effects on cardiorespiratory fitness.[20, 21] Individuals should exercise caution during high-intensity activities and consider alternatives such as social distancing over face mask use.

In summary, the effects of wearing face masks can vary across different groups of individuals. Thus, factors such as age, health status, and activity level must be considered when determining the impact of mask use. Adhering to recommended guidelines, monitoring O_2 levels, and ensuring proper mask hygiene are key practices that can help mitigate potential adverse effects and maintain the health and comfort of individuals across various contexts.

Patients with respiratory diseases

The use of face masks has become a prevalent preventive measure in the ongoing COVID-19 pandemic to curtail the transmission of SARS-CoV-2. Nevertheless, it is vital to acknowledge the potential side effects and precautions associated with wearing face masks, particularly in individuals with underlying respiratory conditions. This analysis synthesize pertinent findings from a selection of studies and comprehensively asesses the effect of face mask use on patients with chronic lung diseases, including asthma, COPD, and pulmonary hypertension (PH) **(Table 2).**

Table 2. Side effects, precautions and recommendations in patients with respiratory diseases.

Group	Side effects	Precautions	Recommendations
Asthma	Breathing impairment, especially in adolescents.[17]	Emphasize asthma control, monitor anxiety.[9, 17]	Optimize mask usage. [19]
COPD	No significant exercise effects.[21]	Educate about discomfort, consider severit.[8, 15]	-
Pulmonary hypertension	No exercise effects.[22]	-	Continue mask usage advocacy.[22]
Pediatric pulmonary hypertension	Increased preventative measures.[23]	-	Recognize caregivers' awareness.[23]

COPD, Chronic obstructive pulmonary disease

7) Asthma: face mask use during the pandemic has garnered substantial attention, particularly regarding its effects on patients with asthma. Research indicates that patients with well-controlled asthmatic patients may experience a slight increase in $PaCO_2$ because of a minimal rise in the dead space.[24] In contrast, adolescents with asthma demonstrated breathing difficulties associated with face mask use. A study involving adolescents with asthma highlighted a significant association between mask-related breathing impairment and asthma severity.[17] In addition, presentations of spurious asthma during the pandemic were reported because of the effects of mask-induced hyperventilation.[9] Despite these challenges, studies suggest that wearing masks can be managed with adequate asthma control and the implementation of recommended strategies, such as mask breaks and comfortable mask usage.[19]; 8) COPD: For individuals with COPD, the effect of face mask use varies across studies. Although some studies have indicated no significant alterations in gas exchange measurements after a 6MWT using surgical masks[25], others have revealed minor physiological changes in gas exchange, heart rate, and breathing frequency.[21] Notably, the use of N95 masks can present risks, particularly in patients with severe COPD; thus, factors such as modified medical research council dyspnea scale scores and forced expiratory volume in 1must be considered.[21] Despite these concerns, the pandemic-induced reduction in exacerbations among patients with COPD underscores the potential benefits of preventive measures, including face mask use.[26, 27]; and 9) PH: Studies have suggested that wearing a face mask during exercise is unlikely to exert substantial negative effects. A study involving patients with pulmonary arterial hypertension (PAH) demonstrated that wearing a facemask during a 6MWT did not lead to significant changes in exercise capacity, rating of perceived exertion, or arterial O_2 saturation.[22] Similarly, caregivers of children with pediatric PH reported practicing preventive measures, including face mask use, more diligently than the general population.[23]

Patients with other diseases

The widespread adoption of face masks as a preventive measure against COVID-19 transmission has brought forth an various challenges and considerations, particularly for individuals with underlying health conditions. Although face masks are effective in reducing the virus spread, their use might have diverse implications for those with specific medical concerns. This article aimed to delve into the side effects, precautions, and recommendations associated with wearing face masks among individuals with ear-nose-throat diseases, eye diseases, heart diseases, neurodegenerative diseases, psychiatric disorders, and skin diseases **(Table 3).**

Table 3. Side effects, precautions and recommendations in other disease.

	Side effects	**Precautions**	**Recommendations**
Ear-nose-throat diseases	Hearing loss[10], hyperventilation [11]	Use of clear window masks[10]	Speak louder, use technology aids[11]
Eye disease	Dry eye[28], ocular irritation[29]	Proper mask fitting[28, 29]	Consult eye care professionals[28, 29]
Heart diseases	Cardiovascular Strain [4, 5]	Monitor physiological responses[4, 5]	Caution during exercise[4, 5]
Neurodegenerative disease	Recognition difficulty [30 , 31]	Use of transparent masks[30, 31]	Employ empathetic communication[30, 31]
Epilepsy	Increased brain network Excitability[32]	Caution during physical activity[32]	-
Psychiatric disorders	Varied mask adherence[33]	-	Tailored public health messaging[33]
Skin diseases	Skin reactions[18], acne[34]	Regular mask hygiene[18, 34]	Employ good skin care routines[18, 34]

1) Ear-nose-throat diseases: Studies have focused on the challenges posed by face mask use to hearing and communication. For instance, hearing loss concerns[10] were addressed by examining how masks muffle sound, complicating communication for those with hearing impairments. This is crucial for individuals reliant on lip-reading and facial expressions. In addition , hyperventilation[11] was asessed to understand how face mask use might affect breathing patterns and speech. This is significant in scenarios where masks can cause discomfort and breathing difficulties, affecting both speech clarity and respiratory function.

2) Eye diseases: Research on eye diseases predominantly dealt with the indirect consequences of face mask use, such as dry eye[28] and ocular irritation.[29] Studies have noted that wearing a mask could redirect the exhaled air toward the eyes, leading to increased dryness and irritation. This is a concern for individuals who wear masks for prolonged periods, as the constant airflow toward the eyes can intensify these symptoms, necessitating proper mask fitting and possibly consultation with eye care professionals for management.

3) Heart diseases: Previous studies [4, 5] have explored how exercising while wearing a mask affects cardiovascular health. The key parameters investigated included O_2 availability, heart rate, and overall cardiovascular strain during physical activity while wearing face mask. This research is relevant for individuals with preexisting heart conditions, because it highlights the need for caution and monitoring during exercises, given the potential for increased cardiac load and altered O_2 exchange while wearing masks.

4) Neurodegenerative diseases: For neurodegenerative diseases, particularly, those recently dianosed with Alzheimer's disease, studies [30, 31] have focused on the cognitive and social challenges posed by mask-wearing. The difficulty in facial recognition and interpreting emotional expressions when wearinf face masks can significantly affect social interactions and emotional well-being in Alzheimer's patients with Alzheimer's disease. Studies have suggested that transparent masks could aid in improving communication and reducing distress for these patients.

5) Epilepsy: In epilepsy[32], the primary concern was the increase in brain network excitability caused by hyperventilation while wearing a mask. This study highlighted the importance of being cautious during activities that might induce hyperventilation, such as physical exercise, because this could intensify the condition in patients with epilepsy.

6) Psychiatric disorders: A study on psychiatric disorders[33] delved into the levels of mask adherence among psychiatric inpatients. This study examined how understanding and compliance with mask-wearing guidelines varied among these patients, emphasizing the need for tailored public health messaging to improve adherence to mask-wearing practices.

7) Skin diseases: For skin diseases, research Zuo Y, *et al.*[18] and Park SR, *et al.*[34] focused on the dermatological effects of prolonged mask face mask use. They highlighted the prevalence of skin reactions, such as acne and dermatitis, among mask wearers. The findings underline the importance of maintaining good skin hygiene and care routines to mitigate the adverse skin reactions associated with prolonged face mask use.

Physiological implications

Respiratory changes

A paramount concern is the effect of N95 masks on respiratory parameters. Study A1 illustrated the occurrence of respiratory alkalosis and hypocarbia after wearing N95 masks, manifesting as headaches and concentration difficulties. Similarly, A7 highlighted reduced oxygen consumption and (CO_2) expulsion in pregnant healthcare workers, indicating a metabolic burden. In contast, Amput P, Wongphon S. [5] and Samannan R, *et al.*[25] reported no significant respiratory impairment in older adults and patients with COPD, respectively, suggesting variability in physiological responses.

Cardiorespiratory fitness

The use of masks during physical activities is another dimension of concern. Chandrasekaran B, Fernandes S. [4] speculated about the potential risks associated with exercising while wearing masks, such as reduced O_2 availability and impaired (CO_2) exchange. Conversely, Ade CJ, *et al.*[20] and Wangüemert Pérez F, *et al.*[21] found no significant compromise in exercise capacity or primary cardiovascular responses, indicating a nuanced understanding of the effect on cardiorespiratory fitness.

Oxygen saturation

The implications for specific groups, such as pregnant women, are notable. Tong PS, *et al.*[6] observed a

significant reduction in o O_2 saturation with double surgical mask, use whereas Goh DYT, *et al.*[7] reported no change in maternal and fetal heart rates when wearing N95 masks. These findings necessitate a cautious approach when recommending face mask use for sensitive demographics.

Psychological and Functional Implications

Quality of life and fatigue

Prolonged face mask use adversely affects the quality of life and induces "mask fatigue". Radhakrishnan N, *et al.*[2] showed a direct correlation between face mask use duration and decreased quality of life among healthcare workers. Kalra S, *et al.*[3] defined "mask fatigue" as a lack of energy following prolonged face mask use, highlighting its prevalence in both healthcare settings and the general population.

Headaches and their cognitive effect

The development of headaches and cognitive impairments is a recurring theme. Ong JJY, *et al.*[12] and Farronato M, *et al.*[13] emphasize a high incidence of de novo PPE-associated headaches and cognitive issues sush as like concentration problems among healthcare workers, underscoring the need for balanced usage guidelines.

Vulnerable populations

Special attention is required for vulnerable group, such as children, pregnant women, and individuals with preexisting conditions. Goh DYT, *et al.*[7] valuated pediatric N95 masks and indicated potential safety concerns, whereas Amirav I, Lavie M. [9], Moumneh A, *et al.*[17] reported significant breathing impairment in adolescents with asthma and misdiagnosis of asthma due to mask-induced hyperventilation, respectively.

Disease-specific concerns

For patients with specific diseases, such as COPD or pulmonary hypertension, studies Kyung SY, *et al.*[8] and Helgeson S, *et al.* [22] suggest a nuanced approach to face mask use, that considers individual respiratory capacities and disease severity.

Precautionary recommendations

- Respiratory implications and altered gas exchange: Prolonged use of N95 masks has been associated with respiratory alkalosis and hypocarbia, leading to symptoms sush as headache and anxiety.[1] In pregnant healthcare workers, the use of N95 masks reduces tidal volume and minute ventilation, which affect gaseous exchange.[6] These findings necessitate careful consideration in scenarios requiring extended face mask use, Particularly among healthcare workers and pregnant women.
- Effect on healthcare workers' quality of life: Prolonged use of masks among healthcare workers significantly affected their quality of life significantly.[2] This finding underscores the need for interventions aimed at reducing the discomfort associated with long-term face mask use in healthcare settings.
- Psychological aspects - of mask fatigue: This phenomenon has emerged as a significant concern, and is marked by a decrease in energy following prolonged face mask use.[3] Addressing this issue requires a holistic approach that includes ergonomic mask design and scheduled breaks for mask wearers.
- Exercise and face mask use: Exercising while wearing masks, particularly N95 masks, could pose health risks because of reduced O_2 availability and hindered CO_2 exchange.[4] This suggests that exercising without masks or maintaining social distancing during physical activities might be more beneficial.
- Effects on - older adults and children: although studies have shown that cloth and surgical masks do not significantly affect cardiorespiratory fitness in older adults[5], research on the effect on children, particularly with the addition of micro ventilators, is ongoing.[7] These findings highlight the importance of population-specific mask guidelines.
- Masks in pregnant women: A study on pregnant women wearing double surgical masks indicated a significant reduction in O_2 saturation[16], raising concerns about the potential risks associated with face mask use during pregnancy.
- Effects on physical comfort and work ability: Accordind to dentists, the discomfort and physical challenges associated with prolonged respirator use, [13], and reduced exercise capacity due to masks[14], suggest that mask mandates must be balanced with considerations for physical comfort and work ability.
- Psychological health - depression and mask reuse: The association between mask reuse, health beliefs, and depressive symptoms in older people [35] indicates a need for clear guidelines on face mask use and mental health support for vulnerable populations.

• Face mask use in Pasthma and COPD: The increased risk of breathing difficulties in patients with asthma [17] and the precautions necessary for patients with COPD wearing N95 masks [8] highlight the need for tailored guidelines for individuals with preexisting respiratory conditions.

• Pediatric patients with special conditions: Special considerations are required for pediatric populations with conditions, sush as PAH, where face mask use does not significantly affect exercise capacity.[22]

• Considerations for patients with chronic diseases: The reduction in severe exacerbations of COPD during the pandemic suggests a protective role of face masks[26], indicating their potential utility beyond viral transmission prevention.

• Addressing sensory and communication challenges: For individuals with sensory impairments, such as those with hearing loss[10, 11] or Alzheimer's disease[30, 31], face mask use can pose significant communication barriers. Clear masks or alternative communication methods may be necessary.

• Dermatological and ocular considerations: Skin reactions and ocular irritation associated with face mask use[18, 29] necessitate the consideration of dermatologically safe materials and designs to mitigate these effects.

Conclusion

A comprehensive examination of studies highlights that face mask use, while crucial for disease control, has diverse implications across different populations. In particular, N95 masks are associated with respiratory challenges, including respiratory alkalosis and symptoms sush as headaches. Healthcare workers face significant quality of life decrements due to prolonged face mask use, and "mask fatigue" is increasingly recognized. In the context of physical exercise, wearing masks, particularly N95 types, may affect O_2 availability and intensify chronic health conditions. However, cloth and surgical masks do not significantly affect cardiorespiratory parameters in older adults, although they may increase perceived exertion. Special considerations are necessary for pregnant women and children using N95 masks. Individuals with respiratory conditions such as asthma and COPD exhibit varying responses to face mask use, ranging from significant breathing difficulties to minimal effects. Masks also create communication barriers for people with hearing loss and can cause ocular discomfort. Positively, masks have shown benefits in reducing exacerbations in patients with COPD and providing cardiovascular advantages in specific groups. In summary, although face masks are essential for mitigating infectious disease spread, their effects are multifaceted; thus customized guidelines and strategies are required for different demographic groups to ensure effective and safe use.

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Data sharing statement

This review is based on the references cited. All data generated or analyzed during this study are included in this published article and cited here. Further details, opinions, and interpretations are available from the corresponding author upon reasonable request.

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