The following information resources have been selected by the National Health Library and Knowledge Service Evidence Virtual Team in response to your question. The resources are listed in our estimated order of relevance to practicing healthcare professionals confronted with this scenario in an Irish context. In respect of the evolving global situation and rapidly changing evidence base, it is advised to use hyperlinked sources in this document to ensure that the information you are disseminating to the public or applying in clinical practice is the most current, valid and accurate. For further information on the methodology used in the compilation of this document—including a complete list of sources consulted—please see our National Health Library and Knowledge Service Summary of Evidence Protocol.

## QUESTION 168

# Does the prolonged use of face-masks by HCWs interfere with the respiratory system by inducing oxidative stress and blood oxygen/carbon dioxide imbalance?

# Main Points

1. The average face mask does not limit the flow of oxygen to the lungs, even in people with severe lung diseases[28].
2. For healthy, active people, wearing a face mask during vigorous exercise has minimal effect on arterial or muscle oxygen levels and no effects on exercise performance[31].
3. WHO advises not to wear masks during vigorous intensity physical activity because masks may reduce the ability to breathe comfortably[1].
4. Face masks, including N95 respirators, surgical masks and cloth face-masks have small effect on the work of breathing, blood gases and other physiological parameters during physical activity, even with heavy/maximal exercise[13].
5. In a study following 10 nurses over two 12-hour shifts, the only negative physiologic change resulting from long-term respiratory protection use was elevated $CO_2$ levels, with $CO_2$ increasing over time. However, these changes were not clinically relevant[25].
6. Effects of prolonged mask and respirator use in healthcare settings include headaches, skin sensitivity, acne, itchy nose, and excessive sweating around the mouth[24, 27].
7. Frequent breaks, improved hydration and rest, skin care, and newly designed, more comfortable masks are recommendations for future management of adverse effects related to prolonged mask use[27].

# Summary of Evidence

Samannan et al[28] evaluated the effect of wearing surgical masks on gas exchange in patients with severe COPD and in healthy controls (n=15). At rest, there were no significant changes in end-tidal $CO_2$ or $SpO_2$ at 5 and 30 minutes. A 6-minute walk test was performed with masks, and hypoxemia was seen in some of the COPD patients — as expected due to their disease severity — without an increase in end-tidal $CO_2$. These findings suggest that wearing a surgical mask does not significantly affect gas exchange physiology in either healthy people or in patients with severe COPD. The interpretation of these results is limited based on observational study design and inability to perform a 6-minute walk without a mask for comparison.

There are limited studies on the benefits and harms of wearing medical masks, respirators and non-medical masks while exercising[1]. In a recent clinical trial, results demonstrated no detrimental effect of wearing either a non-disposable cloth or disposal surgical face mask while exercising vigorously on exercise performance. For healthy, active people, wearing a face mask during vigorous exercise has minimal effect on arterial or muscle oxygen levels and no effects on exercise performance[31].

Hopkins et al[13] conducted a review to synthesize available literature on the effects of various masks and face coverings on the cardiorespiratory system during physical activity. While the body of literature directly is evolving, for healthy individuals, the available data suggest that face-masks, including N95 respirators, surgical masks and cloth face-masks, may increase dyspnea, but have small and often difficult to detect effects on the work of breathing, blood gases and other physiological parameters during physical activity, even with heavy or maximal exercise.

Chan et al[9] conducted a small crossover study in which participants self-measured peripheral oxygen saturation [$SpO_2$] before, during, and after wearing a mask. Participants included individuals aged 65 years or older and excluded those who had comorbid cardiac or respiratory conditions that could lead to dyspnea or hypoxia at rest or who were unable to remove the mask without assistance. Results found that wearing a 3-layer nonmedical face mask was not associated with a decline in oxygen saturation in older participants.

Bourassa et al[7] evaluated the physiologic impact of gas masks on 14 healthy subjects at rest and during effort. The study demonstrated a clear increase of indexes of effort — work of breathing, oesophageal pressure time product, and oesophageal swing pressure — without a relevant impact on respiratory patterns or gas exchanges.

In a 2010 survey involving 159 respondents, 36% of health care workers reported not having difficulty breathing while wearing a respirator. Among all respondents, only 6% reported that they would be able to tolerate continuously wearing a N95 respirator for an 8-hour shift[5].

Roberge et al[26] investigated the physiological impact of the N95 filtering face-piece respirator (FFR) on healthcare workers. In healthy healthcare workers, FFR did not impose any important physiological burden during 1 hour of use, at realistic clinical work rates, but the FFR dead-space carbon dioxide and oxygen levels were significantly above and below, respectively, the ambient workplace standards, and elevated $P(CO_2)$ is a possibility. The statistically significant rise in $CO_2$ levels over time from baseline to the end of the shift did not result in $CO_2$ levels that reached the clinical definition of hypercapnia, defined as an arterial $CO_2$ level ≥ 45. Therefore, from a physiologic perspective, long-term use of respiratory protection proved not to cause negative effects for the nurses who participated in this study. Although clinically significant negative physiologic effects from wearing respiratory protection were not detected, study participants reported several subjective symptoms: eg perceived shortness of breath increased over time when nurses wore any type

of respiratory protection. Although physiologic measures of heart rate, $O_2$ and $CO_2$ did not reflect a difficulty with gas exchange, nurses reported feeling more short of breath the longer they wore respiratory protection. Other subjective symptoms also increased over time, including complaints of headache, light-headedness, perceived exertion, and impeded communication.

In a study of 10 nurses wearing respiratory protection over two 12-hour shifts[25], participants tolerated long-term use of respiratory protection well, regardless of whether they wore an N95 respirator alone or with a surgical mask overlay. The only negative physiologic change resulting from long-term respiratory protection use was elevated $CO_2$ levels, with CO2 increasing over time when wearing an N95 alone; and increasing even more significantly, from a statistical standpoint, when wearing an N95 and a surgical mask overlay compared with an N95 only. However, although there were statistically significant negative physiologic changes over time associated with wearing respiratory protection, especially among those wearing an N95 with a mask overlay, these changes were not clinically relevant.

In a recent cross-sectional study[24] looking at the effects of prolonged usage of N95 respirators and surgical masks in health care workers, 48.8% experienced generalised nasal discomfort, 30.3% dry nose, 26.1% burning sensation in the nose, about 52.0% developed itchy nose, 56.0% acne in the face, 39.0% experienced redness on the face and 67.6% developed excessive sweating around the mouth. 58.2% of the participants reported trouble breathing on exertion which the authors conclude is probably due to the tightness of the mask causing a hypercapnic, hypoxic environment leading to numerous physiological alterations such as cardio-respiratory stress and metabolic shift.

Rosner et al[27] also investigated the adverse effects of prolonged mask use and provided recommendations to ease the burden on healthcare professionals. A total of 343 healthcare professionals on the COVID-19 frontline participated in this study. 314 respondents

reported adverse effects from prolonged mask use with headaches being the most common complaint (n = 245). Skin breakdown was experienced by 175 respondents, and acne was reported in 182 respondents. Impaired cognition was reported in 81 respondents. Previous history of headaches (n = 98), skin sensitivity (n = 164), and acne (n = 121) were found in some respondents. Some respondents experienced resolved adverse effects once masks were removed, while others required physical or medical intervention. Prolonged use of N95 and surgical masks by healthcare professionals during COVID-19 has caused adverse effects such as headaches, rash, acne, skin breakdown, and impaired cognition in the majority of those surveyed. Frequent breaks, improved hydration and rest, skin care, and newly designed, more comfortable masks were recommended for future management of adverse effects related to prolonged mask use.

# International Guidance

## What does the World Health Organization say?

**World Health Organization (01 Dec 2020) Mask use in the context of COVID-19: Interim guidance**[1]

WHO continues to evaluate the evidence on the effectiveness of the use of different masks and their potential harms, risks and disadvantages, as well as their combination with hand hygiene, physical distancing of at least 1 metre and other IPC measures.
The potential physiological harms and risks of mask and respirator use in the health facility setting include:

1. possible development of facial skin lesions, irritant dermatitis or worsening acne, when used frequently for long hours
2. discomfort, facial temperature changes and headaches from mask
3. difficulty wearing a mask in hot and humid environments

This document also looks at the evidence for mask use during physical activity. There are limited studies on the benefits and harms of wearing medical masks, respirators and non-medical masks while exercising. Several studies have demonstrated statistically significant deleterious effects on various cardiopulmonary physiologic parameters during mild to moderate exercise in healthy subjects and in those with underlying respiratory diseases The most significant impacts have been consistently associated with the use of respirators and in persons with underlying obstructive airway pulmonary diseases such as asthma and chronic obstructive pulmonary disease (COPD), especially when the condition is moderate to severe. Facial microclimate changes with increased temperature, humidity and perceptions of dyspnoea were also reported in some studies on the use

[1] World Health Organization (2020). Mask use in the context of COVID-19. https://www.who.int/publications/i/item/advice-on-the-use-of-masks-in-the-community-during-home-care-and-in-healthcare-settings-in-the-context-of-the-novel-coronavirus-(2019-ncov)-outbreak. [Accessed 03 December 2020]

of masks during exercise. A recent review found negligible evidence of negative effects of mask use during exercise but noted concern for individuals with severe cardiopulmonary disease.
WHO advises that people should not wear masks during vigorous intensity physical activity because masks may reduce the ability to breathe comfortably. The most important preventive measure is to maintain physical distancing of at least 1 meter and ensure good ventilation when exercising.

## What do the Centers for Disease Control and Prevention (United States) say?

### Centres for Disease Control and Prevention (12 Nov 2020) Considerations for Wearing Masks: Help Slow the Spread of COVID-19[2]

Wearing a mask does not raise the carbon dioxide ($CO_2$) level in the air you breathe. A cloth mask does not provide an airtight fit across the face. $CO_2$ completely escapes into the air through and around the sides of the cloth mask when you breathe out or talk. $CO_2$ is small enough to easily pass through any cloth mask material. In contrast, the virus that causes COVID-19 is much larger than $CO_2$, so it cannot pass as easily through a properly designed and properly worn cloth mask.

[2] Centres for Disease Control and Prevention (2020). Considerations for wearing masks. https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/cloth-face-cover-guidance.html. [Accessed 02 December 2020]

# International Literature

## What does the international literature say?

**Atangana and Atangana (2020) Face-masks simple but powerful weapons to protect against COVID-19 spread: Can they have side effects?**[3]

The authors provide a literature review on the use of face-masks with the aim of determining which face-masks could be used to avoid re-inhaling rejected $CO_2$. Additionally, the authors presented mathematical models depicting the transport of COVID-19 spread through wind at high speed. Results obtained from the mathematical simulation showed that a wind with speed of 100km/h could transport droplets as far as 300 metres. The authors conclude that wind could have helped spread COVID-19 globally, especially in coastal areas. Therefore, appropriate face-masks should be used every time one is in open air, even when alone and especially in a windy environment.

**Athar et al (2020) [Letter] Biohazards of Prolonged N95 Use: Effects on Arterial Blood Gases, Peak Expiratory Flow Rate and General Well-being of Healthcare Professionals during COVID-19**[4]

The authors recruited 75 HCPs working in different COVID-19 locations throughout Pakistan wearing an N95 respirator ensemble for a duration of > 6 hours. Study participants included doctors, nurses and paramedics working as frontline COVID-19 respondents. Subjects with any physical or psychiatric diagnosis at the time of study were not included in the analysis. Participants were evaluated before and after duty to study the effects of possible $CO_2$ retention on development of related symptoms, peak expiratory flow rate values, variation in oxygen saturation, and long term changes on spirometry.

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[3] Atangana E and Atangana A. Face-masks simple but powerful weapons to protect against COVID-19 spread: Can they have sides effects? Results Phys. 2020 Dec;19:103425. doi: https://doi.org/10.1016/j.rinp.2020.103425 Epub 2020 Sep 30. PMID: 33014697; PMCID: PMC7525365.

[4] Athar, MH, Zubair, UB and Zakir, U (2020). Biohazards of Prolonged N95 Use: Effects on Arterial Blood Gases, Peak Expiratory Flow Rate and General Well-being of Healthcare Professionals during COVID-19 Pandemic. *Journal of the College of Physicians and Surgeons Pakistan : JCPSP*, 30(10), 134–135. https://doi.org/10.29271/jcpsp.2020.10.134

$CO_2$ retention usually manifests with symptoms of headache, dizziness, lethargy, flushing, tachypnea, tachycardia or dyspnea, and these variables were assessed in subjects after documenting basic demographic and clinical characteristics: age, gender, profession, allergies and comorbid conditions.
Among study participants, 70 (93.3%) experienced headaches, 50 (66.7%) lethargy, 38 (50.6%) dizziness, 23 (30.6%) nausea, 18 (24%) dyspnea and 12 (16%) tachypnea. Variability of an average 25ml was observed with peak expiratory flow rate (PEFR) [normal average between 350-500ml/L] pre-and post-N95 use, keeping in mind that post duty fatigue impeded full capacity exhalation. While on duty oxygen saturation variation was documented in a range of 89-95% measured using pulse oximetry. The last parameter that was to ascertain arterial blood gases, but only 50 out of 75 consented; the inference deducted from the partially collected data was that the difference of pre- and post-duty $PCO_2$ was between 0.3 to 0.7kPa. Spirometry could not be performed in any subject due to potential hazards of exposure to aerosols and resource constraints. The authors conclude that use of an N95 respirator should be scrutinised from a biosafety point of view; and assert that quality control must never be compromised in the urgency of launching the product.
Further trials are needed to assess the effects on blood concentration of $O_2$ and $CO_2$, pulmonary function and the negative impacts on frontline HCPs.

### Baig et al (2009) Health care workers' views about respirator use and features that should be included in the next generation of respirators[5]

Background: Numerous studies have demonstrated that health care workers are, in general, poorly compliant with respiratory protection guidelines, especially when a N95 respirator is recommended. The purpose of this study was to assess health care workers' views about respirator use and the features they prefer to be included in the next generation of respirators.

[5] Baig AS, Knapp C, Eagan AE, Radonovich LJ Jr. Health care workers' views about respirator use and features that should be included in the next generation of respirators. Am J Infect Control. 2010 Feb;38(1):18-25. doi: 10.1016/j.ajic.2009.09.005. Epub 2009 Dec 29. PMID: 20036443; PMCID: PMC7132692.

Methods: A 63-item survey was distributed to health care workers in 27 units of 2 tertiary care medical centers.
Results: From a total of 559 surveys distributed at both hospitals, 159 responses were returned. Survey results indicated that health care workers prefer respirators that are more comfortable, interfere less with breathing, diminish heat build-up, are disposable, and permit the user to have facial hair. Multivariate analyses suggest that emergency department staff had 12.3 greater odds of wanting a new respirator (P = .031) as compared with their referent group. Males were more likely to indicate that the N95 respirator was comfortable to wear versus females (P = .003).

**Bakhit et al (June 2020) [Preprint Not Yet Published] Downsides of face masks and possible mitigation strategies: a systematic review and meta-analysis[6]**

Objective: To identify, appraise and synthesise studies evaluating the downside of wearing face-masks in any setting, and strategies to mitigate same.
5471 articles were screened, including 37 (40 references); 11 were meta-analysed. For mask-wearing adherence, 47% more people wore face-masks in the face-mask group compared to control; adherence was significantly higher (26%) in the surgical/medical mask group than in N95/P2 group.
The largest number of studies reported on discomfort and irritation outcomes (20-studies); the fewest reported on the misuse of masks; and none reported on mask contamination or risk compensation behaviour. Risk of bias was generally high for blinding of participants and personnel and low for attrition and reporting biases.
There are insufficient data to quantify all of the adverse effects that might reduce the acceptability, adherence and effectiveness of face masks. New research on face-masks should assess and report the harms and adverse effects. Urgent research is also needed on methods and designs to mitigate the downsides of face-mask wearing, particularly the assessment of alternatives such as face-shields.

[6] Bakhit M, Krzyzaniak N, Scott A, Clark J, Glasziou P, Del Mar C. Downsides of face masks and possible mitigation strategies: a systematic review and meta-analysis. MedRxiv. 2020 doi: 10.1101/2020.06.16.20133207.

## Bourassa et al (2019) Impact of Gas Masks on the Work of Breathing and Breathing Pattern in Subjects With Stable COPD[7]

The aim of the study was to evaluate the impact of the gas mask on respiratory pattern, gas exchange, and indexes of respiratory effort in patients with moderate to severe stable COPD.
Methods: Crossover evaluation with 3 randomized-order, 10-min conditions at rest and with and without a gas mask using 2 different filtered cartridges, each with a distinct inspiratory resistance (cartridge A = 3.5 cm $H_2O$; cartridge B = 2.2 cm $H_2O$, both at 1 L/s). The study involved 8 subjects with COPD, and breathing patterns, indexes of respiratory effort, and capillary blood gases were evaluated. Comparisons of these parameters were made between the tested conditions.
Results: Mean subject age was 69 y, and mean $FEV_1$ = 1.3 L (47% predicted). Short-term utilization of the gas mask was associated with a significant increase in the indexes of effort in comparison to baseline without a mask. The esophageal product-time product significantly increased in comparison with baseline (cartridge A = 281 ± 65 cm $H_2O$/s/min, cartridge B = 253 ± 47 cm $H_2O$/s/min, and baseline = 184 ± 46 cm $H_2O$/s/min, $P < .001$). There were negligible changes in the breathing pattern and gas exchange.
Conclusions: Indexes of respiratory effort increased slightly in subjects with stable COPD while using a gas mask, an effect possibly related to increased inspiratory resistance when the mask was worn. These data are reassuring for the potential short-duration use of such protection for patients with moderate to severe COPD.

## Chan et al (October 2020) [Letter] Peripheral Oxygen Saturation in Older Persons Wearing Nonmedical Face Masks in Community Settings[8]

A small crossover study showing that wearing a 3-layer nonmedical face mask was not associated with a decline in oxygen saturation in older participants. Limitations included the exclusion of patients who

[7] Bourassa S, Bouchard PA, Lellouche F. Impact of Gas Masks on the Work of Breathing and Breathing Pattern in Subjects With Stable COPD. Respir Care. 2019 Sep;64(9):1049-1056. doi: 10.4187/respcare.06550. Epub 2019 Mar 26. PMID: 30914496.
[8] Chan NC, Li K, Hirsh J. Peripheral Oxygen Saturation in Older Persons Wearing Nonmedical Face Masks in Community Settings. *JAMA.* Published online October 30, 2020. doi:10.1001/jama.2020.2190

were unable to wear a mask for medical reasons, investigation of one type of mask only, $SpO_2$ measurements during minimal physical activity, and a small sample size. Results do not support claims that wearing nonmedical face masks in community settings is unsafe.

**Fikenzer et al (Dec 2020) Effects of surgical and FFP2/N95 face masks on cardiopulmonary exercise capacity[9]**

Due to the SARS-CoV2 pandemic, medical face masks are widely recommended for a large number of individuals and long durations. The effect of wearing a surgical and a FFP2/N95 face mask on cardiopulmonary exercise capacity has not been systematically reported.

This prospective cross-over study quantitated the effects of wearing no mask (nm), a surgical mask (sm) and a FFP2/N95 mask (ffpm) in 12 healthy males (age 38.1 ± 6.2 years, BMI 24.5 ± 2.0 kg/m2). The 36 tests were performed in randomized order. The cardiopulmonary and metabolic responses were monitored by ergo-spirometry and impedance cardiography. Ten domains of comfort/discomfort of wearing a mask were assessed by questionnaire.

The pulmonary function parameters were significantly lower with the mask. Peak blood lactate response was reduced with the mask. Cardiac output was similar with and without the mask. Participants reported consistent and marked discomfort wearing the masks, especially ffpm.

Ventilation, cardiopulmonary exercise capacity and comfort are reduced by surgical masks and highly impaired by FFP2/N95 face masks in healthy individuals. These data are important for recommendations on wearing face masks at work or during physical exercise.

[9] Fikenzer S, Uhe T, Lavall D, Rudolph U, Falz R, Busse M, et al Effects of surgical and FFP2/N95 face masks on cardiopulmonary exercise capacity. Clin Res Cardiol. 2020 Jul 6 : 1–9.

## Guan et al (2018) The effects of face-masks on airway inflammation and endothelial dysfunction in healthy young adults: a double-blind, randomized, controlled crossover study[10]

Face-masks are increasingly worn during air pollution episodes in China, but their protective effects are poorly understood. The authors aimed to evaluate the filtration efficiencies of N95 face-masks and the cardiopulmonary benefits associated with wearing face-masks during episodes of pollution. Results: The authors measured the filtration efficiencies of particles in ambient air of six types of N95 face-masks with a manikin headform. The most effective one was used in a double-blind, randomized, controlled crossover study involving 15 healthy young adults, conducted during 2 days of severe pollution in Beijing, China. Subjects were asked to walk along a busy-traffic road for 2 hours wearing authentic or sham N95 face-masks. Clinical tests were performed four times to determine changes in the levels of biomarkers of airway inflammation, endothelial dysfunction, and oxidative stress within 24 h after exposure. The face-masks removed 48%-75% of number concentrations of ambient air particles between 5.6 and 560 nm in diameter. After adjustments for multiple comparisons, the exhaled nitric oxide level and the levels of interleukin-1α, interleukin-1β, and interleukin-6 in exhaled breath condensate increased significantly in all subjects; however, the increases in those wearing authentic face-masks were statistically significantly lower than in the sham group. No significant difference was evident in the urinary creatinine-corrected malondialdehyde level. In arterial stiffness indicators, the ejection duration of subjects wearing authentic face-masks was higher after exposure compared to the sham group; no significant between-group difference was found in augmentation pressure or the augmentation index. Conclusions: In young healthy adults, N95 face-masks partially reduced acute particle-associated airway inflammation, but neither systemic oxidative stress nor endothelial dysfunction improved significantly.

[10] Guan, T., Hu, S., Han, Y., Wang, R., Zhu, Q., Hu, Y., Fan, H., & Zhu, T. (2018). The effects of face-masks on airway inflammation and endothelial dysfunction in healthy young adults: a double-blind, randomized, controlled crossover study. *Particle and fibre toxicology*, *15*(1), 30. https://doi.org/10.1186/s12989-018-0266-0

The clinical significance of these findings long-term remains to be determined.

### Harber et al (2010) Respirator physiologic impact in persons with mild respiratory disease[11]

Objective: To assess whether mild respiratory disease affects physiologic adaptation to respirator use.
Methods: The study compared the respiratory effects of dual cartridge half face mask and filtering facepeice (N95) respirators while performing simulated-work tasks. Subjects with mild chronic obstructive pulmonary disease (n = 14), asthma (n = 42), chronic rhinitis (n = 17), and normal respiratory status (n = 24) were studied. Mixed model regression analyses determined the effects of respirator type, disease status, and the respirator-disease interactions.
Results: Respirator type significantly affected several physiologic measures. Respirator type effects differed among disease categories as shown by statistically significant interaction terms. Respiratory timing parameters were more affected than ventilatory volumes. In general, persons with asthma showed greater respirator-disease interactions than chronic obstructive pulmonary disease, rhinitis, or healthy subjects.
Conclusions: The effects of respirator type differ according to the category of respiratory disease.

### Hopkins et al (Nov 2020) Face-masks and the Cardiorespiratory Response to Physical Activity in Health and Disease[12]

To minimize transmission of SARS-CoV-2, the novel coronavirus responsible for COVID-19, the Center for Disease Control and World Health Organization recommend wearing face-masks in public. Some have expressed concern that these may affect the cardiopulmonary system by increasing the work of breathing (Wb), altering pulmonary gas exchange and increasing dyspnea, especially during physical

[11] Harber P, Santiago S, Bansal S, Liu Y, Yun D, Wu S. Respirator physiologic impact in persons with mild respiratory disease. J Occup Environ Med. 2010;52(2):155-62.
[12] Hopkins, S. R., Dominelli, P. B., Davis, C. K., Guenette, J. A., Luks, A. M., Molgat-Seon, Y., Sá, R. C., Sheel, A. W., Swenson, E. R., & Stickland, M. K. (2020). Face-masks and the Cardiorespiratory Response to Physical Activity in Health and Disease. *Annals of the American Thoracic Society*, 10.1513/AnnalsATS.202008-990CME. Advance online publication. https://doi.org/10.1513/AnnalsATS.202008-990CME

activity. These concerns have been derived largely from studies evaluating devices intentionally designed to severely affect respiratory mechanics and gas exchange. The authors review the literature on the effects of various face-masks and respirators on the respiratory system during physical activity using data from several models: cloth face coverings and surgical masks, N95 respirators, industrial respirators and applied high resistive or high deadspace respiratory loads. Overall, the available data suggest that although dyspnea may be increased and alter perceived effort with activity, the effects on Wb, blood gases and other physiological parameters imposed by face-masks during physical activity are small, often too small to be detected, even during very heavy exercise. There is no current evidence to support sex-based or age-based differences in the physiological responses to exercise while wearing a face-mask. While the available data suggest that negative effects of using cloth or surgical face-masks during physical activity in healthy individuals are negligible and unlikely to impact exercise tolerance significantly, for some individuals with severe cardiopulmonary disease, any added resistance and/or minor changes in blood gases may evoke considerably more dyspnea and, thus, affect exercise capacity.

### Johnson (2016) Respirator masks protect health but impact performance: a review[13]

Respiratory protective masks are used whenever it is too costly or impractical to remove airborne contamination from the atmosphere. Respirators are used in a wide range of occupations from the military to medicine. Respirators have been found to interfere with many physiological and psychological aspects of task performance at levels from resting to maximum exertion. Many of these limitations have been investigated in order to determine quantitatively how much performance decrement can be expected from different levels of respirator properties. The entire system, including respirator and wearer interactions, must be considered when evaluating wearer performances. This information can help respirator designers to

[13] Johnson, A. (2016). Respirator masks protect health but impact performance: A review. Journal of Biological Engineering. 10. 10.1186/s13036-016-0025-4.

determine trade-offs or managers to plan to compensate for reduced productivity of wearers.

**Kao et al (2020) The physiological impact of wearing an N95 mask during hemodialysis as a precaution against SARS in patients with end-stage renal disease**[14]

Background and Purpose: Most patients with end-stage renal disease (ERSD) visiting our hospital for hemodialysis treatment during the SARS outbreak wore an N95 mask. Data on the physiological stress imposed by the wearing of N95 masks remains limited. This study investigated the physiological impact of wearing an N95 mask during hemodialysis (HD) on patients with ESRD.
Methods: ESRD patients who received regular HD at National Taiwan University Hospital between April to June 2003 were enrolled. Each patient wore a new N95 mask (3M Model 8210) during HD (4 hours). Vital signs, clinical symptoms and arterial blood gas measured before and at the end of HD were compared.
Results: 39 patients (23 men; mean age, 57.2 years) were recruited for participation in the study. Seventy percent of the patients showed a reduction in partial pressure of oxygen ($PaO_2$), and 19% developed various degrees of hypoxemia. Wearing an N95 mask significantly reduced the $PaO_2$ level (101.7 +/- 12.6 to 92.7 +/- 15.8 mm Hg, $p = 0.006$), increased the respiratory rate (16.8 +/- 2.8 to 18.8 +/- 2.7/min, $p < 0.001$), and increased the occurrence of chest discomfort (3 to 11 patients, $p = 0.014$) and respiratory distress (1 to 17 patients, $p < 0.001$). Baseline $PaO_2$ level was the only significant predictor of the magnitude of $PaO_2$ reduction ($p < 0.001$).
Conclusion: Wearing an N95 mask for 4 hours during HD significantly reduced $PaO_2$ and increased respiratory adverse effects in ESRD patients.

[14] Kao TW, Huang KC, Huang YL, Tsai TJ, Hsieh BS, Wu MS. The physiological impact of wearing an N95 mask during hemodialysis as a precaution against SARS in patients with end-stage renal disease. J Formos Med Assoc. 2004 Aug;103(8):624-8. PMID: 15340662.

## Kyung et al (2020) Risks of N95 Face Mask Use in Subjects With COPD[15]

The N95 filtering face-piece respirator (FFR) is the most popular individual protective device to reduce exposure to particulate matter. However, concerns have been raised with regard to its use because it can increase respiratory resistance and dead space. This study assessed the safety of N95 use in patients with COPD and air-flow limitation. This prospective study was performed at a tertiary hospital and enrolled 97 subjects with COPD. The subjects were monitored for symptoms and physiologic variables during a 10-min rest period and 6-min walking test while wearing an N95. Of the 97 subjects, 7 with COPD did not wear the N95 for the entire test duration. This mask-failure group showed higher British Modified Medical Research Council dyspnea scale scores and lower FEV1 percent of predicted values than did the successful mask use group. A modified Medical Research Council dyspnea scale score ≥ 3 (odds ratio 167, 95% CI 8.4 to >999.9; $P$= .008) or a $FEV_1$ < 30% predicted (odds ratio 163, 95% CI 7.4 to >999.9; $P$= .001) was associated with a risk of failure to wear the N95. Breathing frequency, blood oxygen saturation, and exhaled carbon dioxide levels also showed significant differences before and after N95 use. This study demonstrated that subjects with COPD who had modified Medical Research Council dyspnea scale scores ≥ 3 or FEV1 < 30% predicted wear N95s only with care.

## Lee and Wang (2011) Objective assessment of increase in breathing resistance of N95 respirators on human subjects[16]

Face masks or respirators are commonly worn by medical professionals and patients for protection against respiratory tract infection and the spread of illnesses, such as severe acute respiratory syndrome and pandemic influenza (H1N1). Breathing discomfort due to increased breathing resistance is known to be a problem with the use of N95 respirators but there is a lack of scientific data to quantify this effect. The purpose of this study was to assess objectively the

[15] Kyung, S. Y., Kim, Y., Hwang, H., Park, J. W., & Jeong, S. H. (2020). Risks of N95 Face Mask Use in Subjects With COPD. *Respiratory care*, *65*(5), 658–664. https://doi.org/10.4187/respcare.06713
[16] Lee HP, Wang de Y. Objective assessment of increase in breathing resistance of N95 respirators on human subjects. Ann Occup Hyg. 2011;55(8):917-21.

impact of wearing N95 face masks on breathing resistance. A total of 14 normal adult volunteers (7 males and 7 females) were recruited. Nasal airflow resistance during inspiration and expiration was measured using a standard rhinomanometry and nasal spirometry. A modified full face mask was produced in-house in order to measure nasal resistance with the use of N95 (3M 8210) respirators. The results showed a mean increment of 126% and 122% in inspiratory and expiratory flow resistances, respectively, with the use of N95 respirators. There was also an average reduction of 37% in air exchange volume with the use of N95 respirators. This is the first reported study that demonstrates quantitatively and objectively the substantial impairment of nasal airflow in terms of increased breathing resistance with the use of N95 respirators on actual human subjects.

**Li et al (2005) Effects of wearing N95 and surgical face-masks on heart rate, thermal stress and subjective sensations[17]**

The study investigated the effects of wearing N95 and surgical face-masks with and without nano-functional treatments on thermophysiological responses and the subjective perception of discomfort.

The subjects had significantly lower average heart rates when wearing nano-treated and untreated surgical face-masks than when wearing nano-treated and untreated N95 face-masks. The outer surface temperature of both surgical face-masks was significantly higher than that of both N95 face-masks. On the other hand, the microclimate and skin temperatures inside the face-mask were significantly lower than those in both N95 face-masks. Both surgical face-masks had significantly higher absolute humidity outside the surface than both N95 face-masks. The absolute humidity inside the surgical face-mask was significantly lower than that inside both N95 face-masks. Both surgical face-masks were rated significantly lower for perception of humidity, heat, breath resistance and overall discomfort than both N95 face-masks. The ratings for other sensations — including feeling unfit, tight, itchy, fatigued, odorous

[17] Li Y, Tokura H, Guo YP, Wong AS, Wong T, Chung J, et al Effects of wearing N95 and surgical face-masks on heart rate, thermal stress and subjective sensations. Int Arch Occup Environ Health. 2005;78(6):501-9.

and salty — that were obtained while the subjects were wearing the surgical face-masks were significantly lower than when the subjects were wearing the N95 face-masks. Subjective preference for the nano-treated surgical face-masks was the highest. There was significant differences in preference between the nano-treated and untreated surgical face-masks and between the surgical and N95 face-masks.

### Matusiak et al (July 2020) Inconveniences due to the use of face masks during the COVID-19 pandemic: A survey study of 876 young people[18]

This study was undertaken to analyse the most bothersome issues reported by young people using face protection during the current viral pandemic.

Out of 876 participants only 27 people (3.1%) did not complain of any problems related to face mask wearing. Out of all reported inconveniences, difficulty in breathing appeared to be the most common one (35.9%), followed by warming/sweating (21.3%), misting up of the glasses (21.3%) and slurred speech (12.3%). Interestingly, other skin bothersome reactions related to wearing of face masks were reported less often (itch - 7.7%, skin irritation - 0.9%).

### Matuschek et al (2020) Face masks: benefits and risks during the COVID-19 crisis[19]

The German government has made it mandatory to wear respiratory masks covering mouth and nose (MNC) as an effective strategy to fight SARS-CoV-2 infections. In many countries, this directive has been extended on shopping malls or public transportation. The aim of this paper is to critically analyse the statutory regulation to wear protective masks during the COVID-19 crisis from a medical standpoint.

[18] Matusiak L, Szepietowska M, Krajewski P, Bialynicki-Birula R, Szepietowski JC. Inconveniences due to the use of face masks during the COVID-19 pandemic: a survey study of 876 young people. Dermatol Ther. 2020. doi: 10.1111/dth.13567

[19] Matuschek C, Moll F, Fangerau H, Fischer JC, Zanker K, van Griensven M, et al Face masks: benefits and risks during the COVID-19 crisis. Eur J Med Res. 2020;25(1):32.

Methods: The authors performed an extensive query of the most recent publications addressing the prevention of viral infections including the use of face masks in the community as a method to prevent the spread of the infection. Issues of practicability, professional use, and acceptability based on the community and the environment where the user resided were addressed.
Results: The authors found only weak evidence for wearing a face mask as an efficient hygienic tool to prevent the spread of a viral infection. However, the use of MNC seems to be linked to relevant protection during close contact scenarios by limiting pathogen-containing aerosol and liquid droplet dissemination. Importantly, the authors found evidence for significant respiratory compromise in patients with severe obstructive pulmonary disease, secondary to the development of hypercapnia. This could also happen in patients with lung infections, with or without SARS-CoV-2.

### Ong et al (2020) Headaches Associated With Personal Protective Equipment - A Cross-Sectional Study Among Frontline Healthcare Workers During COVID-19[20]

Objectives: To determine the risk factors associated with the development of de novo PPE-associated headaches as well as the perceived impact of these headaches on their personal health and work performance. The impact of COVID-19 on pre-existing headache disorders was also investigated. Design: A cross-sectional study among healthcare workers at our tertiary institution who were working in high-risk hospital areas during COVID-19. All respondents completed a self-administered questionnaire. Results: A total of 158 healthcare workers participated in the study. The majority [126/158 (77.8%)] were aged 21-35 years. Participants included nurses [102/158 (64.6%)], doctors [51/158 (32.3%)], and paramedical staff [5/158 (3.2%)]. Pre-existing primary headache diagnosis was present in about a third [46/158 (29.1%)] of respondents. Those based at the emergency department had higher average daily duration of combined PPE exposure compared to those working in isolation wards

[20] Ong, J., Bharatendu, C., Goh, Y., Tang, J., Sooi, K., Tan, Y. L., Tan, B., Teoh, H. L., Ong, S. T., Allen, D. M., & Sharma, V. K. (2020). Headaches Associated With Personal Protective Equipment - A Cross-Sectional Study Among Frontline Healthcare Workers During COVID-19. *Headache*, *60*(5), 864–877. https://doi.org/10.1111/head.13811

[7.0 (SD 2.2) vs 5.2 (SD 2.4) hours, P < .0001] or medical ICU [7.0 (SD 2.2) vs 2.2 (SD 0.41) hours, P < .0001]. Out of 158 respondents, 128 (81.0%) respondents developed de novo PPE-associated headaches. A pre-existing primary headache diagnosis (OR = 4.20, 95% CI 1.48-15.40; P = .030) and combined PPE usage for >4 hours per day (OR 3.91, 95% CI 1.35-11.31; P = .012) were independently associated with de novo PPE-associated headaches. Since the COVID-19 outbreak, 42/46 (91.3%) of respondents with pre-existing headache diagnosis either agreed or strongly agreed that the increased PPE usage had affected the control of their background headaches, which affected their level of work performance.
Conclusion: Most healthcare workers develop de novo PPE-associated headaches or exacerbation of their pre-existing headache disorders.

**Perna et al (Dec 2020) Impact of respiratory protective devices on respiration: Implications for panic vulnerability during the COVID-19 pandemic[21]**

Background: The wearing of respiratory protective devices (RPDs) correctly and continually in situations where people are at risk of respiratory infections is crucial for infection prevention. Certain people are poorly compliant with RPDs due to RPD-related annoyance, including respiratory discomfort. The authors hypothesized that individuals vulnerable to panic attacks are included in this group. No published studies on this topic are available. The evidence for the hypothesis was reviewed in this study as a starting point for future research.
Methods: A set of experimental studies that measured the respiratory physiological burden in RPD wearers through objective and validated methods was selected. A bibliographic search of publications in the PubMed database (January 2000-May 2020) to identify representative studies that may be of interest for panic respiratory pathophysiology was conducted.
Results: 5 studies were included. Wearing RPDs exerted significant respiratory effects, including increased breathing resistance,

[21] Perna G, Cuniberti F, Daccò S, Nobile M, Caldirola D. Impact of respiratory protective devices on respiration: Implications for panic vulnerability during the COVID-19 pandemic. J Affect Disord. 2020 Dec 1;277:772-778. doi: 10.1016/j.jad.2020.09.015. Epub 2020 Sep 7. PMID: 33065816; PMCID: PMC7476564

$CO_2$ rebreathing due to $CO_2$ accumulation in the RPD cavity, and decreased inhaled $O_2$ concentration. The authors discussed the implications of these effects on the respiratory pathophysiology of panic.
Limitations: Most studies had a small sample size, with a preponderance of young participants. Different methodologies were used across the studies. Furthermore, differences in physical responses between wearing RPDs in experimental settings or daily life cannot be excluded.
Conclusions: Panic prone individuals may be at higher risk of respiratory discomfort when wearing RPDs, thereby reducing their tolerance for these devices. Strategies to decrease discomfort should be identified to overcome the risk of poor compliance.

**[Person et al (2018) Effect of a surgical mask on six minute walking distance[22]]**
Introduction: Six minutes walking test (6MWT) is regularly used in pulmonology. To minimize the risk of cross-infection, some patients must wear surgical mask at rest and sometimes during exercise.
Aim: To evaluate the effect of wearing a surgical mask during 6MWT in healthy subjects.
Method: A prospective study on 44 healthy subjects. After a first 6MWT for training, the study participants performed randomly two 6MWT with or without a surgical mask. Distance and dyspnea, heart rate and saturation variations were recorded.
Results: Distance was not modified by the mask (P=0.99). Dyspnea variation was significantly higher with surgical mask (+5.6 vs. +4.6; P<0.001) and the difference was clinically relevant. No difference was found for the variation of other parameters.
Conclusion: Wearing a surgical mask modifies significantly and clinically dyspnea without influencing walked distance.

[22] Person E, Lemercie C, Royer A, Reychler G. [Effect of a surgical mask on six minute walking distance]. Rev Mal Respir. 2018;35(3):264-8.

## Purushothaman et al (2020) Effects of Prolonged Use of Face-mask on Healthcare Workers in Tertiary Care Hospital During COVID-19 Pandemic[23]

Aim: To determine the effects of prolonged usage of N95 respirators and surgical face-masks among health care workers in our institution. Design: A cross-sectional study in SRM Medical College Hospital, Kattankulathur. Methods: A self-constructed questionnaire containing 20 questions regarding the effects of prolonged use of face-masks were distributed to 250 participants. All participants wore either surgical masks or N95 respirators for a minimum of 4 h per day. People aged between 20 and 48 years were selected. The study period was from 20/07/2020 to 26/07/2020. Completed questionnaires were sent for statistical analysis. Results: A total of 250 healthcare workers participated in the study out of which 179 were females. The acquired results were excessive sweating around the mouth (67.6%), difficulty in breathing on exertion (58.2%), acne (56.0%) and itchy nose (52.0%). This study suggests that prolonged use of face-masks induces difficulty in breathing on exertion and excessive sweating around the mouth to the healthcare workers which results in poorer adherence and increased risk of susceptibility to infection.

## Rebmann et al (2013) Physiologic and other effects and compliance with long-term respirator use among medical intensive care unit nurses[24]

Long-term use of respiratory protection may be necessary, but compliance may be low, and physiologic effects have not been well evaluated. Methods: Ten nurses participated; physiologic effects, subjective symptoms, and compliance with wearing an N95 alone or with a surgical mask overlay were assessed. Longitudinal analysis based on multivariate linear regression models assessed changes in outcome variables: $CO_2$, $O_2$, heart rate, perceived comfort items, compliance measures, and others. Analyses recorded changes over

[23] Purushothaman, P. K., Priyangha, E., & Vaidhyswaran, R. (2020). Effects of Prolonged Use of Face-mask on Healthcare Workers in Tertiary Care Hospital During COVID-19 Pandemic. Indian journal of otolaryngology and head and neck surgery : official publication of the Association of Otolaryngologists of India, 1–7. Advance online publication. https://doi.org/10.1007/s12070-020-02124-0

[24] Rebmann, T., Carrico, R., & Wang, J. (2013). Physiologic and other effects and compliance with long-term respirator use among medical intensive care unit nurses. *American journal of infection control*, *41*(12), 1218–1223. https://doi.org/10.1016/j.ajic.2013.02.017

time, and compared wearing only an N95 to wearing an N95 with a surgical mask overlay. Results: Most nurses (90%, n = 9) tolerated wearing respiratory protection for two 12-hour shifts. $CO_2$ levels increased significantly compared with baseline measures, especially when comparing an N95 with a surgical mask to only an N95, but changes were not clinically relevant. Perceived exertion, perceived shortness of air, and complaints of headache, lightheadedness, and difficulty communicating also increased over time. Almost one-quarter (22%) of respirator removals were due to reported discomfort. N95 adjustments increased over time, but other compliance measures did not vary by time. Compliance increased on day 2, except for adjustments, touching under the N95, and eye touches.
Conclusion: Long-term use of respiratory protection did not result in any clinically relevant physiologic burden for health care personnel, although many subjective symptoms were reported. N95 compliance was fairly high.

**Roberge et al (May 2020) Physiological impact of the N95 filtering facepiece respirator on healthcare workers**[25]
Objective: To assess the physiological impact of the N95 filtering facepiece respirator (FFR) on healthcare workers.
Methods: Ten healthcare workers each conducted multiple 1-hour treadmill walking sessions, at 1.7 miles/h, and at 2.5 miles/h, while wearing FFR with exhalation valve, FFR without exhalation valve, and without FFR. Heart rate, respiratory rate, tidal volume, minute volume, blood oxygen saturation, and transcutaneously measured $P(CO_2)$ were monitored. User comfort and exertion, FFR moisture retention, and the carbon dioxide and oxygen concentrations in the FFR's dead space were also measured.
Results: There were no significant differences between FFR and control in the physiological variables, exertion scores, or comfort scores. There was no significant difference in moisture retention between FFR with and without exhalation valve. Two subjects had peak $P(CO_2)$ > or = 50 mm Hg. The FFR with exhalation valve offered no benefit in physiological burden over the FFR without valve. The

[25] Roberge RJ, Coca A, Williams WJ, Powell JB, Palmiero AJ. Physiological impact of the N95 filtering facepiece respirator on healthcare workers. Respir Care. 2010 May;55(5):569-77. PMID: 20420727.

FFR dead-space oxygen and carbon dioxide levels did not meet the Occupational Safety and Health Administration's ambient workplace standards.
Conclusions: In healthy healthcare workers, FFR did not impose any important physiological burden during 1 hour of use, at realistic clinical work rates, but the FFR dead-space carbon dioxide and oxygen levels were significantly above and below, respectively, the ambient workplace standards, and elevated $P(CO_2)$ is a possibility. Exhalation valve did not significantly ameliorate the FFR's $P(CO_2)$ impact.

### Rosner et al (2020) Adverse Effects of Prolonged Mask Use among Healthcare Professionals during COVID-19[26]

Healthcare professionals report side effects of prolonged use of PPE when caring for COVID-19 patients. This study delves into various adverse effects of prolonged mask use and provides recommendations to ease the burden on healthcare professionals.
This is a cross sectional study among healthcare professionals, primarily located in New York City, who worked in hospital during the COVID-19 pandemic. All respondents completed an anonymous survey consisting of 21 questions regarding adverse effects of PPE, medical history, and demographics.
A total of 343 healthcare professionals on the COVID-19 frontline participated in the study. The majority were female (n = 315) and 227 were located in New York City. 225 respondents identified as White, 34 as Hispanic, 23 as African American, and 61 as another ethnicity. 314 respondents reported adverse effects from prolonged mask use with headaches being the most common complaint (n = 245). Skin breakdown was experienced by 175 respondents, and acne was reported in 182 respondents. Impaired cognition was reported in 81 respondents. Previous history of headaches (n = 98), skin sensitivity (n = 164), and acne (n = 121) were found in some respondents. Some respondents experienced resolved side effects once masks were removed, while others required physical or medical intervention.
Prolonged use of N95 and surgical masks by healthcare professionals during COVID-19 has caused adverse effects such as headaches, rash,

[26] Rosner E (2020) Adverse Effects of Prolonged Mask Use among Healthcare Professionals during COVID-19. J Infect Dis Epidemiol 6:130. https:// doi.org/10.23937/2474-3658/1510130

acne, skin breakdown, and impaired cognition in the majority of those surveyed. As a second wave of COVID-19 is expected, and in preparation for future pandemics, it is imperative to identify solutions to manage these adverse effects. Frequent breaks, improved hydration and rest, skin care, and newly designed, more comfortable masks are recommendations for future management of adverse effects related to prolonged mask use.

### Samannan et al (2020) Effect of Face Masks on Gas Exchange in Healthy Persons and Patients with COPD[27]

To evaluate whether gas exchange abnormalities occur with the use of surgical masks in subjects with and without lung function impairment. In order to demonstrate the changes in end-tidal $CO_2$ (ETCO2) and oxygen saturation ($SpO_2$) before and after wearing a surgical mask, the authors used a convenience sample of 15 staff physicians without lung conditions (aged 31.1 ± 1.9 years, 60% male) and 15 veterans with severe COPD (aged 71.6 ± 8.7 years, FEV1 44.0 ± 22.2%, 100% male). The patients needed to have a post-bronchodilator FEV1. Although changes in tidal volume or minute ventilation were not measured, these data suggest that gas exchange is not significantly affected by the use of a surgical mask, even in subjects with severe lung impairment.

### Scarano et al (2020) Facial Skin Temperature and Discomfort When Wearing Protective Face Masks: Thermal Infrared Imaging Evaluation and Hands Moving the Mask[28]

Individual respiratory protective devices and face-masks represent critical tools in protecting health care workers in hospitals and clinics, and play a central role in decreasing the spread of the high-risk pandemic infection of 2019, coronavirus disease (COVID-19). The aim of the present study was to compare the facial skin temperature and the heat flow when wearing medical surgical masks to the same

[27] Samannan, R., Holt, G., Calderon-Candelario, R., Mirsaeidi, M., & Campos, M. (2020). Effect of Face Masks on Gas Exchange in Healthy Persons and Patients with COPD. *Annals of the American Thoracic Society*, 10.1513/AnnalsATS.202007-812RL. Advance online publication. https://doi.org/10.1513/AnnalsATS.202007-812RL
[28] Scarano, A., Inchingolo, F., & Lorusso, F. (2020). Facial Skin Temperature and Discomfort When Wearing Protective Face Masks: Thermal Infrared Imaging Evaluation and Hands Moving the Mask. *International journal of environmental research and public health*, *17*(13), 4624. https://doi.org/10.3390/ijerph17134624

factors when wearing N95 respirators. A total of 20 subjects were recruited and during the evaluation, each subject was invited to wear a surgical mask or respirator for 1 h. The next day in the morning at the same hour, the same subject wore a N95 mask for 1 h with the same protocol. Infrared thermal evaluation was performed to measure the facial temperature of the perioral region and the perception ratings related to the humidity, heat, breathing difficulty, and discomfort were recorded. A significant difference in heat flow and perioral region temperature was recorded between the surgical mask and the N95 respirator ($p < 0.05$). A statistically significant difference in humidity, heat, breathing difficulty, and discomfort was present between the groups. The study results suggest that N95 respirators are able to induce an increased facial skin temperature, greater discomfort and lower wearing adherence when compared to the medical surgical masks.

### Scheid et al (2020) [Commentary] Physiological and Psychological Impact of Face Mask Usage during the COVID-19[29]

The authors discuss the physiological effects of wearing masks for prolonged periods of time, including special considerations such as mask wearing among those who engage in exercise training, and concerns for individuals with pre-existing chronic diseases. In healthy populations, wearing a mask does not appear to cause any harmful physiological alterations, and the potentially life-saving benefits of wearing face masks seem to outweigh the documented discomforts such as headaches. However, there continues to be controversy over mask wearing in the United States even though wearing a mask appears to have only minor physiological drawbacks. While there are minimal physiological impacts, theoretical evidence suggests that there may be consequential psychological impacts of mask wearing on the basic psychological needs of competence, autonomy and relatedness. These psychological impacts may contribute to the controversy associated with wearing masks during the COVID-19 pandemic in the United States. After discussing the physiological

[29] Scheid, J. L., Lupien, S. P., Ford, G. S., & West, S. L. (2020). Commentary: Physiological and Psychological Impact of Face Mask Usage during the COVID-19 Pandemic. *International journal of environmental research and public health*, *17*(18), 6655. https://doi.org/10.3390/ijerph17186655

impacts of mask wearing, the authors address the psychological effects associated with wearing masks during the COVID-19 pandemic.

**Shaw et al (Nov 2020) Wearing of Cloth or Disposable Surgical Face Masks has no Effect on Vigorous Exercise Performance in Healthy Individuals[30]**

Wearing face masks is recommended for the prevention of contracting or exposing others to cardiorespiratory infections such as COVID-19. Controversy exists on whether wearing face masks during vigorous exercise affects performance. The authors used a randomized, counterbalanced cross-over design to evaluate the effects of wearing a surgical mask, a cloth mask or no mask in 14 participants (7 men and 7 women; 28.2 ± 8.7 y) during a cycle ergometry test to exhaustion. Arterial oxygen saturation (pulse oximetry) and tissue oxygenation index (indicator of hemoglobin saturation/desaturation) at vastus lateralis (near-infrared spectroscopy) were assessed throughout the exercise tests. Wearing face masks had no effect on performance (time to exhaustion (mean ± SD): no mask 622 ± 141 s, surgical mask 657 ± 158 s, cloth mask 637 ± 153 s ($p$ = 0.20); peak power: no mask 234 ± 56 W, surgical mask 241 ± 57 W, cloth mask 241 ± 51 W ($p$ = 0.49)). When expressed relative to peak exercise performance, no differences were evident between wearing or not wearing a mask for arterial oxygen saturation, tissue oxygenation index, rating of perceived exertion, or heart rate at any time during the exercise tests. Wearing a face mask during vigorous exercise had no discernible detrimental effect on blood or muscle oxygenation, and exercise performance in young, healthy participants.

[30] Shaw K, Butcher S, Ko J, Zello GA, Chilibeck PD. Wearing of Cloth or Disposable Surgical Face Masks has no Effect on Vigorous Exercise Performance in Healthy Individuals. Int J Environ Res Public Health. 2020 Nov 3;17(21):8110. doi: 10.3390/ijerph17218110. PMID: 33153145; PMCID: PMC7662944.

## Vidua et al (2020) Problems arising from PPE when worn for long periods[31]

This article considers the discomfort associated with wearing PPE based upon the personal experience of a Forensic team at AIIMS Bhopal in India who wore it during autopsy work and proposed recommendations to minimise adverse effects.

## Wong et al (Jul 2020) Impact of the COVID-19 pandemic on sports and exercise[32]

Methods: A small sample of video footage of professional football players was analysed to track each players' time of close body contact and frequency of infection-risk behaviours to investigate the risk of virus transmission during football games. To investigate the physiological effect of wearing a face-mask during exercise, the authors conducted a controlled laboratory, within-subject, repeated measures study of 23 healthy volunteers of various sporting backgrounds. The volunteers underwent graded treadmill walking at 4 km per hour for 6 min with and without wearing a surgical mask in a randomized order with sufficient rest between trials. Heart rate and rate of perceived exertion (RPE) were recorded.
Results: In a 90 min match, the average duration of close contact between professional football players was 19 minutes and each player performed an average of 52 episodes of infection-risk behaviours. The heart rate and RPE of subjects wearing a face-mask was 128 beats per minute and 12.7 respectively. In those without a face-mask, the results were a heart rate of 124 beats per minute and a RPE of 10.8.
Conclusion: The infection risk was high for the players, even without spectators. The laboratory study to investigate the physiological effect of wearing a face-mask found that it significantly elevated heart rate and perceived exertion. Those participating in exercise need to be aware that face-masks increase the physiological burden of the body, especially in those with multiple underlying comorbidities. Elite athletes, especially those training for the upcoming Olympics, need to balance and reschedule their training regime to balance the risk of

[31] Vidua, R. K., Chouksey, V. K., Bhargava, D. C., & Kumar, J. (2020). Problems arising from PPE when worn for long periods. *The Medico-legal journal*, *88*(1_suppl), 47–49. https://doi.org/10.1177/0025817220935880
[32] Wong AY, Ling SK, Louie LH, Law GY, So RC, Lee DC, et al Impact of the COVID-19 pandemic on sports and exercise. Asia Pac J Sports Med Arthrosc Rehabil Technol. 2020;22:39-44.

deconditioning versus the risk of infection. The multiple infection-control measures imposed by the Hong Kong national team training centre was highlighted.

**Zhu et al (2014) Effects of long-duration wearing of N95 respirator and surgical face-mask: a pilot study[33]**

The protection efficacy of face-masks and respirators has been well documented. The change of human nasal functions after wearing N95 respirator and surgical face-mask is not known. In a parallel group study, 87 healthy healthcare workers were recruited. Each of the volunteers attended two sessions, and wore N95 respirator in session 1 (S1) and surgical face-mask in session 2 (S2) for 3 hours. Mean minimum cross sectional area (mMCA) of the two nasal airways via acoustic rhinometry and nasal resistance via rhinomanometry were measured before and immediately after the mask wearing. Rhinomanometry was repeated every 30 minutes for 1.5 hours after the removal of masks. A questionnaire was distributed to each of the volunteers during the 3-hour mask wearing period to report subjective feelings on discomfort level of breathing activity. Among 77 volunteers who completed both sessions, the mean nasal resistance immediately increased upon removal of the surgical face-mask and N95 respirator. The mean nasal resistance was significantly higher in S1 than S2 at 0.5 hours and 1.5 hours after removal of the masks.

[33] Zhu JH, Lee SJ, Wang DY, et al Effects of long-duration wearing of N95 respirator and surgical face-mask: a pilot study. J Lung Pulm Respir Res. 2014;1(4):97–100. DOI: https://doi.org/10.15406/jlprr.2014.01.00021

# Other

**Williams et al [Blog] The Physiological Burden of Prolonged PPE Use on Healthcare Workers during Long Shifts**[34]

A blog post assessing the physiological effects of prolonged PPE use on healthcare workers.

[34] Williams J et al [Blog] The Physiological Burden of Prolonged PPE Use on Healthcare Workers during Long Shifts https://blogs.cdc.gov/niosh-science-blog/2020/06/10/ppe-burden/ [Accessed 27 November 2020]

Produced by the members of the National Health Library and Knowledge Service Evidence Team†. Current as at 07 DECEMBER 2020. This evidence summary collates the best available evidence at the time of writing and does not replace clinical judgement or guidance. Emerging literature or subsequent developments in respect of COVID-19 may require amendment to the information or sources listed in the document. Although all reasonable care has been taken in the compilation of content, the National Health Library and Knowledge Service Evidence Team makes no representations or warranties expressed or implied as to the accuracy or suitability of the information or sources listed in the document. This evidence summary is the property of the National Health Library and Knowledge Service and subsequent re-use or distribution in whole or in part should include acknowledgement of the service.



The following PICO(T) was used as a basis for the evidence summary:

| | |
|---|---|
| Population (P: person; location; condition/patient characteristic) | HEALTH CARE WORKERS |
| Intervention (I: length; location; type) | PROLONGED FACE MASK USE |
| Comparison (C: another intervention; no intervention; location of the intervention) | |
| Outcome (O) | |

The following search strategy was used:

(MASK*[TITLE/ABSTRACT] OR OR FACE-MASK*[TITLE/ABSTRACT] OR FACE-MASKS OR "FACE MASK*"[TITLE/ABSTRACT] OR "MEDICAL MASK*"[TITLE/ABSTRACT] OR "SURGICAL MASK*"[TITLE/ABSTRACT] OR N95[TITLE/ABSTRACT] OR FFP[TITLE/ABSTRACT] OR RESPIRATOR [TITLE/ABSTRACT]) OR ("RESPIRATORY PROTECTIVE DEVICES"[MESH])

AND

((("OXIDATIVE STRESS"[TITLE/ABSTRACT] OR "OXYGEN TENSION"[TITLE/ABSTRACT] OR "OXYGEN STRESS"[TITLE/ABSTRACT]) OR ("OXIDATIVE STRESS"[MESH])) OR ("WORK OF BREATHING"[MESH])) OR ("RESPIRATORY SYSTEM"[MESH])

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