The Physiological Impact of Masking Is Insignificant and Should Not Preclude Routine Use During Daily Activities, Exercise, and Rehabilitation

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Purpose: Masking has been employed as a strategy for reducing transmission of a variety of communicable diseases. With the outbreak of SARS-CoV-2, many countries have implemented mandatory public masking. However, the perceived impact of mask use on pulmonary function has been a deterrent to public compliance with recommendations. COVID-19 has shed light on the impact that comorbid cardiac and pulmonary conditions may have on disease severity. This knowledge has led to increased primary and secondary prevention efforts for which exercise and rehabilitation are central. The importance of safe methods of exercise while mitigating risk of viral transmission is paramount to global recovery from the pandemic and prevention of future outbreaks.

Methods: We constructed a focused literature review of the impact of various masks on pulmonary function at rest and with exercise. This was then incorporated into recommendations for the integration of masks with exercise and rehabilitation in the COVID-19 era.

Results: While there is a paucity of evidence, we identified the physiological effects of masking at rest and during exercise to be negligible. The perceived impact appears to be far greater than the measured impact, and increased frequency of mask use leads to a physiological and psychological adaptive response.

Conclusions: Masking during daily activities, exercise, and rehabilitation is safe in both healthy individuals and those with underlying cardiopulmonary disease. Rehabilitation participants should be reassured that the benefits of masking during COVID-19 far outweigh the risks, and increased frequency of mask use invokes adaptive responses that make long-term masking tolerable.

Key Words: adaptation • comfort • COVID-19 • masking • rehabilitation

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Face masks have been employed to reduce the risk of transmission of certain communicable diseases as far back as the Middle Ages. Centuries of evidence supports the hypothesis that masking can confer protective benefits from airborne pathogens to the wearer and others by reducing airborne droplet transmission.[1,2] The SARS-CoV-2 pandemic has demonstrated the efficacy of widespread use of face masks in reducing infection rate, decreasing mortality, and delaying the peak time of outbreaks in a given community.[3]

Since the start of the coronavirus-19 (COVID-19) outbreak, public masking mandates have become increasingly commonplace around the world. Amidst discussions on resource allocation, masking requirements remain controversial and vary by region. Widespread implementation of their use has been demonstrated in multiple validated predictive models to significantly decrease transmission of COVID-19 and reduce mortality rates,[4] but there remains a significant lack of high-quality evidence to support universal masking.[5] The estimated benefit of masking is thought to result from reduction in viral particle transmission by the wearer, thus being particularly important in asymptomatic individuals. Recent hypotheses also suggest that universal masking may decrease rates of viral inoculum, leading to asymptomatic infection rather than severe disease.[6] Despite the obvious benefits, noncompliance with masking recommendations also remains evident throughout many communities. The perception of difficulty breathing with physical activity, anxiety, humidity under the mask, and ability to communicate have all been historically cited as reasons for diminished adherence.[7]

COVID-19 has clearly exhibited the impact that cardiovascular disease, chronic lung disease, obesity, and metabolic syndrome have on illness severity and mortality risk.[8] More than ever, the implementation of aggressive primary and secondary prevention measures, including comprehensive tailored exercise-based cardiac rehabilitation (CR) and pulmonary rehabilitation (PR) programs for those with comorbid conditions, will be crucial to ensuring recovery from the pandemic and promoting a healthier global community overall.[9] Unfortunately, even prior to the SARS-CoV-2 outbreak participation rates in CR and PR were low[10-12]; the additional impact that masking requirements may have on patient motivation and adherence has yet to be fully realized.

The purpose of this report is to review the physiological and psychological impact of wearing face coverings at rest and during exercise for both healthy individuals and those with underlying heart and lung disease. We aim to identify key barriers to masking and propose specific adaptations that may be employed to promote adherence and improve participation in CR, PR, and other exercise programs.

Table 1

A Comparison of the Impact, Efficacy, and Cost-Effectiveness of Common Types of Masks Available During the COVID-19 Pandemic


Mask	Respirator Mask (N95)	Triple-Layer Mask (Surgical Mask)[a]	Single-Layer Mask (Cloth Mask)
Material	Nonwoven fibrous filter	Nonwoven fibrous filter	Cotton
Cost	High	Moderate	Low
Efficacy			
Filtration efficiency, %			
PFE (0.1 μm)	99.7-99.9	98.2-98.6	...
BFE (3 μm, droplets)	99.6-99.9	97.4-99.8	...
NaCl method (10 nm to 10 μm)	98.1-99.6	54.7-88.4	...
Relative droplet transmission[b]	0.1	1	10-25
Estimated protection from COVID-19	99	75-80	50-70
Fluid resistance	Yes	Yes	No
Physiological impact	Decrease in V_T and Spo_2 Increase in heart rate Potentially significant increase in Pco_2	No clear physiological impact	No clear physiological impact but may vary on the basis of fabric used
Recommended use	Health care workers in high-risk settings[c]	Health care workers General public, symptomatic, or asymptomatic	General public, asymptomatic

Abbreviations: BFE, bacterial filtration efficiency; Pco_2, partial pressure of carbon dioxide; PFE, particulate filtration efficiency; Spo_2, oxygen saturation; V_T, tidal volume.

[a]ASTM-certified moderate barrier surgical masks.

[b]With normal speech.

[c]Defined as close contact for prolonged period of time (≥10 min) with a laboratory-confirmed COVID-19 positive patient or during aerosol-generating procedures in a laboratory-confirmed COVID-19 positive patient.

METHODS

We conducted a literature review of the impact of different types of masks on cardiac and pulmonary physiological parameters. Although there are limited data on the impact of masking in individuals with underlying cardiopulmonary comorbidities, the existing evidence was extrapolated to formulate practical adaptations that may be employed by individuals participating in CR or PR during the COVID-19 era.

RESULTS

MASKS DURING COVID

The most common disposable masks utilized during the COVID-19 pandemic are surgical masks, respirator masks, and single- or multilayer cloth masks (Table 1). A discussion of the wide range of less frequently used mask types (such as reusable masks, masks containing exhalation valves, or masks made of less common materials) is beyond the scope of this article. The efficacy of each mask type is based on measurable qualities (such as filtration capacity and water resistance), as well as subjective metrics such as breathability and comfort that affect duration of use and overall compliance.

Surgical masks are composed of three layers that function in fluid resistance, particle filtration, and absorption of wearer mucosalivary droplets, respectively. While it has a significantly higher relative droplet transmission (1%) as compared with respirator masks,[13] previous studies have suggested that surgical masks may be comparable to respirators in the protection that they offer wearers against similar viral respiratory infections (influenza and influenza-like illness) both in the community and in the health care settings.[5,14-16] In addition to decreasing viral transmission, surgical masks have the benefit of affordability and comfort and thus are typically worn easily during even long exercise periods.

Respirator masks (eg, N95 and FFP2) are the most efficacious in reducing particle penetration and air leakage and are therefore most frequently applied in health care settings in which aerosol-generating procedures are performed. When worn correctly, respirator masks have been shown to have a relative droplet transmission of 0.1% and a filtration capacity of 98-99%.[13,17] The protective benefits of respirator masks directly correlate to proper fit, as even a small amount of air leakage can reduce mask efficacy.[1] For this reason, wearers should undergo professional fit testing, making the applicability of these masks to the general public much less feasible. Widespread use of respirator masks is also limited by cost, resource availability, and comfort.

Cloth masks (typically cotton) are most often used by the general public due to their low cost, comfort level, and reusability. Cloth masks composed of a single cotton layer have a relative droplet transmission of 10-25%,[13] and multilayer cotton masks likely improve efficacy further. However, the clinical benefit may be reduced by a variety of factors, including moisture retention and method of cleaning.[18] As with all masks, cloth masks may help reduce transmission by other features as well, such as prevention of hand-to-mouth contact.

Importantly, some have advocated for widespread use of face shields, noting benefits such as overall comfort (less heat, less claustrophobic, no breathing resistance) and psychosocial factors (no impact on speech or nonverbal communication).[19] However, even in combination with a mask, the evidence for the benefit of face shields is conflicting.[20-23] In general, it is widely agreed upon that face shields do not create an adequate peripheral seal to be used as the sole form of face and eye protection, but they can be considered as adjunctive personal protective equipment in certain high-risk scenarios.[24] There may be some cumulative benefit with community-wide implementation of face shields in combination with masks and social distancing, but this theory has yet to be validated by any trials or mathematical models.[25]

THE IMPACT OF MASKING

The primary function of pulmonary ventilation is to preserve the partial pressure of arterial blood oxygen and carbon dioxide at rest and with exercise, thus supporting metabolism and maintaining acid-base homeostasis.[26] This complex physiological response requires the coordination of central motor output from the autonomic nervous system to the inspiratory and expiratory respiratory muscles to match breathing pattern with the ever-changing feed-forward (motor output) and feedback (afferent discharge) stimuli.[27] The impact that masking has on this physiological response is incompletely understood.

Surgical masks have been shown to have no physiological effect on gas exchange (as measured by end-tidal carbon dioxide and oxygen saturation) in both healthy persons and those with underlying COPD at mild to moderate exertion (eg, during a 6-min walk test).[28] Some studies have demonstrated an impact on subjective comfort without evidence of any objective changes in cardiopulmonary response to exercise (including hemodynamic, pulmonary, and metabolic parameters).[29] These data suggest that widespread use of surgical masks during exercise may be reasonable, even for those with underlying cardiac disease, pulmonary disease, and comorbid conditions.

Perceived comfort and work of breathing may affect duration and frequency of mask use. Importantly, mask tolerance is related to both objective physiological effects and subjective parameters.[30] Work performance and efficiency may be reduced and subjective discomfort levels increased in anxious individuals wearing masks compared with those without underlying anxiety,[31] supporting the theory that there is a significant psychological component to the impact of mask use on behavior and productivity. Anxiety has also been shown to be predictive of likelihood of experiencing respiratory distress while exercising with a mask in place.[32] Wearers cite moisture, heat, and humidity as contributing factors to discomfort and increased work of breathing,[33] although exhaled moisture has been demonstrated to have minimal to no effect on breathing resistance in respirators.[34] Still, inspiratory and expiratory resistance is likely to be most easily perceptible to wearers, and while the overall physiological impact may be negligible, higher resistance masks are expected to have a greater magnitude of psychological impact on the wearer. Notably, the psychological impact of mask use may vary with time and community expectations, suggesting that there is an adaptive psychological response once masks are perceived as the new normal.[35]

There is minimal evidence that masking significantly inhibits oxygen uptake or exhalation of carbon dioxide. In respirator masks, evidence has varied on the basis of workload and duration of use. Studies in healthy individuals identified subjective concerns, including warmth, sweating, itching, and irritation but reported no change in objective measures of oxygenation at rest and low-intensity exercise.[29,36,37] One study demonstrated a modest increase in exhaled partial pressure of arterial carbon dioxide, though this is unlikely to be of any true clinical significance.[36] Others have shown that a minor physiological impact becomes detectable at moderate- to high-intensity exercise, though still without a demonstrable effect on oxygenation.[29,38]

Of note, the use of surgical or respirator masks is less common than cloth masks or alternative face coverings (eg, bandanas, scarves). These alternative face coverings not only have reduced efficacy in reducing the transmission of infected particles[13] but may also increase the sensation of discomfort due to intrinsically restrictive properties of the covering material. While evidence is scarce, there are objective data to suggest that cloth masks of certain fabrics have increased exhalation and inhalation resistances compared with surgical masks and respirator masks.[39] Such impedance of airflow may theoretically increase workload for muscles of inspiration, resulting in heightened work of breathing during daily activities and exercise tasks. However, recent evidence has demonstrated that the use of a triple-layer cloth mask at rest and with normal activities of daily living does not have any effect on peripheral oxygen saturation, regardless of underlying cardiac or pulmonary comorbidities.[40] Further data argue that with training, even perceived exercise limitations may be overcome as the body adapts to the minor physiological changes.[7]

DISCUSSION

With a mounting need for safe, accessible CR and PR for post–acute recovery in both COVID and non-COVID individuals, it is paramount that social distancing, sanitization, and masking measures are in place. At rest and during mild to moderate exercise, surgical masks and likely cloth masks have been demonstrated to have no physiological impact. At intensive exercise, the available evidence (albeit very limited) suggests that there may be marginal physiological impact that is unlikely to be clinically significant. In fact, it has been suggested that some individuals will experience more discomfort at rest than during exercise due to lack of active engagement of the respiratory muscles.[7] Therefore, we propose that all individuals participating in CR or PR should be expected to wear a mask (Table 2). The most practical mask for this setting is a triple-layer surgical mask, given its efficacy, minimal physiological impact, widespread accessibility, and perceived level of comfort.

Table 2

Recommendations for Mask Use During Cardiac and Pulmonary Rehabilitation

Recommendations
• All individuals should wear a mask when participating in outpatient cardiac or pulmonary rehabilitation.
• Surgical masks are preferred over respirators during exercise, as they have insignificant impact on major physiological parameters, even during maximum exertion.
• Surgical masks are preferred over cotton masks during exercise, as they are significantly more efficacious in both filtration efficiency and droplet transmission.
• Outpatient cardiac and pulmonary rehabilitation centers should provide all patients with a surgical face mask.
• Some patients may benefit from donning a mask more frequently outside of rehabilitation, especially anxious individuals in the hours prior to exercise, to promote psychological adaptation.

Importantly, the psychological impact of masking during exercise may be substantial for some individuals. The sensation of increased inspiratory and expiratory resistance, warmth, and humidity may dissuade adherence. However, these sensations have yet to be correlated with clinically significant physiological changes. Therefore, health care workers should incorporate adequate and supported familiarization of mask use into patient daily routines, with reassurance that masking during exercise is safe in healthy individuals and those with cardiopulmonary comorbidities alike. Given the perceived increase in work of breathing, those individuals who exhibit anxiety with mask wearing would likely benefit from masking more frequently outside of the rehabilitation setting, especially in the hours prior to exercise. This should help promote the expected mental adaptive response to become accustomed to the change in sensation.

CONCLUSIONS

With the persistent uptrend in COVID-19 cases globally, the use of face masks during daily life, informal exercise, and CR and PR is likely to be commonplace for some time. It is generally agreed upon that masking is an important aspect in the prevention of community spread of various viral illnesses. Simultaneously, exercise rehabilitation efforts are more important than ever for post–acute recovery from COVID-19 as well as other chronic cardiac and pulmonary diseases. The findings presented previously suggest that masking should not impact ability to participate in CR or PR programs, as requiring surgical masks during exercise is unlikely to have any impact on pulmonary or cardiac function but will confer significant benefit in reducing viral transmission and promoting public health efforts.

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