COVID-19 Living Evidence Synthesis 14.1b: Unintended consequences/outcomes of masking in response to COVID-19 in non-health care community-based settings

Executive Summary

Question

What is the best-available evidence about the unintended health and social consequences/outcomes (positive and negative) of masking in response to COVID-19 in non-health care community-based settings?

Sub-questions:

1. What are the unintended physiological health consequences/outcomes of wearing a mask? (e.g., gas exchange/cardio-respiratory function, smothering feeling, skin impact, exercise impact, toxicity, pathogenicity)
2. What are the unintended psychological and/or developmental consequences/outcomes of mask wearing? (e.g., anxiety, discrimination/social pressures, facial recognition, reading faces and emotions, inability to lip read, harder to hear speech)

Background

- The aim of this review is to analyze and summarize the evidence from randomized controlled trials (RCTs) and quasi-experimental studies with comparison groups about the unintended consequences/outcomes of masks (including different types of masks) in response to COVID-19 in community settings. Other study designs (e.g., observational studies) were excluded.
- Unintended consequences occur when results differ from an expected outcome, in this case masking, and vary across context, country, and age group. Unintended consequences can be positive or negative.

Key points

- We included 46 studies, 30 RCTs and 16 quasi-experimental, conducted across 19 countries.
- Studies examining the physiological effects of masking while exercising (cycling, treadmill, walking) are heterogenous in intervention and outcome measures (32 studies).
- Most studies examining the physiological effects of masking were RCTs and conducted with healthy young adults aged 18-30 years (23/34 studies).
- Most common physiological parameters measured were heart rate (HR) (26 studies), oxygen saturation (SpO_2) (24 studies), and Rating of Perceived Exertion (RPE) (17 studies).
- RPE was recurrent in the data with significant unintended consequences/outcomes related to dyspnea (15 studies) and to overall body discomfort (2 studies).
- Surgical masks were the most frequently studied (35/46).
- Masking while exercising, although uncomfortable, is safe in young healthy people aged 18-30 years (22/26 studies).
- Body temperature and thermal comfort are not significantly altered by masking (3 studies).
- Masking may contribute to dry eye conditions (2 studies).
- Masks significantly impair facial emotion recognition (4 studies), possibly leading to difficulty with expressing and or recognizing emotional states during brief interactions.
- Misperceptions of expressions of emotions such as surprise, fear, anger, disgust, and happiness while masked are common (4 studies).
- Masks attenuate the accuracy of voice recognition in noisy environments (1 study).
- Surgical masks may have a slight edge compared to N95 and cloth in contributing to accuracy of voice recognition (1 study).
- Masking did not negatively impact cognitive performance in healthy young adults (18-30) (3 studies) and school children (grades 5-7) (1 study).

- Mild but statistically significant changes in HR and SpO_2 did not attenuate cognitive performance in university students (1 study).

Suggested Tweet
Although heart rate and oxygen levels are largely unaffected by masking, it contributed to feelings of breathlessness and a perception of greater exertion.

Date of Literature Search: 22 February 2023

Suggested citation: Macdonald, M., Weeks, L., Langman, E., Leid, C., Khan, T., MacNeil, M., Ibekaku, M., McLaughlin, J., Batt, J., Curran, J., Comeau, J., Gaetz, K., Nyhof, M., Warmerdam, M., Roach, S., Tricco, A.C., Straus, S. COVID-END PHSM LES Working Group. COVID-19 Living Evidence Synthesis 14.1b: Unintended consequences/outcomes of masking in response to COVID-19 in non-health care community-based settings. Aligning Health Needs and Evidence for Transformative Change: A JBI Centre of Excellence and SPOR Evidence Alliance, 24 March 2023.

Please note: This living evidence synthesis (LES) is part of a suite of LESs of the best-available evidence about the effectiveness of six PHSMs (masks, quarantine and isolation, ventilation, physical distancing and reduction of contacts, hand hygiene and respiratory etiquette, cleaning, and disinfecting), as well as combinations of and adherence to these measures, in preventing transmission of COVID-19 and other respiratory infectious diseases in non-health care community- based settings. The next update to this and other LESs in the series is to be determined, but the most up-to-date versions in the suite are available on the COVID-END website. We provide context for synthesizing evidence about public health and social measures in Box 1 and an overview of our approach in Box 2.

Box 1: Context for synthesizing evidence about public health and social measures (PHSMs)

This series of living evidence syntheses was commissioned to understand the effects of PHSMs during a global pandemic to inform current and future use of PHSMs.

General considerations for identifying, appraising and synthesizing evidence about PHSMs

- PHSMs are population-level interventions and typically evaluated in observational studies.
  - Many PHSMs are interventions implemented at a population level, rather than at the level of individuals or clusters of individuals such as in clinical interventions.
  - Since it is typically not feasible and/or ethical to randomly allocate entire populations to different interventions, the effects of PHSMs are commonly evaluated using observational study designs that evaluate PHSMs in real-word settings.
  - As a result, a lack of evidence from RCTs does not necessarily mean the available evidence in this series of LESs is weak.
- Instruments for appraising the risk of bias in observational studies have been developed; however, rigorously tested and validated instruments are only available for clinical interventions.
  - Such instruments generally indicate that a study has less risk of bias when it was possible to directly assess outcomes and control for potential confounders for individual study participants.
  - Studies assessing PHSMs at the population level are not able to provide such assessments for all relevant individual-level variables that could affect outcomes, and therefore cannot be classified as low risk of bias.
- Given feasibility considerations related to synthesizing evidence in a timely manner to inform decision-making for PHSMs during a global pandemic, highly focused research questions and inclusion criteria for literature searches were required.

- As a result, we acknowledge that this series of living evidence syntheses – about the effectiveness of specific PHSMs (i.e., quarantine and isolation; mask use, including unintended consequences; ventilation, reduction of contacts, physical distancing, hand hygiene and cleaning and disinfecting measures), interventions that promote adherence to PHSMs, and the effectiveness of combinations of PHSMs – does not incorporate all existing relevant evidence on PHSMs.
- Ongoing work on this suite of products will allow us to broaden the scope of this review for a more comprehensive understanding of the effectiveness of PHSMs.
- Decision-making with the best available evidence requires synthesizing findings from studies conducted in real-world settings (e.g., with people affected by misinformation, different levels of adherence to an intervention, different definitions and uses of the interventions, and in different stages of the pandemic, such as before and after availability of COVID-19 vaccines).

Our approach to presenting findings with an appraisal of risk of bias (ROB) of included studies

To ensure we used robust methods to identify, appraise and synthesize findings and to provide clear messages about the effects of different PHSMs, we:

- acknowledge that a lack of evidence from RCTs does not mean the evidence available is weak
- assessed included studies for ROB using the approach described in the methods box
- typically introduce the ROB assessments only once early in the document if they are consistent across sub-questions, sub-groups and outcomes, and provide insight about the reasons for the ROB assessment findings (e.g., confounding with other complementary PHSMs) and sources of additional insights (e.g., findings from LES 20 in this series that evaluates combinations of PHSMs)
- note where there are lower levels of ROB where appropriate
- note where it is likely that risk of bias (e.g., confounding variables) may reduce the strength of association with a PHSM and an outcome from the included studies
- identify when little evidence was found and when it was likely due to literature search criteria that prioritized RCTs over observational studies.

Implications for synthesizing evidence about PHSMs

Despite the ROB for studies conducted at the population level that are identified in studies in this LES and others in the series, they provide the best-available evidence about the effects of interventions in real life. Moreover, ROB (and GRADE, which was not used for this series of LESs) were designed for clinical programs, services and products, and there is an ongoing need to identify whether and how such assessments and the communication of such assessments, need to be adjusted for public-health programs, services and measures and for health-system arrangements.

Findings

- Forty-six studies (30 randomized controlled trials [RCTs], 16 quasi-experimental) are included in this review. Thirty-four studies (n=1331) report on the physiological outcomes of masking, and 12 studies (n=2,148) report on the psychological and/or developmental outcomes of masking. Two of the 34 physiological studies are ocular in focus, with their own unique outcomes.
- JBI quality appraisal/risk of bias (ROB) for included studies rated 35/46 studies at moderate and the remainder at low for ROB. Of the RCTs, 24/30 were assessed as moderate risk of bias, and 6/30 were assessed as low risk of bias.
- A PRISMA 2020 flow diagram of the screening process is shown in **Figure 1**.

This LES included 46 studies addressing the physiological, psychological and/or developmental outcomes of wearing a face mask of one or more types versus no mask (NM). The studies were conducted in Germany (n=7), USA (n=7), China (n=5), the UK (n=3), Portugal (n=3), Spain (n=3), Canada (n=3), Brazil (n=2), Israel (n=2), and Tunisia (n=2), and the following countries had one study each: Saudi Arabia, Turkey, the Netherlands, Austria, Denmark, Iran, Italy, Japan, and Thailand.

Summary of findings about the primary outcome #1: Unintended physiological consequences/outcomes of masking

Thirty-four studies were included that report on the physiological **effects** of masking. The characteristics, findings, and assessment of risk of bias for each study are presented in **Table 3** and **Table 4**.

Physiological parameters and masking

Key observations

- Studies examining the physiological effects of masking while exercising are heterogenous (cycling, treadmill, walking).
- Most studies examining the physiological effects of masking while exercising were

Box 2: Our approach

We retrieved candidate studies by searching: 1) MEDLINE; 2) the iCite pre-print server; 3) Embase; 4) CINAHL; and 5) ERIC. Searches were conducted for studies reported in English, conducted with humans, and published since 1 January 2020 (to coincide with the emergence of COVID-19 as a global pandemic). Our detailed search strategy is included in **Appendix 1**.

Randomized controlled trials (RCTs) and studies that report on empirical data with a comparator were considered for inclusion, with modelling studies, simulation studies, cross-sectional studies, case reports, case series, and press releases excluded. A full list of included studies is provided in **Tables 3-5**

Reviews were not included but relevant reviews, including those identified in LES 14.1a, were mined for included studies.

Population of interest: People in non-health care community-based settings.

Intervention and control/comparator: Masks and face coverings, including cloth masks and surgical grade masks, in public or private non-healthcare community settings.

Primary outcomes: 1. Unintended physiological consequences/outcomes (e.g., impacts on gas exchange/cardio-respiratory function, discomfort/sensation of inability to breathe, impacts on ability to exercise, impacts on skin, other impacts); 2. Unintended psychological and developmental consequences/outcomes (e.g. anxiety, discrimination, social pressures, reading faces and emotions, facial recognition, inability to lip-read, harder to hear speech, etc.).

Data extraction: Data extraction was conducted by one team member and checked for accuracy and consistency by another using the template provided in **Appendix 2**.

Critical appraisal: Risk of Bias (ROB) of individual studies was assessed using JBI Critical Appraisal tools. For RCTs we used JBI Critical Appraisal Tool for Assessment of Risk of Bias for Randomized Controlled Trials (Barker et al., 2023), for non-randomized experimental studies we used JBI Checklist for Quasi-Experimental Studies (Non-Randomised Experimental Studies) (Tufanaru et al., 2020), and for case control studies we used JBI Checklist for Case Control Studies (Moola et al., 2020). Our detailed approach to critical appraisal is provided in **Appendix 3.**

Summaries: We summarized the evidence by presenting key observations by outcome measure. Future versions may include statistical pooling of results if deemed appropriate.

The next update to this document is to be determined.

RCTs and conducted with healthy young adults aged 18-30 (23/32).
- Most common physiological parameters measured were HR, oxygen saturation (SpO_2), Rating of Perceived Exertion (RPE) (See **Appendix 4** for more information on RPE).
- RPE was recurrent in the data with significant unintended consequences in relation to dyspnea and to overall body discomfort.
- Surgical masks were the most frequently studied in community settings (26/32).
- Masking while exercising, although uncomfortable, is safe in young healthy people aged 18-30.

Thirty-two studies (see **Table 3**) involved a variety of physical activity interventions (cycling – 14, treadmill – 7, walking – 4, running – 4, whole body vibration – 1, performing light tasks – 1, warm-up exercises - 1). The physiological parameters most frequently measured wearing masks (surgical, N95 and cloth) versus NM included heart rate (HR), SpO_2, RPE, respiratory/breathing rate (RR), blood pressure (BP), and end-tidal carbon dioxide ($etCO_2$) (note that for the purposes of this report, we use the term N95 to encompass FFP1, FFP2, FFP3, K95, KN95, etc. mask types). Other physiological parameters less commonly measured included spirometry measures of lung function (forced vital capacity [FVC], forced expiratory volume [FEV_1]), and work rate in watts was measured in several studies, as well as serum lactate.

Twenty-five of the 32 studies that involved physical activity had study populations of healthy young adults between the ages of 18-30 years. Six of these studies reported no significant unintended consequences of masking of all types across all physiological parameters measured (Ahmadian et al., 2021; Apolo-Arenas et al., 2022; Guardieiro et al., 2024 low ROB; Martin et al., pre-print; Pasqualetto, 2022 low ROB; Shaw et al., 2020 low ROB). Three of these six studies had a low ROB and the remainder moderate.

Fifteen studies found no statistically significant changes in HR and SpO_2 (Ade et al.., 2021; Cabanillas-Barea et al., 2021; Doherty et al., 2021; Driver et al., 2022; Egger et al., 2022; Epstein et al., 2021; Fischer et al., 2022; Ferguson et al., 2023 low ROB; Jesus et al., 2022; Jones et al., 2023; Ng et al., 2022; Poon et al., 2021 low ROB; Dacha et al., 2022; Steinhilber et al., 2022; Yoshihara et al., 2021). These 15 combined with the six above total 21 studies in which HR and SpO_2 were not significantly negatively altered while exercising with a mask in healthy young adults. Five of these 21 studies had a low ROB and the remainder moderate.

Of the remaining studies, one reported statistically significant changes in SpO_2 (Bar-On et al., 2021), and four reported statistically significant changes in HR (Fukushi et al., 2021 low ROB; Lassing, Vogt et al., 2022; Zhang et al., 2021). Five studies did not measure HR and SpO_2 (Dantas et al., 2021; Morris et al., 2021, Slimani et al., 2021; Slimani et al., 2022; Zhou & Dong, 2023).

Twenty-two of the 32 studies that involved an exercise activity measured RPE using the Borg Modified RPE Scale (0-10) and or original Borg (6-20). RPE (0-10) was sometimes referred to by authors of included studies as the Borg dyspnea scale particularly where participants reported breathlessness or a feeling of smothering while exercising. Sixteen of 21 studies examining RPE reported statistically significant unintended consequences/outcomes (Ade et al., 2021 dyspnea; Bar-On et al., 2021 perceived exertion; 2021; Dantas et al., 2021 perceived exertion; Doherty et al., 2021 dyspnea; Driver et al., 2022 perceived exertion; Ferguson et al., 2023 dyspnea low ROB; Fukushi et al., 2021 perceived exertion low ROB; Ng et al., 2022 breathlessness; Poon et al., 2021 perceived exertion low ROB; Dacha et al., 2022 dyspnea; Slimani et al., 2021 perceived exertion; Steinhilber et al., 2022 perceived respiratory effort; Vogt et al., 2022 perceived exertion; Wong et al., 2020 perceived exertion; Yoshihara et al., 2021 breathing discomfort; Zhang et al., 2021 dyspnea). Three of these 16 studies had low ROB and the remainder moderate ROB. Further explanation of these instruments is included in Appendix 4.

We purposely decided against a description of each of the 32 studies that involved exercising while masked because most were conducted with healthy young adults and could not be considered representative of the population in community settings. Instead, we focus on the studies with populations that better approximate community settings. Six studies that involved a physical activity and that examined physiological outcomes with more heterogenous samples are illustrated in **Table 1** and described below (Bar-On et al., 2021; Fischer et al., 2022; Martin et al., pre-print; Morris et al., 2021; Steinhilber et al., 2022; Vogt et al., 2022). ROB for these studies was moderate.

Table 1: Physiological results, physical activity studies with heterogenous samples

Citation	Country	n	Mask type	Results
Bar-On et al. (2021)	Israel	21	SM	Sig↑: $etCO_2$ (during slow walk) and RPE NS: SpO_2
Fischer et al. (2022)	Germany	50	SM, N95	Sig↓: peak power cycling (SM & N95 vs NM) Sig↑: $etCO_2$ (N95) NS: HR, serum lactate
Martin et al. (pre-print)	Austria	10	SM	NS: across parameters while climbing stairs
Morris et al. (2021)	Denmark	8	N95	Sig↑: RPE for prolonged N95 use during light tasks NS: HR, SpO_2, body & face temperature, cognitive performance
Steinhilber et al., 2022	Germany	39	SM, N95, cloth	RPE trended upward when masked ($P < 0.05$) while cycling NS: physical performance, SpO_2, BP and pCO_2
Vogt et al. (2022)	USA	19	SM, N95	Sig↑: HR (SM), $etCO_2$ (N95 vs NM; N95 vs SM), RPE (N95), RPD (N95), workload (N95 & SM) while cycling NS: workload across all masks

Sig↓ = Significant decrease; Sig↑ = Significant increase; NS = No significant difference
SM = surgical mask; NM = no mask; HR = heart rate; RPE = rating of perceived exhaustion; RPD = rating of perceived dyspnea; etCO2 = end-tidal carbon dioxide; pCO_2 = partial pressure of carbon dioxide; SpO_2 = oxygen saturation

Bar-On et al. (2021) (Israel) conducted a controlled trial study to evaluate the effects of surgical facemasks on gas exchange. The sample consisted of 21 healthy adults ranging in age from 29-57 years, mean age 38, 11 females and 10 males. Participants engaged in five-minute slow and brisk walks with mask and without. Parameters measured included SpO_2, $etCO_2$, and RPE using the Borg scale to rate their feeling of effort/exertion/breathlessness and fatigue during the activity (see **Appendix 4** for more information on the Borg scale). There was no significant decrease in SpO_2, $etCO_2$ increased significantly, $P = 0.004$ during the slow walk. This increase was speculated to be due to the rebreathing of expired air. During the brisk walk while masked resulted in a statistically significant increase in $etCO_2$ from baseline without a mask $P = 0.009$. There was a statistically significant increase in RPE results while masked with both slow and brisk walking $P = -0.002$ and $P < 0.001$ respectively. These authors summarized the results stating, wearing masks is safe, and that the changes in SpO_2, and $etCO_2$ were small yet reached significance. They speculate whether the gas exchange abnormalities would have been greater if the exercise intensity had been greater.

Fischer et al. (2022) (Germany) conducted a RCT at a University Hospital Medical Centre with a group of participants diagnosed with cardiovascular disease (CVD) and hypertension and scheduled for cycling exercise tests for clinical reasons. Sample included 50 participants, 40 with CVD as the intervention group and 10 healthy untreated participants as controls. Each participant completed the same ET protocol twice or 3 times (SM, N95, NM), respectively and were instructed to maintain a constant speed between 50 and 60 revolutions per minute. The protocol started with a 30 second warm-up period without load, followed by 1 min of constant load at 25 W. Thereafter, the load was increased every minute for 25 W using a ramp protocol. Participants exercised until they were exhausted or showed signs of discomfort such as angina, dyspnea, or dizziness. Parameters measured included peak power, serum lactate, partial pressure of carbon dioxide (pCO_2, capillary gas). In the intervention group power output differed significantly between surgical mask (SM) and NM -5.0 ± 7.0%, $P = 0.005$; FFP2 vs NM: -4.7 ± 14%, $P = 0.03$; control group: SM vs NM: -6.8 ± 4.4%, $P = 0.008$; FFP2 vs NM: -8.9 ± 6.3%; $P = 0.01$. Earlobe capillary pCO_2 levels increased significantly in CVD group wearing a N95 compared with NM: 36.0 ± 3.2 mm Hg vs 33.3 ± 4.4 mm Hg, $P = 0.019$; control group: N95: 32.6 ± 2.8 mm Hg vs NM: 28.1 ±1.7 mm Hg, $P < 0.001$. Serum lactate changes were not considered clinically critical and no significant changes in hemodynamic parameters (HR, BP). Authors conclude exercise testing while wearing a face mask is feasible for people with CVD.

Martin et al. (pre-print) (Austria) evaluated (design not reported) the impact of SMs on HR and SpO_2 in a sample of 10 healthy individuals, five <30 years of age and five >45 years of age by having them climb 96 steps. There was no significant difference in parameters measured and authors concluded that healthy adults wearing a SM while exercising did not experience a significant effect on oxygen supply or cardiac load.

Morris et al. (2021) (Denmark) conducted a counter-balance crossover study of effects of mask versus NM on thermal comfort, perceived dyspnea, HR, SpO_2, body temp, skin temp and cognitive function. The study sample n=8 male participants with a mean age of 35 carried out 45 minutes of light exercise in a climate chamber approximating work in healthcare settings. Cognitive assessments consisted of math calculations, body temp was rectal, skin temp was measured in two places on the face, dyspnea was measured with the Borg breathlessness scale and thermal comfort by a whole-body comfort scale. Perceived dyspnea worsened significantly with prolonged FM use $P = 0.04$, neither body temp nor facial temp were affected by masking. Cognitive performance, HR and SpO_2 were not affected by mask wearing.

Steinhilber et al. (2022) (Germany) conducted a randomized cross-over study in a sample n=39 of healthy adults, 20 men average age 38 and four were smokers. The study aim was to investigate whether face masks (SM, N95, cloth) would impair physical performance and affect physiological and subjective response during submaximal physical activity. Primary outcome was physical working capacity (watts/kg to measure mechanical load of the heart at a rate of 130 beats per minute) with and without mask. Additional outcomes SpO_2, BP, pCO_2, respiratory effort and perceived exertion (Modified Borg 0-10). Participants completed a cycle ergometry protocol to exhaustion. Masking had no statistically significant effect on physical performance, SpO_2, BP and pCO_2. RPE trended upward when masked ($P < 0.05$)

Vogt et al. (2022) (USA) in a randomized crossover study examined the effects of different types of masks (NM, SM, and N95) on physiological and perceptual responses during 30-min of self-paced cycle ergometer exercise. The sample (n=19) consisted of community dwelling adults ranging in age from 54-83 years, 9 males, 10 females, four with a history of CVD, six taking prescribed medications for hypertension, four with high cholesterol levels, two with sleep apnea, two with multiple sclerosis, one with type I diabetes, one with type II diabetes and two with vertigo. Outcomes included workload measured in watts (W), SpO_2, $etCO_2$, HR, RR, RPE, RPD. RPE, RPD, and $etCO_2$ were significantly higher with a N95-mask vs. NM ($P = 0.012$), ($P = 0.002$), ($P < 0.001$) respectively. HR was significantly higher with the SM compared to NM ($P = 0.027$) (NM 107.18 ± 9.96) (SM 112.34 ± 10.28), but no significant difference was found when comparing the SM to the N95 condition or when comparing the N95 condition to the NM. Watts increased across time in each mask type ($P = 0.003$). In summary no significant differences were found in workload, RR or SpO_2 regardless of mask type. The N95 mask was associated with increased breathing resistance suggesting trapping of expired air as suggested by Bar-On et al. (2021) above. Wearing a N95 mask may be less comfortable for older adults.

Thermal comfort and masking

Key observations

- Body temperature and thermal comfort are not significantly altered by masking.
- Masking does contribute to increased RPE and overall body discomfort.

In this LES of the unintended consequences of masking three studies (Morris et al., 2021; Yoshihara et al., 2021; Zhou & Dong, 2023) meeting the review criteria addressed thermal comfort; however, only one of the three had this as the unique focus (Zhou & Dong, 2023). ROB for these studies was moderate.

In a longitudinal (9 months) experimental study conducted in China the neutral temperature, outdoor thermal comfort, effects of masks, and outdoor conditions were studied across the seasons with participants while masked (SM), unmasked, sitting quietly and while walking on a treadmill (Zhou & Dong, 2023). The sample consisted of n=42 participants, 20 males, and 22 females who used an outdoor rooftop garden on a regular basis and were in good health. Neutral temperature refers to (point at which the human body can achieve an equilibrium core temperature without shivering or sweating) in terms of skin temperature the neutral zone is in the range of 33 to 35 C, thermal comfort masked and unmasked, and general body discomfort. Results demonstrated significantly lower neutral temperatures in summer meaning the body worked harder to establish core temp equilibrium; discomfort with masks was worse walking than sitting, and facial and chest discomfort increased with mask wearing. Mask wearing was better tolerated at lower outdoor climate temperatures.

Yoshihara et al. (2021) (USA) conducted a RCT focused on thermoregulation to determine if a FM influenced rectal temperature, HR and RPE while walking/jogging for 60 minutes in the heat. The study sample n=12, consisted of 8 males and 4 females, mean age 24 and physically active. Participants had a choice of face mask (SM, N95, gaiter, sport) and performed an exercise protocol for treadmill. Results included no significant difference between FM type, and no significant changes in Temp and HR masked or unmasked. RPE, overall breathing discomfort was significantly higher in masked compared with unmasked.

A description of the Morris et al. (2021) study is provided in the previous section.

In these three studies regarding thermal comfort and regulation physiological variables of temperature, HR and SpO_2 were not significantly altered while masked compared to NM. Across the dataset for this review the significance of breathing discomfort while masked is recurrent and evident in relation to thermal comfort as well.

Physiological measures of eye surface and masking (no exercise involved)

Key Observations

- Masking may contribute to dry eye conditions.

Two studies focused on the effects of masking on the surface of the eye and although physiologic measures were examined the measures were not related to the cardio-respiratory systems (see **Table 4**). One study with low ROB and the other moderate.

Marta et al. (2022) low ROB (Portugal) examined the surface of the eye to further understanding of exacerbated dry eye symptoms during the COVID-19 pandemic. Using a retrospective comparative design with a sample of n=274 patients, 548 eyes, mean age 66.15, and range of 18-89, three groups were formed. Group 1 retrospective data pre-pandemic, Group 2 early pandemic before mask mandates, Group 3 mask mandates in place. Parameters measured included Lipid Layer Thickness (LLT), blink rate, tear meniscus height, osmolarity and impact on meibomian (lipid source), and non-invasive tear break-up time (NITBUT). LLT was better in Groups 2 ($P = 0.001$) and 3 ($P < 0.001$); Blink rate and tear meniscus height were similar in group 2 and worse in group 3 ($P < 0.001$ and $P = 0.038$, respectively); Tear osmolarity and loss area of the meibomian glands were worse in group 2 ($P = 0.031$ and $P < 0.001$, respectively) and in group 3 (both with $P < 0.001$). Non-invasive tear break-up time (NITBUT tests tear film for dry eyes) was worse in group 2 ($P = 0.030$) and similar in group 3 ($P = 0.263$). Authors suggest the increase in LLT was to compensate for surface evaporation from increased air flow over the eye from masks, and this plus increased screen time from (e-devices) contributed to decreased tear osmolarity.

Alanazi et al. (2022) (Saudi Arabia) assessed the impact of wearing a mask for one hour on the quantity and quality of tears in participants with normal eye function. In a sample n=104 of participants free of eye surface disease, an intervention group n=54, mean age 23.8, 14 females and 40 males wore a SM for one hour and had non-invasive tear break-up time (NITBUT), phenol red thread (PRT), osmolarity, tear meniscus height, tear fern (TF, a test of the eye film), and tear evaporation rate (TER) tests before and after. The control group had the same tests one hour apart. Participants also completed questionnaires to rate dry eye presence. Comparisons of participant self-reports of dry eyes with NITBUT results demonstrated strong correlations ($r = 0.590$; $P < 0.001$), NITBUT measurements ($r = 0.631$; $P < 0.001$), and the tear ferning (drying a small sample of tear fluid onto a microscope slide) grades ($r = 0.517$; $P < 0.001$) before and after wearing the mask. Authors conclude wearing SMs for short periods of time alters tear film contributing to dry eye symptoms.

Summary of findings about primary outcome 2: Unintended psychological and/or developmental consequences of masking

Twelve studies were included that report on the unintended psychological and/or developmental consequences of masking. The characteristics, findings, and assessment of risk of bias for each study are presented in **Table 5**.

Communication and masking

Key observations

- Masks significantly impair facial emotion recognition, possibly leading to difficulty with expressing and or recognizing emotional states during brief interactions.
- Misperceptions of expressions of emotions such as surprise, fear, anger, disgust and happiness while masked are common.
- Masks attenuate the accuracy of voice recognition in noisy environments.
- SMs may have a slight edge compared to N95 and cloth in contributing to accuracy of voice recognition.

In response to this question the data from included studies addressed emotion (4) (Grenville & Dwyer, 2022; Gulbetekin et al., pre-print 2022; Langbehn et al., pre-print 2020; Rinck et al., 2022; Shepherd & Rippon, 2023 low ROB) as well as speech/acoustic recognition (4) (Lin et al., in press; Joshi et al., in press; Toscano & Toscano, 2021; Polo and Lã, pre-print 2021 low ROB) across nine studies. These studies are summarized in **Table 2** and described below. One of the emotion studies had low ROB, and one of the speech/acoustic recognition studies, a pre-print, had low ROB. The remainder were moderate.

Table 2: **Psychological and/or developmental results, emotion and speech/acoustic recognition and masking**

Citation	Country	n	Mask type	Results
Recognition type: emotion				
Rinck et al. (2022)	the Netherlands	91	superimposed image of N95	Sig↓: emotion recognition for disgust, fear, sadness, surprise, & happiness for masked faces vs unmasked NS: emotion recognition for anger and neutrality Sig↑: emotion confusion in mask faced vs NM (disgust for anger, surprise for fear)
Shepherd & Rippon (2023)	UK	199	superimposed image of SM	Sig↓: emotion recognition accuracy of happiness, sadness, fear, surprise and disgust when viewing masked faced vs unmasked NS: emotion recognition accuracy of anger Sig↑: emotion recognition accuracy of happiness vs surprise, surprise vs sadness, and disgust vs fear NS: emotion recognition accuracy between anger and disgust
Langbehn et al. (pre-	USA	222	SM, N95, & cloth	Target emotion was less perceived in masked versus NM faces Happy and disgust expressions less accurate than anger and surprise

Citation	Country	n	Mask type	Results
print) (2020)				
Grenville & Dwyer (2022)	UK	100	SM or superimposed image of SM	Sig ↓: emotion recognition for masked faces vs unmasked Accuracy with masked faces highest for happiness & sadness Accuracy with unmasked faces lower for anger & fear
Lin et al. (in press)	China	53	SM	Sig↑: Sound Pressure Level (SPL) while masked vs unmasked
Gulbetekin et al.(pre-print). (2022)	Turkey	#1 102 #2/3 134	Superimpose image of SM	Experiment 1: Sig ↓ in recognition accuracy for masked faces. Accuracy for Caucasian faces was higher than for Asian faces. Experiment 2: Sig ↓ in recognition accuracy for emotion in masked faces. Target emotions was also recognized better on Caucasian faces than they were on Asian faces. Best recognized to the least recognized: 1. happy; 2. disgust; 2. fear Experiment 3: Participants preferred a greater social distance from unmasked faces in comparison to masked faces and preferred greater social distances to faces having an expression of disgust, fear, neutrality, and happiness respectively.
Recognition type: speech/acoustic				
Joshi et al. (in press)	USA	19	SM, cloth, N95, SM over a N95	NS: across parameters
Toscano & Toscano (2021)	USA	200	SM, N95, cloth	Sig↓: speech recognition in areas of high background noise for N95 and cloth NS: speech recognition in areas with low background noise with SM having the least effect
Polo & Lã (pre-print) (2021)	Spain	558	no specified – survey about past experiences of mask use	Sig↑: self-perceived voice handicap while masked for Portuguese and Spanish speakers

Sig↓ = Significant decrease; Sig↑ = Significant increase; NS = No significant difference
SM = surgical mask; NM = no mask

Rinck et al. (2022) (the Netherlands) conducted three non-randomized experimental studies to determine the impact of SMs on the recognition of different facial expressions, and which emotions are mistaken with one another. The emotions examined in each experiment were happiness, sadness, anger, surprise, fear, disgust and neutral displayed by male and female actors from the Radboud Faces Database. Study sample n=91, mean age 33.23 years, 23 males, 67 females, 1 non-binary. The sample was drawn from five countries, four European and one from the USA. Twenty-nine participants reported masking was not mandatory. Overall participants correctly identified the emotions of unmasked faces 87.9% compared to 69.2% of masked faces. The untoward effects of masks varied by emotion. The most significant reduction in emotion recognition was for that of disgust (57%) $P < 0.001$, fear 27% $P < 0.001$, sadness 22% $P < 0.001$, surprise 9% $P < 0.001$, happiness 7% $P < 0.001$. For expressions of anger and neutrality significance was not reached. Regarding mistaking one emotion for another, fear when mistaken was most often taken as surprise, 25% in unmasked and 57% in masked. Similarly anger and disgust were mistaken in the unmasked most often with disgust 7% and sadness 6%, while with masked results were 13% $P < 0.001$, and 5% respectively. Authors conclude masks significantly impair facial emotion recognition resulting in misunderstandings, confusion, and mistaken perceptions in communication.

Shepherd and Rippon (2023) (UK) conducted a RCT to examine the impact of FMs on facial emotion recognition in a sample n=199, of masked n=102, and unmasked n=97 participants, with a mean age of 37.44, and an age range of 18-73. The masked group had n=39 males, mean age 43.51, range 20-69, 63 females, mean age 32.10, range 19-68. The unmasked group had n=39 males, mean age 43.72, range 20-66, and n=58 females, mean age 34.93, age range 18-73. Participants briefly viewed facial expressions from the Radboud Faces Database masked (SM) and unmasked conveying anger, disgust, fear, happiness, sadness, and surprise. Results demonstrated that emotion recognition was significantly decreased when viewing masked faces, compared to unmasked ($M = 56.22$, $SD = 7.20$), $F(1,197) = 245.06$, $P < 0.001$, $\eta p\ 2 = .55$). There were also significant differences among types of emotion recognition accuracy. In terms of accuracy of recognition of emotion, the most success occurred with happiness, more so than surprise ($M = 10.08$, $SD = 1.94$, $P < .001$); recognition of surprise was more accurate than for sadness ($M = 8.36$, $SD = 2.73$, $P < .001$); and greater success accuracy in recognizing disgust in comparison with fear ($M = 4.73$, $SD = 3.32$, $P < 0.001$). There was no significant difference between recognition of anger and disgust. The impact of masks was significant in reducing recognition of happiness, sadness, fear, surprise, and disgust at the level of ($P < 0.001$). Recognition of anger did not reach significance. Authors suggest that wearing FMs may cause difficulty with expressing and or recognizing emotional states during brief interactions.

In a third study (Langbehn et al., pre-print) (USA) focused on emotion recognition, researchers carried out two studies with Amazon employees on (Mechanical Turk, on-demand micro-task platform) the first investigated perceptions of happiness, disgust, anger, and surprise in a sample n=162, mean age 35.25 and age range of 23-68, 60% male, 68.3% White, 28.3% African American, 3.3% Asian. Participants viewed 168 videos of 14 different actors (3 black females, 4 white females, 4 black males, 3 white males) starting with neutral expressions followed by happiness, disgust, anger, and surprise. The face was fully visible for half of the videos and masked (using either SM, N95, cloth, white rectangle, approximately 40 per mask type) for the remaining. Overall, the target emotion was less perceived in masked versus NM faces, no matter the mask, in others words the degree of happy, disgust, angry and surprised were less evident to participants. Perceiving happy and disgust expressions was less accurate than anger and surprise which are reported to be more expressed in the upper part of the face. In study two, participants viewed videos of reward, affiliation and dominance smiles masked (N95) and unmasked and rated them as to the extent each conveyed positive feelings, reassurance, and superiority. Results demonstrated reward smiles signaled significantly more positive feelings ($M = 72.5$, $SE = 1.99$) than reassurance and superiority ($M = 59.1$, $SE = 247\ 2.43$), $t(59) = 5.25$, $P < 0.001$, $d = .68$). Dominance smiles signaled more superiority ($M = 64.2$, $SE = 2.33$) than positive feelings and reassurance ($M = 58.2$, $SE = 2.28$), $t(59) = 3.43$, $P = .001$, $d = .44$). Affiliation smiles were not significantly more reassuring than positive feelings and superiority. Results were deemed to be unaffected by political attitudes or gender.

Grenville and Dwyer (2022) (UK) conducted a RCT in a sample n=100 (91 female, 9 male) psychology undergraduate students, mean age 34. 8, white, 15 Asian, 1 black, and 4 mixed; all participants reported normal or corrected-to-normal vision. The aim of the study was to determine the accuracy of facial emotional recognition masked and unmasked. Participants viewed images online of masked (SM) and unmasked faces expressing outcomes of anger, disgust, fear, happiness, sadness, and neutrality. Subsequently they were required to identify the emotion expressed by each face. Overall accuracy was higher without a mask than with. Accuracy was highest for recognizing happiness and sadness of masked faces. Without masks accuracy was lower for anger and fear.

In addition to studies of emotion recognition this review also included four studies about masking and voice alteration. Lin et al. (in press) (China) measured Sound Pressure Level (SPL) Parameters (10) in a sample n=53 of healthy participants (25 males, 28 females) mean age 42.62, range 20-85. Participants presented to a clinical exam room where baseline parameters were gathered by a Laryngologist, subsequently participants donned SMs and measures were repeated. Researchers found SPL, particularly loudness increased significantly while masked $P = 0.021$ and was not impacted by sex and age. This means the various dimensions of the voice such as frequency, intensity, perturbation (vocal fold vibration) and aerodynamics increased.

Gulbetekin et al. (2022) (pre-print) (Turkey) studied mask use influence on a) face recognition; b) facial expression recognition; c) interaction with facial expression and race of the other person to influence social distancing in three separate experiments. In experiment 1 the sample was n=102 (80 female, 20 male), with a mean age of 20.4±2.8. Participant accuracy in matching facial stimuli under four conditions was tested: a) both faces unmasked; b) both faces masked; c) sample's face unmasked and test face masked; d) sample's face masked and test face unmasked. Accuracy for Caucasian faces (n = 102, M = 0.96±0.08) was higher than for Asian faces (n = 102, M = 0.92±0.09). The mask condition had a significant effect on accuracy F(2.6, 263.08) = 60.79, P = 0.001 ηp2 = 0.38. Participants demonstrated the highest performance when they were shown an unmasked sample and tested with unmasked faces. In comparison, they produced the worst performance when shown an unmasked sample and tested with masked faces. In experiments 2 and 3 the sample was n=134 (105 female, 29 male), with a mean age of 21±1.6. In experiment 2, researchers tested the accuracy in correctly matching an emotion to a presented facial expression. The results indicated a significant main effect of mask F(1,133) = 761.96, P = 0.001, ηp2 = 0.85, race F(1,133) = 397.39, P = 0.001 ηp2 = 0.75 and emotion F(1,363.12) = 201.09, P = 0.001 ηp2 = 0.60. Expressions were better recognized on unmasked faces (n = 134, M =0.75±0.08) than masked faces (n = 134, M =0.55±0.09). They were also recognized better on Caucasian faces (n = 134, M =0.71±0.09) than they were on Asian faces (n = 134, M =0.58±0.08). The expressions from the best recognized to the least recognized were happy (n = 134, M =0.84±0.16), neutral (n = 134, M =0.73±0.15), disgust (n = 134, M =0.56±0.10) and fear (n = 134, M =0.45±0.15) respectively. In experiment 3 the researchers looked at preference for amount (meters) of social distance participant would want from presented face/mask/emotion conditions. The results indicated a significant main effect of mask wearing F(1,133) = 67.551, P = 0.001, ηp2 = 0.34 and emotion F(1.48,196.175) = 111.83, P = .001, ηp2 = 0.46. The participants tended to indicate a preference for a wider social distance from unmasked faces (n = 134, M =4.47±1.72) in comparison to masked faces (n = 134, M =3.62±1.49) and preferred greater social distances to faces having an expression of disgust (n = 134, M =4.66±1.59), fear (n = 134, M =4.52±1.56), neutrality (n = 134, M =3.63±1.67) and happiness (n = 134, M =3.37±1.66) respectively.

Joshi et al. (in press) (USA) focused on mask type in relation to six mask conditions (NM, cloth, SM, KN95, SM over KN95, with and without a face shield) and alterations to SPL parameters. In a sample n=19 of 10 females and 9 males the mean age and range were 30.5 years and 18-56 years respectively. Participants voices were assessed and recorded at baseline and considered to have normal voice quality. This was followed by recordings wearing the various masks and at 1-foot and 6-foot distances. Study results found no significant impact of mask type on SPL level parameters of voice intensity, fundamental frequency, Cestral Peak Prominence (CPP) or formant frequency. There was statistical significance between males and females for intensity measures with males having higher intensity levels.

Similarly, Toscano and Toscano (2021) (USA) investigated the effects of four types of masks (SM, N95, cloth x 2) on speech/voice recognition in low and high levels of background noise. The study sample n= 200 with 73 females and a mean age of 37 working for Amazon's Mechanical Turk. Recordings were prepared for participants to assess in conditions of low and high noise levels with each of the talkers wearing four different masks. Participants listened to the recordings via headphones and typed what they heard. Masks had little to no effect (5.5% decrease) with low background noise, the SMs having the least effect, however, in areas of high background noise and with N95 and cloth accuracy of speech recognition dropped ranging from 2.8-18.2%.

Polo and Lã (pre-print) (2021) (Spain) investigated self-perceptions of voice-related handicap when masked with Portuguese and Spanish speakers. In a sample of n=558, 297 were Portuguese speakers and 261 Spanish speakers mean age 42.39 with no diagnosed hearing impairment. Male Portuguese participants numbered 97, Spanish 79, 20% from each language group were smokers, most reported wearing SMs followed by N95. All completed the 10 item Voice Handicap Index (VHI). Results demonstrated both Portuguese and Spanish speakers reported a higher self-perceived voice handicap.

Cognition and masking

Key observations

- Masking did not impact cognitive performance in healthy young adults (18-30) and school children grades 5-7.
- Mild but significant changes in HR and SpO_2 did not attenuate cognitive performance in university students.
- Rating of perceived dyspnea with mask wearing is a possibility.

Four studies examined the effects of masking on cognition, one using a warm-up exercise (Slimani et al., 2021), and three had participants perform cognition related activities (Schlegtendal et al., 2022; Spang and Pieper, 2021 low ROB; Tornero-Aguilera & Clemente-Suarez, 2021 low ROB). Two of the four studies had low ROB and two moderate ROB. One study examined cognitive function via visual attention during maximum aerobic exercise (Slimani et al. 2022).

Slimani et al. (2022) conducted a randomized crossover study to examine the effect of a facemask on cognitive function (visual attention) and RPE during a maximal aerobic fitness test. In a sample of 14 healthy physical education students, participants completed three 20-minute fitness tests, one for orientation, one masked and one unmasked. Results demonstrated that wearing a facemask significantly lowered cognitive performance as participants made more errors in visual attention while masked $P < 0.001$ and changes in RPE did not reach significance.

Slimani et al. (2021) (Tunisia) conducted a RCT to verify the effect of a warm-up protocol on cognitive function with and without FM. In a sample of n=17 healthy physical education students, 9 males, 8 females, mean age 17.6 years, participants were randomized to perform a 15-minute warm-up (run, arm circles, jumping jacks, high knee jogs, back kicking). Following the warmup, participants were given a document to scan and to cross out all letter “d”s. Results of the cognitive exercise demonstrated the warm-up activity improved cognitive performance for both masked and unmasked participants. Therefore, wearing a cloth FM had a positive effect on cognitive function.

Spang and Pieper (2021) (Germany) conducted an RCT to assess cognitive efficacy in relation to masking. In a sample n=45, there were 24 female participants, and the mean age of the sample was 30.3. Most participants were university students and the intervention involved solving mathematical equations while masked and unmasked. Measures included HR, SpO_2, task performance and perceived mental load. None of the parameters showed a significant difference between wearing and not wearing a mask.

Schlegtendal et al. (2022) (Germany) in a RCT studied cognitive performance in school children in grades 5, 6 and 7 with a sample n=133, and 72 were girls. Student participants both intervention (without mask) and control (FM) attended class for two hours in the morning followed by a 15 - minute break, then returned to class where the intervention group removed their masks, controls remained masked, and all students performed a computerized set of cognitive tests. There were no significant differences between groups of masked and unmasked in cognitive performance.

Lastly Tornero-Aguilera and Clemente-Suarez (2021) (Spain) hypothesized that the wearing of a SM in a group of university students would increase the autonomic sympathetic modulation thus decreasing cognitive performance and SpO_2. The sample n=50 had a mean age of 21.2 and 38 males. Student cognitive performance was assessed in a face-to-face class wearing a mask and in a virtual class unmasked. Both lectures were held at 0830 and lasted 150 minutes. Parameters measured before and after lectures included

HR, Heart Rate Variability (HRV), SpO_2, RR, mental fatigue. Results demonstrated significant increase in HR (77.7 ± 18.2 vs. 89.3 ± 11.2 bpm, $P < 0.001$ not mask, mask respectively) and SpO_2 significantly lower (98.4 ± 0.5 vs. 96.0 ± 1.8%, mask, not mask respectively) $P < 0.001$. Although statistical significance was reached, these results are not clinically significant. Despite these changes they did not significantly effect mental fatigue, reaction time, and RR.

Knowledge gaps and/or methodological gaps in the scientific literature related to masks for COVID-19

- Personal comfort and masking are somewhat at odds. Traditionally masking is associated with healthcare settings and equipment. Mask mandates and equipment for the public were informed by existing healthcare knowledge.
- Studies engaging the public from conception to completion about masking are needed through the lens of people in community settings to further understanding related to perceptions of dyspnea and breathlessness in the absence of physiological alterations.
- Across included studies only biological sex was reported, with one exception (non-binary).
- Optimizing communication while masked requires further study.
- Continued studies on mask fit and comfort are needed.

Breathing is essential to life as is water. Water supply is regulated, air is not nor is masking. Masks go on individual faces and coming up with the material for optimal protection and comfort will not be the obstacle but rather the challenge that one size fits none.

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References

Ade, C. J., Turpin, V.-R. G., Parr, S. K., Hammond, S. T., White, Z., Weber, R. E., Schulze, K. M., Colburn, T. D., & Poole, D. C. (2021). Does wearing a facemask decrease arterial blood oxygenation and impair exercise tolerance? *Respiratory Physiology & Neurobiology*, *294*, Article 103765. https://doi.org/10.1016/j.resp.2021.103765

Ahmadian, M., Ghasemi, M., Borujeni, N. N., Afshan, S., Fallah, M., Ayaseh, H., Pahlavan, M., Chashmi, S. M. N., Haeri, T., Imani, F., Zahedmanesh, F., Akbari, A., Nasiri, K., & Roshan, V. D. (2022). Does wearing a mask while exercising amid COVID-19 pandemic affect hemodynamic and hematologic function among healthy individuals? Implications of mask modality, sex, and exercise intensity. *The Physician and Sportsmedicine*, *50*(3), 257-268. https://doi.org/10.1080/00913847.2021.1922947

Alanazi, M. A., El-Hiti, G. A., Al-Tamimi, R., Bawazir, A. M., Almutleb, E. S., Fagehi, R., Alanazi, S. A., & Masmali, A. M. (2022). Assessment of the effect of wearing a surgical face mask on tear film in normal eye subjects. *Journal of Ophthalmology*, *2022*, Article 2484997. https://doi.org/10.1155/2022/2484997

Apolo-Arenas, M. D., Tomas-Carus, P., Galan-Lopez, P., Escribano, J. N., Carvalho, B., Caña-Pino, A., & Parraca, J. A. (2022). The influence of surgical mask on heart rate, muscle saturation of oxygen, and hemoglobin during whole-Body vibration exercise. *BioMed Research International*, *2022*, Article 3958554. https://doi.org/10.1155/2022/3958554

Barker, T.H., Stone, J.C., Sears, K., Klugar, M., Tufanaru, C., Leonardi-Bee, J., Aromataris, E., Munn, Z. (2023). The revised JBI critical appraisal tool for the assessment of risk of bias for randomized controlled trials. *JBI Evidence Synthesis, 21*(3):494-506

Bar-On, O., Gendler, Y., Stafler, P., Levine, H., Steuer, G., Shmueli, E., Prais, D., & Mei-Zahav, M. (2021). Effects of wearing facemasks during brisk walks: A COVID-19 dilemma. *Journal of the American Board of Family Medicine*, *34*(4), 798-801. https://doi.org/10.3122/jabfm.2021.04.200559

Cabanillas-Barea, S., Rodríguez-Sanz, J., Carrasco-Uribarren, A., López-De-celis, C., González-Rueda, V., Zegarra-Chávez, D., Cedeño-Bermúdez, S., & Pérez-Bellmunt, A. (2021). Effects of using the surgical mask and FFP2 during the 6-min walking test. A randomized controlled trial. *International Journal of Environmental Research and Public Health*, *18*(23), Article 12420. https://doi.org/10.3390/ijerph182312420

Dacha, S., Chuatrakoon, B., Sornkaew, K., Suttakhun, K., & Weeranorpanich, P. (2022). Effects of wearing different facial masks on respiratory symptoms, oxygen saturation, and functional capacity during six-minute walk test in healthy subjects. *Canadian Journal of Respiratory Therapy*, *58*, 85-90. https://doi.org/10.29390/cjrt-2022-014

Dantas, M., Barboza-Neto, R., Guardieiro, N. M., Pinto, A. L. D. S., Gualano, B., & Saunders, B. (2021). A cloth facemask increased ratings of perceived exertion and reduced affect, without affecting sprint or muscular performance. *Research in Sports Medicine*. https://doi.org/10.1080/15438627.2021.2010202

Doherty, C. J., Mann, L. M., Angus, S. A., Chan, J. S., Molgat-Seon, Y., & Dominelli, P. B. (2021). Impact of wearing a surgical and cloth mask during cycle exercise. *Applied Physiology, Nutrition and Metabolism*, *46*(7), 753-762. https://doi.org/10.1139/apnm-2021-0190

Driver, S., Reynolds, M., Brown, K., Vingren, J. L., Hill, D. W., Bennett, M., Gilliland, T., McShan, E., Callender, L., Reynolds, E., Borunda, N., Mosolf, J., Cates, C., & Jones, A. (2022). Effects of wearing a cloth face mask on performance, physiological and perceptual responses during a graded treadmill running exercise test. *British Journal of Sports Medicine*, *56*(2), 107-113. https://doi.org/10.1136/bjsports-2020-103758

Egger, F., Blumenauer, D., Fischer, P., Venhorst, A., Kulenthiran, S., Bewarder, Y., Zimmer, A., Böhm, M., Meyer, T., & Mahfoud, F. (2022). Effects of face masks on performance and cardiorespiratory response in well-trained athletes. *Clinical Research in Cardiology: Official Journal of the German Cardiac Society*, *111*, 264-271. https://doi.org/10.1007/s00392-021-01877-0

Epstein, D., Korytny, A., Isenberg, Y., Marcusohn, E., Zukermann, R., Bishop, B., Minha, S., Raz, A., & Miller, A. (2021). Return to training in the COVID-19 era: The physiological effects of face masks during exercise. *Scandinavian Journal of Medicine and Science in Sports*, *31*(1), 70-75. https://doi.org/10.1111/sms.13832

Ferguson, O. N., Mitchell, R. A., Schaeffer, M. R., Ramsook, A. H., Dhillon, S. S., Dominelli, P. B., Molgat-Seon, Y., & Guenette, J. A. (2023). Effects of face masks on the multiple dimensions and neurophysiological mechanisms of exertional dyspnea. *Medicine and Science in Sports and Exercise*, *55*(3), 450-461. https://doi.org/10.1249/MSS.0000000000003074

Fischer, P., Blumenauer, D., Egger, F., Fikenzer, S., Zimmer, A., Kulenthiran, S., Laufs, U., Bewarder, Y., Böhm, M., & Mahfoud, F. (2022). Effects of medical face masks on physical performance in patients with coronary artery disease or hypertension. *The American Journal of Cardiology*, *173*, 1-7. https://doi.org/10.1016/j.amjcard.2022.02.056

Fukushi, I., Nakamura, M., & Kuwana, S. (2021). Effects of wearing facemasks on the sensation of exertional dyspnea and exercise capacity in healthy subjects. *PLoS One*, *16*(9), Article e0258104. https://doi.org/10.1371/journal.pone.0258104

Grenville, E., & Dwyer, D. M. (2022). Face masks have emotion-dependent dissociable effects on accuracy and confidence in identifying facial expressions of emotion. *Cognitive Research: Principles and Implications*, *7,* Article 15. https://doi.org/10.1186/s41235-022-00366-w

Guardieiro, N. M., Barreto, G., Marticorena, F. M., Nunes Oliveira, T., Oliveira, L. F. D., Pinto, A. L. D. S., Prado, D. M. L. d., Saunders, B., & Gualano, B. (2023). A cloth facemask causes no major respiratory or cardiovascular perturbations during moderate to heavy exercise. *Journal of Physical Activity & Health*, *20*(1), 35-44. https://doi.org/10.1123/jpah.2022-0145

Jesus, J. P., Gomes, M., Dias-Gonçalves, A., Correia, J. M., Pezarat-Correia, P., & Mendonca, G. V. (2022). Effects of surgical masks on the responses to constant work-rate cycling performed at different intensity domains. *Clinical Physiology and Functional Imaging*, *42*(1), 43-52. https://doi.org/10.1111/cpf.12734

Jones, N., Oke, J., Marsh, S., Nikbin, K., Bowley, J., Dijkstra, H. P., Hobbs, F. R., & Greenhalgh, T. (2023). Face masks while exercising trial (MERIT): A cross-over randomised controlled study. *BMJ Open: Public Health*, *13*(1), Article e063014. https://doi.org/10.1136/bmjopen-2022-063014

Joshi, A., Procter, T., & Kulesz, P. A. (in press). COVID-19: Acoustic measures of voice in individuals wearing different facemasks. *Journal of Voice*. https://doi.org/10.1016/j.jvoice.2021.06.015

Langbehn, A., Yermol, D., Zhao, F., Thorstenson, C., & Niedenthal, P. (pre-print). Wearing N95, surgical and cloth face masks compromises the communication of emotion. *Research Square*. https://doi.org/10.21203/rs.3.rs-133686/v1

Lässing, J., Falz, R., Pökel, C., Fikenzer, S., Laufs, U., Schulze, A., Hölldobler, N., Rüdrich, P., & Busse, M. (2020). Effects of surgical face masks on cardiopulmonary parameters during steady state exercise. *Scientific Reports*, *10*, Article 22363. https://doi.org/10.1038/s41598-020-78643-1

Lin, Y., Cheng, L., Wang, Q., & Xu, W. (in press). Effects of medical masks on voice assessment during the COVID-19 pandemic. *Journal of Voice*. https://doi.org/10.1016/j.jvoice.2021.04.028

Marta, A., Marques, J. H., Almeida, D., José, D., Sousa, P., & Barbosa, I. (2022). Impact of COVID-19 pandemic on the ocular surface. *World Journal of Clinical Cases*, *10*(27), 9619-9627. https://doi.org/10.12998/wjcc.v10.i27.9619

Martin, E., Stefan, O., & Reinhold, K. (pre-print). Effects of wearing face masks under moderate physical effort. *medRixv*. https://doi.org/10.1101/2021.03.18.21253539

Moola, S., Munn, Z., Tufanaru, C., Aromataris, E., Sears, K., Sfetcu, R., Currie, M., Qureshi, R., Mattis, P., Lisy, K., Mu, P-F. (2020). Chapter 7: Systematic reviews of etiology and risk. In E. Aromataris & Z. Munn (Eds.), *JBI Manual for Evidence Synthesis.* https://synthesismanual.jbi.global

Morris, N. B., Piil, J. F., Christiansen, L., Flouris, A. D., & Nybo, L. (2021). Prolonged facemask use in the heat worsens dyspnea without compromising motor-cognitive performance. *Temperature: Medical Physiology and Beyond*, *8*(2), 160-165. https://doi.org/10.1080/23328940.2020.1826840

Ng, H. L., Trefz, J., Schönfelder, M., & Wackerhage, H. (2022). Effects of a taped filter mask on peak power, perceived breathlessness, heart rate, blood lactate and oxygen saturation during a graded exercise test in young healthy adults: A randomized controlled trial. *BMC Sports Science, Medicine and Rehabilitation*, *14*, Article 19. https://doi.org/10.1186/s13102-022-00410-8

Pasqualetto, M. C., Tuttolomondo, D., Gaibazzi, N., Baratella, M. C., Casolino, P., Stefani, M., Reato, S., Tattan, E., Sorbo, M. D., Bigon, L., Giada, F., Nizzetto, M., Ferrara, C., Galiotto, A., Scevola, M., & Rigo, F. (2022). Safety of surgical masks during physical activity evaluated with graded cycle ergometry test. *The Journal of Sports Medicine and Physical Fitness*, *62*(6), 846-850. https://doi.org/10.23736/S0022-4707.21.12814-2

Polo, N., & Lã, F. M. B. (pre-print). Self-perceived voice handicap during COVID19 compulsory facemask use: A comparative study between Portuguese and Spanish speakers. *Journal of Voice.* https://doi.org/10.1016/j.jvoice.2021.08.003

Poon, E. T., Zheng, C., & Wong, S. H. (2021). Effect of wearing surgical face masks during exercise: Does intensity matter? *Frontiers in Physiology*, *12,* Article 775750. https://doi.org/10.3389/fphys.2021.775750

Rinck, M., Primbs, M. A., Verpaalen, I. A. M., & Bijlstra, G. (2022). Face masks impair facial emotion recognition and induce specific emotion confusions. *Cognitive Research: Principles and Implications*, *7,* Article 83. https://doi.org/10.1186/s41235-022-00430-5

Schlegtendal, A., Eitner, L., Falkenstein, M., Hoffmann, A., Lücke, T., Sinningen, K., & Brinkmann, F. (2022). To mask or not to mask-evaluation of cognitive performance in children wearing face masks during school lessons (MasKids). *Children, 9*(1), Article 95. https://doi.org/10.3390/children9010095

Shaw, K., Butcher, S., Ko, J., Zello, G. A., & Chilibeck, P. D. (2020). Wearing of cloth or disposable surgical face masks has no effect on vigorous exercise performance in healthy individuals. *International Journal of Environmental Research and Public Health*, *17*(21), Article 8110. https://doi.org/10.3390/ijerph17218110

Shepherd, J. L., & Rippon, D. (2023). The impact of briefly observing faces in opaque facial masks on emotion recognition and empathic concern. *Quarterly Journal of Experimental Psychology*, *76*(2), 404-418. https://doi.org/10.1177/17470218221092590

Slimani, M., Miarka, B., Znazen, H., Moalla, W., Hammami, A., Paravlic, A., & Bragazzi, N. L. (2021). Effect of a warm-up protocol with and without facemask-use against COVID-19 on cognitive function: A pilot, randomized counterbalanced, cross-sectional study. *International Journal of Environmental Research and Public Health*, *18*(11), Article 5885. https://doi.org/10.3390/ijerph18115885

Slimani, M., Paravlic, A., Abazovic, E., Znazen, H., & Bragazzi, N. L. (2022). Effect of facemask use on cognitive function during a maximal running aerobic fitness test. *Frontiers in Physiology*, *13*, Article 912740. https://doi.org/10.3389/fphys.2022.912740

Spang, R. P., & Pieper, K. (2021). The tiny effects of respiratory masks on physiological, subjective, and behavioral measures under mental load in a randomized controlled trial. *Scientific Reports*, *11*, Article 19601. https://doi.org/10.1038/s41598-021-99100-7

Steinhilber, B., Seibt, R., Gabriel, J., Brountsou, J., Muljono, M., Downar, T., Bär, M., Bonsch, R., Brandt, A., Martus, P., & Rieger, M. A. (2022). Effects of face masks on physical performance and physiological response during a submaximal bicycle ergometer test. *International Journal of Environmental Research and Public Health*, *19*(3), Article 1063. https://doi.org/10.3390/ijerph19031063

Tornero-Aguilera, J. F., & Clemente-Suárez, V. J. (2021). Cognitive and psychophysiological impact of surgical mask use during university lessons. *Physiology & Behavior*, *234*, Article 113342. https://doi.org/10.1016/j.physbeh.2021.113342

Toscano, J. C., & Toscano, C. M. (2021). Effects of face masks on speech recognition in multi-talker babble noise. *PLoS One*, *16*(2), Article e0246842. https://doi.org/10.1371/journal.pone.0246842

Tufanaru, C., Munn, Z., Aromataris, E., Campbell, J., Hopp, L. (2020.). Chapter 3: Systematic reviews of effectiveness. In E. Aromataris & Z. Munn (Eds.), *JBI Manual for Evidence Synthesis.* https://synthesismanual.jbi.global

Vogt, G., Radtke, K., Jagim, A., Peckumn, D., Lee, T., Mikat, R., & Foster, C. (2022). Effect of face masks on physiological and perceptual responses during 30 minutes of self-paced exercise in older community dwelling adults. *International Journal of Environmental Research and Public Health*, *19*(19), Article 12877. https://doi.org/10.3390/ijerph191912877

Wong, A. Y., Ling, S. K., Louie, L. H., Law, G. Y., So, R. C., Lee, D. C., Yau, F. C., & Yung, P. S. (2020). Impact of the COVID-19 pandemic on sports and exercise. *Asia-Pacific Journal of Sports Medicine, Arthroscopy, Rehabilitation and Technology*, *22*, 39-44. https://doi.org/10.1016/j.asmart.2020.07.006

Yoshihara, A., Dierickx, E. E., Brewer, G. J., Sekiguchi, Y., Stearns, R. L., & Casa, D. J. (2021). Effects of face mask use on objective and subjective measures of thermoregulation during exercise in the heat. *Sports Health*, *13*(5), 463-470. https://doi.org/10.1177/19417381211028212

Zhang, G., Li, M., Zheng, M., Cai, X., Yang, J., Zhang, S., Yilifate, A., Zheng, Y., Lin, Q., Liang, J., Guo, L., & Ou, H. (2021). Effect of surgical masks on cardiopulmonary function in healthy young subjects: A crossover study. *Frontiers in Physiology*, *12*, Article 710573. https://doi.org/10.3389/fphys.2021.710573

Zhou, Z., & Dong, L. (2023). Experimental investigation of the effect of surgical masks on outdoor thermal comfort in Xiamen, China. *Building and Environment*, *229*, Article 109893. https://doi.org/10.1016/j.buildenv.2022.109893

Table 3: Summary of studies reporting on the physiological outcomes of masking in response to COVID-19

Reference	Date released	Setting	Study characteristics	Summary of key findings in relation to the outcome	JBI critical appraisal/ROB
Ade, C. J., Turpin, V.-R. G., Parr, S. K., Hammond, S. T., White, Z., Weber, R. E., Schulze, K. M., Colburn, T. D., & Poole, D. C. (2021). Does wearing a facemask decrease arterial blood oxygenation and impair exercise tolerance? *Respiratory Physiology & Neurobiology*, *294*, Article 103765. https://doi.org/10.1016/j.resp.2021.103765	3 August 2021	USA	**Design**: Randomized controlled trial **Intervention**: SM, flannel mask, and N95 worn during four incremental exercise tests to exhaustion **Sample**: 11 healthy recreationally active participants, 5 men and 6 women, mean age 30 ± 11 **Key outcomes**: SpO_2, HR, mean arterial pressure (MAP), stroke volume, cardiac output, RPE and dyspnea, peri-oral end-expired CO_2 and O_2	• Sig↑ for ratings of dyspnea during submaximal work rates of the ramp test for all mask types (P = 0.007) • NS for all other parameters	Moderate
Ahmadian, M., Ghasemi, M., Borujeni, N. N., Afshan, S., Fallah, M., Ayaseh, H., Pahlavan, M., Chashmi, S. M. N., Haeri, T., Imani, F., Zahedmanesh, F., Akbari, A., Nasiri, K., & Roshan, V. D. (2022). Does wearing a mask while exercising amid COVID-19 pandemic affect hemodynamic and hematologic function among healthy individuals? Implications of mask modality, sex, and exercise intensity. *The Physician and Sportsmedicine*, *50*(3), 257-268. https://doi.org/10.1080/00913847.2021.1922947	10 May 2021	Iran	**Design**: Randomized controlled trial **Intervention**: SM and N95 worn during submaximal and maximal exercise **Sample**: 144 healthy participants, 72 women and 72 men, mean age 29.73 **Key outcomes**: HR, BP, SpO_2, Rate Pressure Product (RPP = HR x systolic BP), hematologic (serum) parameters	• NS for all parameters	Moderate

LES 14.1b: Unintended consequences of masking in response to COVID-19

Reference	Date released	Setting	Study characteristics	Summary of key findings in relation to the outcome	JBI critical appraisal/ROB
Apolo-Arenas, M. D., Tomas-Carus, P., Galan-Lopez, P., Escribano, J. N., Carvalho, B., Caña-Pino, A., & Parraca, J. A. (2022). The influence of surgical mask on heart rate, muscle saturation of oxygen, and hemoglobin during whole-Body vibration exercise. *BioMed Research International*, *2022*, Article 3958554. https://doi.org/10.1155/2022/3958554	22 November 2022	Portugal	**Design**: Randomized controlled trial **Intervention**: SM worn during whole-body vibration exercise **Sample**: 47 university students, 16 women, 31 men, mean age 19.9 ± 2.0 years **Key outcomes**: HR, muscle oxygen saturation ($SatO_2$), oxyhemoglobin, deoxyhemoglobin	• NS for all parameters	Moderate
Bar-On, O., Gendler, Y., Stafler, P., Levine, H., Steuer, G., Shmueli, E., Prais, D., & Mei-Zahav, M. (2021). Effects of wearing facemasks during brisk walks: A COVID-19 dilemma. *Journal of the American Board of Family Medicine*, *34*(4), 798-801. https://doi.org/10.3122/jabfm.2021.04.200559	26 July 2021	Israel	**Design**: Non-randomized experimental study with comparator **Intervention**: SM worn (a) at rest, (b) during a slow walk, and (c) during a brisk walk. **Sample**: 21 participants without underlying cardiopulmonary morbidity, 11 female, 10 male, median age 38, range 29-57 years **Key outcomes**: SpO_2, CO_2, RPE, $etCO_2$, subjective perception questionnaire	• Small but sig↑ in etCO2 during the slow walk while wearing a SM vs NM (*P* = 0.004) • Small but sig↓ in O_2 range while walking with a SM vs (*P* = 0.08). • In the subjective perception questionnaire, participants described that walking briskly with SM vs NM caused difficulty breathing (86%), shortness of breath, (33%), choking feeling (57%), and dizziness (19%)	Moderate
Cabanillas-Barea, S., Rodríguez-Sanz, J., Carrasco-Uribarren, A., López-De-celis, C., González-Rueda, V., Zegarra-Chávez, D., Cedeño-Bermúdez, S., & Pérez-Bellmunt, A. (2021).	25 November 2021	Spain	**Design**: Randomized controlled trial	• Sig. ↑ perception of dyspnea with the N95 mask and the SM compared to NM	Moderate

Reference	Date released	Setting	Study characteristics	Summary of key findings in relation to the outcome	JBI critical appraisal/ROB
Effects of using the surgical mask and FFP2 during the 6-min walking test. A randomized controlled trial. *International Journal of Environmental Research and Public Health*, *18*(23), Article 12420. https://doi.org/10.3390/ijerph182312420			**Intervention**: SM, N95 mask, and NM worn during a 6-minute walking test. **Sample**: 50 healthy volunteers, 26 men, 24 women, mean age 20.96 (SD=3.6) **Key outcomes**: distance walked, oxygenometry, HR, sensation of dyspnea, tone of the inspiratory accessory muscles		
Dacha, S., Chuatrakoon, B., Sornkaew, K., Suttakhun, K., & Weeranorpanich, P. (2022). Effects of wearing different facial masks on respiratory symptoms, oxygen saturation, and functional capacity during six-minute walk test in healthy subjects. *Canadian Journal of Respiratory Therapy*, *58*, 85-90. https://doi.org/10.29390/cjrt-2022-014	22 June 2022	Thailand	**Design**: Randomized controlled trial **Intervention**: SM, N95, and cloth masks worn during a 6-minute walk test **Sample**: 29 healthy participants, 19 women, 3 men, mean age of 22 **Key outcomes**: respiratory symptoms (dyspnea and breathing effort), SpO_2, and functional capacity	• Sig. ↑ in breathing effort for wearing a cloth mask and a N95 mask compared to NM, between SM and N95 mask, and between a SM and cloth mask. • Sig. ↑ in dyspnea between wearing a cloth mask and NM	Moderate
Dantas, M., Barboza-Neto, R., Guardieiro, N. M., Pinto, A. L. D. S., Gualano, B., & Saunders, B. (2021). A cloth facemask increased ratings of perceived exertion and reduced affect, without affecting sprint or muscular performance. *Research*	29 November 2021	Brazil	**Design**: Randomized controlled trial **Intervention**: Wearing a cloth mask during sprint training – 5	• Wearing a mask may impact subjective feelings of training (e.g., RPE) without necessarily harming sprint performance	Moderate

Reference	Date released	Setting	Study characteristics	Summary of key findings in relation to the outcome	JBI critical appraisal/ROB
in Sports Medicine. https://doi.org/10.1080/15438627.2021.2010202			30 metre sprints on an outdoor track **Sample**: 10 competitive track and field athletes, mean age of 23 ± 4 years, 3 women, 7 men **Key outcomes**: exercise performance (sprint times, acceleration, jump height), subjective affect (e.g., RPE, pleasure, or discontent)		
Doherty, C. J., Mann, L. M., Angus, S. A., Chan, J. S., Molgat-Seon, Y., & Dominelli, P. B. (2021). Impact of wearing a surgical and cloth mask during cycle exercise. *Applied Physiology, Nutrition and Metabolism*, *46*(7), 753-762. https://doi.org/10.1139/apnm-2021-0190	7 May 2021	Canada	**Design**: Randomized controlled trial **Intervention**: SM and cloth mask worn while doing 3 5-8 minute submaximal cycle tests **Sample**: 12 healthy adults, 5 women, 7 men, age 26 (SD=3). **Key outcomes**: mask resistance/mouth pressure, HR, SpO_2, breathing frequency, relative respiration, dyspnea, face temperature	• Sig. ↑ in dyspnea with wearing a cloth mask vs. NM • Wearing a mask during short-term moderate-intensity exercise may increase dyspnea but has minimal impact on the cardiopulmonary response • Differences in respiratory gas pressures were inconsequential during exercise	Moderate

Reference	Date released	Setting	Study characteristics	Summary of key findings in relation to the outcome	JBI critical appraisal/ROB
Driver, S., Reynolds, M., Brown, K., Vingren, J. L., Hill, D. W., Bennett, M., Gilliland, T., McShan, E., Callender, L., Reynolds, E., Borunda, N., Mosolf, J., Cates, C., & Jones, A. (2022). Effects of wearing a cloth face mask on performance, physiological and perceptual responses during a graded treadmill running exercise test. *British Journal of Sports Medicine*, *56*(2), 107-113. https://doi.org/10.1136/bjsports-2020-103758	13 April 2021	USA	**Design**: Randomized controlled trial **Intervention**: cardiopulmonary exercise tests on a treadmill wearing a cloth mask versus NM, exhaustive incremental exercise (exercise to volitional fatigue) **Sample**: 31 participants, 14 women, 17 men, median age 23 (range=18-29) **Key outcomes**: BP, HR, SpO_2, RPE, perception of wearing facemasks	• Wearing a cloth mask led to a sig. reduction in exercise time, maximal oxygen consumption, minute ventilation, maximal HR, beats per minute, and increased dyspnea • 30/31 participants agreed or strongly agreed that that it was harder to give maximal effort while they were wearing a cloth mask	Moderate
Egger, F., Blumenauer, D., Fischer, P., Venhorst, A., Kulenthiran, S., Bewarder, Y., Zimmer, A., Böhm, M., Meyer, T., & Mahfoud, F. (2022). Effects of face masks on performance and cardiorespiratory response in well-trained athletes. *Clinical Research in Cardiology: Official Journal of the German Cardiac Society*, *111*, 264-271. https://doi.org/10.1007/s00392-021-01877-0	6 June 2021	Germany	**Design**: Randomized cross-over **Intervention**: Cycling 50 RPM till exhaustion while wearing SM or FFP2 **Sample**: n=16, healthy male athletes, mean age 27 **Key outcomes**: Max performance, HR, SpO_2, BP, VO_2, VCO_2, RPE	• Statistically significant decrease in maximum performance measured in watts with SM • Significance not attained with other parameters	Moderate
Epstein, D., Korytny, A., Isenberg, Y., Marcusohn, E., Zukermann, R., Bishop, B., Minha, S., Raz, A., & Miller, A. (2021). Return to	24 September 2020	Israel	**Design**: Multiple cross-over trial	• Significant increase in $etCO_2$ while wearing N95 ($P = 0.001$)	Moderate

Reference	Date released	Setting	Study characteristics	Summary of key findings in relation to the outcome	JBI critical appraisal/ROB
training in the COVID-19 era: The physiological effects of face masks during exercise. *Scandinavian Journal of Medicine and Science in Sports*, *31*(1), 70-75. https://doi.org/10.1111/sms.13832			**Intervention**: Cycle ergometry ramp protocol till exhaustion while wearing SM and N95 **Sample**: n=16 healthy adult males, mean age 34 **Key outcomes**: HR, SpO_2, $etCO_2$, BP, RR, RPE	• Significance not reached with other parameters	
Ferguson, O. N., Mitchell, R. A., Schaeffer, M. R., Ramsook, A. H., Dhillon, S. S., Dominelli, P. B., Molgat-Seon, Y., & Guenette, J. A. (2023). Effects of face masks on the multiple dimensions and neurophysiological mechanisms of exertional dyspnea. *Medicine and Science in Sports and Exercise*, *55*(3), 450-461. https://doi.org/10.1249/MSS.0000000000003074	March 2023	Canada	**Design**: Randomized cross-over **Intervention**: Incremental cycling tests over 3 visits while wearing SM **Sample**: n=16 healthy young adults, 9 women, mean age 25 **Key outcomes**: Spirometry (FVC, FEV_1) HR, RR (breaths per minute), dyspnea (Borg 0-10), work rate in watts (W)	• Mean exercise duration (min) significantly reduced while masked (16.4 ± 4.0 vs 15.9 ± 4.0 min, $P = 0.02$). No significant cardio-respiratory impact • Dyspnea unpleasantness significantly greater with FM at both sub-maximal exercise level and at peak (5.9 ± 1.7 vs 3.9 ± 2.9 Borg 0–10 units, $P = 0.007$) and at peak exercise (7.8 ± 2.1 vs 5.9 ± 3.4 Borg 0–10 units, $P = 0.01$)	Low
Fischer, P., Blumenauer, D., Egger, F., Fikenzer, S., Zimmer, A., Kulenthiran, S., Laufs, U., Bewarder, Y., Böhm, M., & Mahfoud, F. (2022). Effects of medical face masks on physical performance in patients with coronary artery disease or hypertension. *The American Journal of*	10 April 2022	Germany	**Design**: Randomized controlled trial **Intervention**: Cycle ergometer 30 seconds warm-up period without load, followed by 1	• Significant reduction in peak power output (W) across groups while masked compared to NM. SM vs NM: (5.0 ± 7.0%, *P*	Moderate

Reference	Date released	Setting	Study characteristics	Summary of key findings in relation to the outcome	JBI critical appraisal/ROB
Cardiology, *173*, 1-7. https://doi.org/10.1016/j.amjcard.2022.02.056			min of constant load at 25 W increased every minute for 25 W using a ramp protocol while wearing SM or N95 **Sample**: n=50, 40 individuals with CVD and 10 healthy controls, mean age intervention group 58, 13 women, control 26, 10 men **Key outcomes**: HR, BP, SpO_2, $etCO_2$, work output (W), pCO_2	= 0.005; FFP2 vs NM: 4.7 ± 14%, *P* = 0.03; control group: SM vs NM: 6.8 ± 4.4%, *P* = 0.008; FFP2 vs NM: 8.9 ± 6.3%; *P* = 0.01) • Wearing N95 compared to NM significantly higher pCO_2. CVD group: FFP2: 36.0 ± 3.2 mm Hg vs NM: 33.3 ± 4.4 mm Hg, *P* = 0.019; control group: FFP2: 32.6 ± 2.8 mm Hg vs NM: 28.1 ± 1.7 mm Hg, *P* <0.001)	
Fukushi, I., Nakamura, M., & Kuwana, S. (2021). Effects of wearing facemasks on the sensation of exertional dyspnea and exercise capacity in healthy subjects. *PLoS One*, *16*(9), Article e0258104. https://doi.org/10.1371/journal.pone.0258104	30 September 2021	Japan	**Design**: Randomized controlled trial **Intervention**: Treadmill, Bruce Protocol until participant HR exceeded 174 bpm while wearing SM or cloth mask **Sample**: n=24 healthy young adults mean age 21, 15 men **Key outcomes**: HR, SpO_2, RPE	• SpO_2 unaffected • Wearing cloth FM significantly worsens dyspnea more so than SM • RPE dyspnea: Control 5 (3.75–6) & SM 6 (5–7.25) (*P* < 0.05).	Low
Guardieiro, N. M., Barreto, G., Marticorena, F. M., Nunes Oliveira, T., Oliveira, L. F. D., Pinto, A. L. D. S., Prado, D. M. L. d., Saunders, B., & Gualano, B. (2023). A cloth facemask causes no major respiratory or cardiovascular perturbations	7 December 2022	Brazil	**Design**: Randomized controlled trial **Intervention**: Cloth mask worn while running on a	• NS for all parameters	Low

Reference	Date released	Setting	Study characteristics	Summary of key findings in relation to the outcome	JBI critical appraisal/ROB
during moderate to heavy exercise. *Journal of Physical Activity & Health*, *20*(1), 35-44. https://doi.org/10.1123/jpah.2022-0145			treadmill, starting at 4-5km/hour up to a max of 13-14km/hour, until exhaustion **Sample**: 35 heathy adults, 18 women average age 28, 17 men average age 30 **Key outcomes**: Spirometry, RPE, RF, HR, BP, SpO_2		
Jesus, J. P., Gomes, M., Dias-Gonçalves, A., Correia, J. M., Pezarat-Correia, P., & Mendonca, G. V. (2022). Effects of surgical masks on the responses to constant work-rate cycling performed at different intensity domains. *Clinical Physiology and Functional Imaging*, *42*(1), 43-52. https://doi.org/10.1111/cpf.12734	9 November 2021	Portugal	**Design**: Randomized controlled trial **Intervention**: SM work while using a cycle ergometer cycle for 3-min at 60 W, then the work rate was increased by 15 W min until the participant was unable to continue **Sample**: 32 healthy and active volunteers, 16 female, 16 male, mean age 24 (SD 3.3) **Key outcomes**: SpO2, HR, BP, VO_2, minute ventilation, time to exhaustion, respiratory exchange ratio	• Sig↓ in VO_2 and minute ventilation during moderate and severe exercise while wearing a SM ($P <$ 0.0001) • Sig↓ in time to exhaustion while wearing a SM ($P =$ 0.014) • NS in HR and respiratory exchange ratio	Moderate
Jones, N., Oke, J., Marsh, S., Nikbin, K., Bowley, J., Dijkstra, H. P., Hobbs, F. R., & Greenhalgh, T. (2023). Face masks while exercising trial (MERIT): A cross-over randomised controlled study. *BMJ Open: Public Health*, *13*(1), Article e063014. https://doi.org/10.1136/bmjopen-2022-063014	5 January 2023	UK	**Design**: Randomized controlled trial **Intervention**: Mask (surgical, FFP3, or cloth) worn during four 15-min bouts of moderate-to-high intensity (mostly running, 1 rowing)	• NS in SpO_2 or HR with any of the three masks • Wearing a face mask caused additional symptoms such as breathlessness (n=13, 18%) and dizziness (n=7, 10%)	Moderate

Reference	Date released	Setting	Study characteristics	Summary of key findings in relation to the outcome	JBI critical appraisal/ROB
			Sample: 72 healthy young adults who exercised regularly, 1 smoker, 33 women, 29 men, mean age 23.9 **Key outcomes**: ease of breathing score, SpO_2, HR, perceived impact of mask		
Lässing, J., Falz, R., Pökel, C., Fikenzer, S., Laufs, U., Schulze, A., Hölldobler, N., Rüdrich, P., & Busse, M. (2020). Effects of surgical face masks on cardiopulmonary parameters during steady state exercise. *Scientific Reports*, *10*, Article 22363. https://doi.org/10.1038/s41598-020-78643-1	21 December 2020	Germany	**Design:** Randomized controlled trial **Intervention:** SM worn during maximal lactate steady state **Sample:** 14 participants (all male), mean age 25.7 **Key outcomes:** HR, RR, airway resistance	• HR while wearing SM significantly increased 160.1±11.2, $P < 0.01$, compared to NM 154.5±11.4 • Respiratory rate significantly increased with NM 34.03±7.29, $P = 0.02$ compared to SM 32.09±5.4 • Surgical face masks increase airway resistance: NM 0.32 ± 0.08 vs SM 0.58 ± 0.16 $P = < 0.01$	Moderate
Martin, E., Stefan, O., & Reinhold, K. (pre-print). Effects of wearing face masks under moderate physical effort. *medRixv*. https://doi.org/10.1101/2021.03.18.21253539	20 March 2021 (pre-print only)	Austria	**Design**: Randomized controlled trial **Intervention**: SM worn while climbing up four floors (96 steps) **Sample**: 10 healthy volunteers, 6 female, 4 male, 5 < 30 years old, 5 > 30 years old **Key outcomes**: HR and SpO_2	• NS for all parameters	Moderate

Reference	Date released	Setting	Study characteristics	Summary of key findings in relation to the outcome	JBI critical appraisal/ROB
Morris, N. B., Piil, J. F., Christiansen, L., Flouris, A. D., & Nybo, L. (2021). Prolonged facemask use in the heat worsens dyspnea without compromising motor-cognitive performance. *Temperature: Medical Physiology and Beyond*, *8*(2), 160-165. https://doi.org/10.1080/23328940.2020.1826840	9 October 2020	Denmark	**Design**: Non-randomized experimental study with comparator **Intervention**: KN95 worn during light 45 min of light exercise simulating work in healthcare and related settings **Sample**: Eight participants, all male, mean age 35 **Key outcomes**: perceived dyspnea, thermal comfort, moto-cognitive performance, and rectal, skin, and facial temperature	• Sig↑ in perceived dyspnea for prolonged KN95 use ($P = 0.04$) • NS for all other parameters	Moderate
Ng, H. L., Trefz, J., Schönfelder, M., & Wackerhage, H. (2022). Effects of a taped filter mask on peak power, perceived breathlessness, heart rate, blood lactate and oxygen saturation during a graded exercise test in young healthy adults: A randomized controlled trial. *BMC Sports Science, Medicine and Rehabilitation*, *14*, Article 19. https://doi.org/10.1186/s13102-022-00410-8	7 February 2022	Germany	**Design:** Randomized controlled trial **Intervention:** Taped filter mask worn during graded exercise test compared to SM and NM **Sample:** 8 participants (4 male, 4 female), mean age 24.5 **Key outcomes:** Perception of breathlessness, HR, blood lactate concentration, SpO_2, maximal workload	• Taped face mask (247±56) significantly reduces maximal workload compared to no face mask (278±56) and SM (269±56), $P < 0.001$ • Taped face mask (25.6±6.2) significantly decreased time (min) to exhaustion compared to no face mask (29.2±6.6) and SM (27.5±6.3), $P < 0.001$	Moderate
Pasqualetto, M. C., Tuttolomondo, D., Gaibazzi, N., Baratella, M. C., Casolino, P., Stefani, M., Reato, S., Tattan, E., Sorbo, M. D., Bigon, L., Giada, F., Nizzetto, M., Ferrara, C., Galiotto, A., Scevola, M., & Rigo, F. (2022). Safety of surgical	June 2022	Italy	**Design**: Randomized cross-over	• Wearing of SM while exercising had no significant effects on parameters measured	Low

Reference	Date released	Setting	Study characteristics	Summary of key findings in relation to the outcome	JBI critical appraisal/ROB
masks during physical activity evaluated with graded cycle ergometry test. *The Journal of Sports Medicine and Physical Fitness*, *62*(6), 846-850. https://doi.org/10.23736/S0022-4707.21.12814-2			**Intervention**: incremental (30watts) cycle ergometry test to exhaustion with SM **Sample**: n=32 17 men, mean age 30 **Key outcomes**: exercise time, max power (W), BP, SpO_2, HR		
Poon, E. T., Zheng, C., & Wong, S. H. (2021). Effect of wearing surgical face masks during exercise: Does intensity matter? *Frontiers in Physiology*, *12,* Article 775750. https://doi.org/10.3389/fphys.2021.775750	26 November 2021	China	**Design**: Randomized controlled trial **Intervention**: SM worn during incremental treadmill protocol with three 6-min stages, for a total of 18 min, at 25% (light), 50% (moderate), and 75% (vigorous) **Sample**: n=14 healthy recreationally active young adults age 18-25 years, 6 females **Key outcomes**: HR, SpO_2, RPE, VO_2	• Significant increase in RPE during vigorous exercise wearing SM mask: 15.5 ± 1.5 vs. NM: 14.2 ± 2.1, $P < 0.05$ • Significance not reached across remaining parameters	Low
Shaw, K., Butcher, S., Ko, J., Zello, G. A., & Chilibeck, P. D. (2020). Wearing of cloth or disposable surgical face masks has no effect on vigorous exercise performance in healthy individuals. *International Journal of Environmental Research and Public Health*, *17*(21), Article 8110. https://doi.org/10.3390/ijerph17218110	3 November 2020	Canada	**Design:** Randomized controlled trial **Intervention:** Wearing a face mask during progressive cycle ergometer test	• No detrimental effect on exercise performance (HR, SpO2 or RPE) while wearing either a non-disposable cloth mask or disposable SM	Low

Reference	Date released	Setting	Study characteristics	Summary of key findings in relation to the outcome	JBI critical appraisal/ROB
			Sample: 14 (7 men, 7 women), mean age 26.1, all healthy young adults **Key outcomes:** HR, SpO2, RPE	while exercising vigorously	
Slimani, M., Miarka, B., Znazen, H., Moalla, W., Hammami, A., Paravlic, A., & Bragazzi, N. L. (2021). Effect of a warm-up protocol with and without facemask-use against COVID-19 on cognitive function: A pilot, randomized counterbalanced, cross-sectional study. *International Journal of Environmental Research and Public Health*, *18*(11), Article 5885. https://doi.org/10.3390/ijerph18115885	30 May 2021	Tunisia	**Design**: Randomized controlled trial **Intervention**: Warm-up exercises of 15 minutes with and without cloth facemasks **Sample**: 17 healthy physical education students, 8 females 9 males, mean age of 17.6 **Key outcomes**: attention assessment (concentration performance, errors), RPE	• Sig. ↑ rates of concentration performance and rate of perceived exertion for those wearing cloth masks. • Wearing a cloth facemask during warm-up may stimulate the cognitive function.	Moderate
Slimani, M., Paravlic, A., Abazovic, E., Znazen, H., & Bragazzi, N. L. (2022). Effect of facemask use on cognitive function during a maximal running aerobic fitness test. *Frontiers in Physiology*, *13*, Article 912740. https://doi.org/10.3389/fphys.2022.912740	29 September 2022	Tunisia	**Design**: Randomized controlled trial **Intervention**: Maximal running aerobic fitness test for 20 minutes using cloth masks and NM **Sample**: 14 physical education students, 9 males, 5 females, mean age of 17.5. **Key outcomes**: physical performance, attention	• Lower maximal aerobic speed (MAS), $V0_{2max}$, and distance covered • Significantly greater decreases in concentration performance and more errors	Moderate

Reference	Date released	Setting	Study characteristics	Summary of key findings in relation to the outcome	JBI critical appraisal/ROB
			assessment (concentration performance, errors), RPE		
Steinhilber, B., Seibt, R., Gabriel, J., Brountsou, J., Muljono, M., Downar, T., Bär, M., Bonsch, R., Brandt, A., Martus, P., & Rieger, M. A. (2022). Effects of Face masks on physical performance and physiological response during a submaximal bicycle ergometer test. *International Journal of Environmental Research and Public Health*, *19*(3), Article 1063. https://doi.org/10.3390/ijerph19031063	18 January 2022	Germany	**Design:** Randomized controlled trial **Intervention:** Wearing a face mask during sub-maximal physical activity **Sample:** 39 participants (20 men, 19 women), mean age 38.2±14.2 **Key outcomes:** physical working capacity, SpO_2, BP, pCO_2, respiratory effort and RPE	• Perceived respiratory effort one point higher (zero-to-ten Likert scale) while using face masks compared to control, $P < 0.05$ • Differences in physical performance, SpO_2, BP and pCO_2 did not reach significance	Moderate
Vogt, G., Radtke, K., Jagim, A., Peckumn, D., Lee, T., Mikat, R., & Foster, C. (2022). Effect of face masks on physiological and perceptual responses during 30 minutes of self-paced exercise in older community dwelling adults. *International Journal of Environmental Research and Public Health*, *19*(19), Article 12877. https://doi.org/10.3390/ijerph191912877	8 October 2022	USA	**Design**: Randomized controlled trial **Intervention**: 30 minutes of self-paced exercise on an exercise cycle ergometer, SM and 95 masks **Sample**: 19 community-dwelling participants, 9 males, 10 females, age 54-83 who could tolerate exercising for 30 minutes without adverse effects **Key outcomes**: pulmonary function; HR, SpO_2, $etCO_2$, RPE and dyspnea, subjective questions, power output	• HR was significantly higher with the surgical compared to the NM condition • N95 was significantly associated with increased RPE, rating of perceived dyspnea compared to NM. • $petCO_2$ was significantly higher in the N95 and SMs compared to NM • $petCO_2$ was significantly higher in the N95 compared to the SM	Moderate

Reference	Date released	Setting	Study characteristics	Summary of key findings in relation to the outcome	JBI critical appraisal/ROB
				• The results suggest CO_2 trapping inside the mask. Wearing an N95 mask may be less comfortable for older adults during prolonged exercise.	
Wong, A. Y., Ling, S. K., Louie, L. H., Law, G. Y., So, R. C., Lee, D. C., Yau, F. C., & Yung, P. S. (2020). Impact of the COVID-19 pandemic on sports and exercise. *Asia-Pacific Journal of Sports Medicine, Arthroscopy, Rehabilitation and Technology*, *22*, 39-44. https://doi.org/10.1016/j.asmart.2020.07.006	28 July 2020	China	**Design:** Randomized controlled trial **Intervention:** SM during walking on a treadmill at 4 km/hour for 6 minutes **Sample:** 23 healthy adults, 10 males (mean age 35), 13 females (mean age 32.7) **Key outcomes:** HR, RPE	• Sig. ↑ of HR and RPE while wearing a SM • Those wearing SMs reported subjectively higher physiological demands	Moderate
Yoshihara, A., Dierickx, E. E., Brewer, G. J., Sekiguchi, Y., Stearns, R. L., & Casa, D. J. (2021). Effects of face mask use on objective and subjective measures of thermoregulation during exercise in the heat. *Sports Health*, *13*(5), 463-470. https://doi.org/10.1177/19417381211028212	1 July 2021	USA	**Design:** Randomized controlled trial **Intervention:** 60 minutes of walking and jogging between 35% and 60% of relative VO_{2max}. Four face mask trials (SM; N95; cloth mask and gaiter) and 1 control trial (NM) in the heat (32.3°C ± 0.04°C; 54.4% ± 0.7% relative humidity)	• Sig. ↑ in RPE (breathing discomfort) for all mask types vs. NM • Gaiter and sport masks retained more water vapor and sweat after the exercise compared with surgical and N95 masks • Face mask use is feasible during	Moderate

Reference	Date released	Setting	Study characteristics	Summary of key findings in relation to the outcome	JBI critical appraisal/ROB
			Sample: 12 participants, 8 males, 4 females, mean age 24 **Key outcomes:** rectal temperature, HR, temperature and humidity inside and outside the face masks, RPE, thermal sensation, thirst sensation, fatigue level, overall breathing discomfort	exercise in the heat at low to moderate intensities.	
Zhang, G., Li, M., Zheng, M., Cai, X., Yang, J., Zhang, S., Yilifate, A., Zheng, Y., Lin, Q., Liang, J., Guo, L., & Ou, H. (2021). Effect of surgical masks on cardiopulmonary function in healthy young subjects: A crossover study. *Frontiers in Physiology*, *12*, Article 710573. https://doi.org/10.3389/fphys.2021.710573	10 September 2021	China	**Design**: Randomized controlled trial **Intervention**: SM influence on changes in cardiopulmonary function during cycle ergometer exercise test **Sample**: 71 participants (35 men, 36 women), mean age 27.7 **Key outcomes**: Changes in cardiopulmonary function and metabolic parameters (e.g., HR, RPE/Dyspnea, RR, VO2, SpO_2)	• Mean HR significantly increased with surgical face mask 26.2±14.2 compared to NM 22±12.9, $P = 0.006$ • Peak exercise VO2 with NM 1628.6±447.2, and with mask 1454.8±418.9, $P < 0.001$ • RR significantly different with SM 33.8±7.98 compared to NM 37.9±6.72, $P < 0.001$ • NS difference in SpO_2	Moderate
Zhou, Z., & Dong, L. (2023). Experimental investigation of the effect of surgical masks on outdoor thermal comfort in Xiamen, China. *Building and Environment*, *229*, Article 109893. https://doi.org/10.1016/j.buildenv.2022.109893	1 February 2023	China	**Design**: Non-randomized experimental study with comparator **Intervention**: SM worn while walking, performed on a treadmill at a speed of 1.2 m/s	• SMs significantly increased facial discomfort especially when walking (TSV Thermal sensation sig at $P < 0.05$) • Wearing a mask in a warm environment	Moderate

Reference	Date released	Setting	Study characteristics	Summary of key findings in relation to the outcome	JBI critical appraisal/ROB
			Sample: 42 healthy young adults, 22 female, 20 male, mean age males 25.5, females 24.5 **Key outcomes**: thermal comfort questionnaire (subjective perception survey)	decreases subjective thermal comfort	

Sig↓ = Significant decrease; Sig↑ = Significant increase; NS = No significant change
B*P* = blood pressure; CVD = cardiovascular disease; etCO2 = end-tidal carbon dioxide; HR = heart rate; pCO_2 = partial pressure of carbon dioxide; SpO_2 = oxygen saturation; VO_2 = maximal oxygen consumption; VCO2 = carbon dioxide production; RPE = rating of perceived exertion; RR = respiratory rate; RF = respiratory frequency; SM = surgical mask; NM = no mask

Table 4: Summary of studies reporting on physiological measures of eye surface and masking (no exercise involved)

Reference	Date released	Setting	Study characteristics	Summary of key findings in relation to the outcome	JBI critical appraisal/ROB
Alanazi, M. A., El-Hiti, G. A., Al-Tamimi, R., Bawazir, A. M., Almutleb, E. S., Fagehi, R., Alanazi, S. A., & Masmali, A. M. (2022). Assessment of the effect of wearing a surgical face mask on tear film in normal eye subjects. *Journal of Ophthalmology*, *2022*, Article 2484997. https://doi.org/10.1155/2022/2484997	16 August 2022	Saudi Arabia	**Design:** Non-randomized experimental study **Intervention:** Wearing a face mask versus not wearing a face mask **Sample:** 104 participants. 52 in intervention group (14 female, 40 male, mean age 23.8±4.4), 50 in control group (15 female, 35 male, mean age 22.9±4.1) **Key outcomes:** Severity of dry eye symptoms using the SPEED questionnaire. NITBUT was recorded as the number of seconds between blinks, appearance of dry spot in the tear film.	• Control group: no significant differences between variables • Significant differences were found between the SPEED scores ($P = 0.002$) and the NITBUT ($P < 0.001$), before and after wearing a face mask.	Moderate
Marta, A., Marques, J. H., Almeida, D., José, D., Sousa, P., & Barbosa, I. (2022). Impact of COVID-19 pandemic on the ocular surface. *World Journal of Clinical Cases*, *10*(27), 9619-9627. https://doi.org/10.12998/wjcc.v10.i27.9619	26 September 2022	Portugal	**Design:** Non-randomized experimental study (case-control) **Intervention:** Multimodal ocular surface evaluation between August 2019 and April 2021 **Sample:** 274 participants (43.4% male, 56.6% female, mean age 66.15±13.4). Group 1 (before lockdown Aug 2019 – Mar 2020), Group 2 (after lockdown without mask mandate Apr 2020 – Oct 2020), Group 3 (after lockdown with	• Mean lipid layer thickness significantly better in group 2 ($P = 0.001$) and 3 ($P < 0.001$) compared to group 1 • Schirmer test better in group 3 ($P = 0.002$) compared to group 1 • Tear osmolarity and loss of area to meibomian glands significantly worse in group 2 ($P = 0.031$ and $P < 0.001$, respectively) and in group 3 ($P < 0.001$) compared to group 1	Low

Reference	Date released	Setting	Study characteristics	Summary of key findings in relation to the outcome	JBI critical appraisal/ROB
			mask mandate Nov 2020 – Apr 2021) **Key outcomes:** Differences in tear film properties (lipid thickness, Schirmer test, tear osmolarity, blink rate, tear meniscus height, non-invasive break-up test)	• Blink rate and tear meniscus height significantly worse in group 3 compared to group 1 (*P* < 0.001 and *P* = 0.038, respectively) • Non-invasive break up test significantly worse in group 2 (*P* = 0.03) compared to group 1	

Table 5: Summary of studies reporting on the psychological and/or developmental outcomes of masking in response to COVID-19

Reference	Date released	Setting	Study characteristics	Summary of key findings in relation to the outcome	JBI critical appraisal/ROB
Grenville, E., & Dwyer, D. M. (2022). Face masks have emotion-dependent dissociable effects on accuracy and confidence in identifying facial expressions of emotion. *Cognitive Research: Principles and Implications*, *7,* Article 15. https://doi.org/10.1186/s41235-022-00366-w	15 July 2022	United Kingdom	**Design**: Randomized controlled trial **Intervention**: NM, a posed mask, or imposed mask **Sample**: 100 (91 female, 9 male) psychology undergraduate students, mean age 19.5±2.34. 80 white, 15 Asian, 1 black, and 4 mixed; all participants reported normal or corrected-to-normal vision. **Key outcomes**: Participants' accuracy and confidence in identifying the emotions (i.e., anger, disgust, fear, happiness, neutral, sadness) portrayed in photographs presented to them of people wearing NM, a posed mask, or imposed mask.	• The accuracy of emotion recognition from faces can become impaired when the lower part of the face is obscured by masks, but the effect is not consistent across all emotions investigated in this study. It was absent or reversed for the emotions of anger, fear, and neutral emotions. • Accuracy was highest for happiness and sadness, there was a clear effect from the masks. • Accuracy was generally the same for the posed mask and imposed mask conditions. • Participants' confidence in their emotion judgements was higher for stimuli not obscured by masks and was similar between the posed and imposed conditions.	Moderate
Gulbetekin, E., Fidanci, A., Altun, E., Er, M. N., & Gürcan, E. (pre-print). Effects of mask use and race on face perception, emotion recognition, and social distancing during the COVID-19 pandemic. *Research Square*. https://doi.org/10.21203/rs.3.rs-692591/v2	18 July 2021	Turkey	**Design:** Randomized controlled trial **Intervention:** Mask use influence on a) face recognition; b) facial expression recognition; c) interaction with facial expression and race of the	• Experiment 1: Accuracy for Caucasian faces (n = 102, M = 0.96±0.08) was higher than for Asian faces (n = 102, M = 0.92±0.09). The mask condition had a significant effect on accuracy F(2.6, 263.08) = 60.79, *P* = 0.001 ηp^2 =	Moderate

Reference	Date released	Setting	Study characteristics	Summary of key findings in relation to the outcome	JBI critical appraisal/ROB
			other person to influence social distancing **Sample:** Experiment 1: 102 participants (80 female, 20 male) mean age 20.4±2.8. Experiments 2 & 3: 134 participants (105 female, 29 male) mean age 21±1.6. Undergraduate students. **Key outcomes:** Experiment 1: Accuracy in matching facial stimuli under four conditions: a) both faces unmasked; b) both faces masked; c) sample's face unmasked and test face masked; d) sample's face masked and test face unmasked. Experiment 2: Accuracy in correctly matching an emotion to a presented facial expression. Experiment 3: Preference for amount (meters) of social distance participant would want from presented face/mask/emotion conditions	0.38. Participants demonstrated highest performance when they were shown an unmasked sample and tested with unmasked faces. In comparison, they produced the worst performance when shown an unmasked sample and tested with masked faces. • Experiment 2: The results indicated a significant main effect of mask F(1,133) = 761.96, *P* = 0.001, ηp^2 = 0.85, race F(1,133) = 397.39, *P* = 0.001 ηp^2 = 0.75 and emotion F(1,363.12) = 201.09, *P* = 0.001 ηp^2 = 0.60. Expressions were better recognized on unmasked faces (n = 134, M =0.75±0.08) than masked faces (n = 134, M =0.55±0.09). They were also recognized better on Caucasian faces (n = 134, M =0.71±0.09) than they were on Asian faces (n = 134, M =0.58±0.08). The expressions from the best recognized to the least recognized were happy (n = 134, M =0.84±0.16), neutral (n = 134, M =0.73±0.15),	

Reference	Date released	Setting	Study characteristics	Summary of key findings in relation to the outcome	JBI critical appraisal/ROB
				disgust (n = 134, M =0.56±0.10) and fear (n = 134, M =0.45±0.15) respectively. • Experiment 3: The results indicated a significant main effect of mask wearing F(1,133) = 67.551, *P* = 0.001, ηp^2 = 0.34 and emotion F(1.48,196.175) = 111.83, *P* = .001, ηp^2 = 0.46. The participants tended to indicate a preference for a wider social distance from unmasked faces (n = 134, M =4.47±1.72) in comparison to masked faces (n = 134, M =3.62±1.49) and preferred greater social distances to faces having an expression of disgust (n = 134, M =4.66±1.59), fear (n = 134, M =4.52±1.56), neutrality (n = 134, M =3.63±1.67) and happiness (n = 134, M =3.37±1.66) respectively.	
Joshi, A., Procter, T., & Kulesz, P. A. (in press). [COVID-19: Acoustic measures of voice in individuals wearing different facemasks](https://doi.org/10.1016/j.jvoice.2021.06.015). *Journal of Voice*. https://doi.org/10.1016/j.jvoice.2021.06.015	19 June 2021	United States	**Design:** Non-randomized experimental study **Intervention:** Face mask influence on measures of voice	• Males (1ft mean = 83.46 dB SPL, SE = 1.34; 6ft mean = 64.13 dB SPL, SE = 1.11) had higher intensity levels than females (1ft mean = 76.23 dB SPL, SE =	Moderate

Reference	Date released	Setting	Study characteristics	Summary of key findings in relation to the outcome	JBI critical appraisal/ROB
			Sample: 19 participants (9 male, 10 female), mean age males 39.4 (21-67), mean age females 30.5 (18-56) **Key outcomes:** 1) Intensity level for /a/ at 1ft and 6ft distances from the speaker, 2) F0, F1, F2 for /a/ and /i/, 3) Cepstral peak prominence for /a/	1.21; 6ft mean = 58.84 dB SPL, SE = 1.01) at both 1ft and 6ft • Intensity while wearing a KN95 + face shield (mean = 81.97, SE = 1.03) was significantly higher than KN95 alone (mean = 78.54, SE = 1.6) for /a/ at 1ft • Main effects of sex F(5,17) = 5.18, *P* = 0.005 were significant for cepstral peak prominence value for /a/ with males (mean = 14.61, SE = 0.45) having higher cepstral peak prominence values than females (mean = 10.99, SE = 0.43), and KN95 + face shield (mean = 12.17, SE = 0.31) resulting in a lower cepstral peak prominence than KN95 alone (mean = 13.02, SE = 0.39) • For F0 and F1 for /a/, only a main effect of sex was significant F(1,17) = 82.93, *P* < 0.001; F(1,17) = 34.34, *P* < 0.001, respectively	
Langbehn, A., Yermol, D., Zhao, F., Thorstenson, C., & Niedenthal, P. (pre-print). Wearing N95, surgical and cloth face masks compromises the communication of emotion.	23 December 2020	United States	**Design:** Non-randomized experimental study **Intervention:** Wearing a variety of masks (N95,	• Experiment 1: Significant interaction effect between face presentation and rating	Moderate

Reference	Date released	Setting	Study characteristics	Summary of key findings in relation to the outcome	JBI critical appraisal/ROB
Research Square. https://doi.org/10.21203/rs.3.rs-133686/v1			surgical, cloth) while communicating emotion **Sample:** Experiment 1: 162 participants (55% male, 45% female), mean age 36.46±10.85 Experiment 2: 60 participants (60% male, 40% female), mean age 32.25±9.01 **Key outcomes:** Experiment 1: Rating the extent to which faces presented were expressing each emotion during each mask condition Experiment 2: Rating smiles in terms of the extent to which each conveyed a) positive feelings b) reassurance c) superiority, while faces were masked with an N95	scale F(1,158) = 277.52, *P* < 0.001, np^2 = 0.637. Significant interaction effect between face presentation (masked versus unmasked) and facial action predominance (upper versus lower face), F(1,158) = 7.17, *P* = 0.008, np^2 = 0.043 • Experiment 2: Reward smiles were seen as signaling significantly more positive feelings (M = 72.5, SE = 1.99) than reassurance and superiority (M = 59.1, SE = 2462.43), t(59) = 5.25, *P* < 0.001, d = 0.68). Dominance smiles also signaled more superiority (M = 64.2, SE = 2.33) than positive feelings and reassurance (M = 58.2, SE = 2.28), t(59) 248 = 3.43, *P* = 0.001, d = 0.44. The interaction between face presentation (visible, masked), smile type (reward, affiliation, dominance), and rating scale (target, non-target), F(2,118) = 4.79, *P* = 0.01, np^2 = 0.075, was significant	
Lin, Y., Cheng, L., Wang, Q., & Xu, W. (in press). Effects of medical masks on voice	9 May 2021	China	**Design:** Non-randomized experimental study	• Significant increases while wearing masks	Moderate

Reference	Date released	Setting	Study characteristics	Summary of key findings in relation to the outcome	JBI critical appraisal/ROB
assessment during the COVID-19 pandemic. *Journal of Voice*. https://doi.org/10.1016/j.jvoice.2021.04.028			**Intervention:** Medical masks worn while producing /a/ sound **Sample:** 53 participants, 25 male, 28 female, mean age 42.62±14.43 **Key outcomes:** 1) Acoustic parameters including a) fundamental frequency b) sound pressure level c) percentage of jitter d) percentage of shimmer e) noise to harmonic ratio f) cepstral peak prominence; 2) Formant parameters including a) F1 b) F2 c) F3 d) maximal phonation time	included sound pressure level (*P* = 0.021), jitter (*P* = 0.005), and shimmer (*P* = 0.002) • A significant decrease was noted in F3 (*P* = 0.004) while wearing a face mask • Significant decrease in maximum phonation time among participants >45yr while wearing masks, and a significant increase in participants <45yr (*P* = 0.032)	
Polo, N., & Lã, F. M. B. (pre-print). Self-perceived voice handicap during COVID19 compulsory facemask use: A comparative study between Portuguese and Spanish speakers. *Journal of Voice*. https://doi.org/10.1016/j.jvoice.2021.08.003	16 August 2021	Spain	**Design:** Non-randomized experimental study **Intervention:** Voice handicap index as a function of facemask use in the general working population **Sample:** 558 participants (31.5% male, 68.3% female, mean age 42.39±13.9). 261 Portuguese participants (37.2% male, mean age 44.8±15.9) and 297 Spanish participants (26.6% male, mean age 40.3±11.5) **Key outcomes:** Voice handicap index scores in	• Both Portuguese and Spanish speakers perceived higher voice-related handicap when using a facemask • Without facemasks, Spanish speakers perceived significantly higher overall voice-related handicap compared to Portuguese speakers (*P* = 0.007) • All dimensions of visual handicap index (functional, physical, emotional) were significantly different between the masked and unmasked conditions for	Low

Reference	Date released	Setting	Study characteristics	Summary of key findings in relation to the outcome	JBI critical appraisal/ROB
			masked and unmasked conditions	both Spanish and Portuguese groups (*P* < 0.001)	
Rinck, M., Primbs, M. A., Verpaalen, I. A. M., & Bijlstra, G. (2022). [Face masks impair facial emotion recognition and induce specific emotion confusions](https://doi.org/10.1186/s41235-022-00430-5). *Cognitive Research: Principles and Implications*, *7,* Article 83. https://doi.org/10.1186/s41235-022-00430-5	5 September 2022	Netherlands	**Design:** Non-randomized experimental study **Intervention:** Face masks worn during emotional expression recognition **Sample:** <u>Experiment 1</u>: 91 participants (23 male, 67 female, 1 non-binary), mean age 33.23±10.42. <u>Experiment 2</u>: 89 participants (29 male, 60 female), mean age 38.66±12.09. <u>Experiment 3</u>: 153 participants (36 male, 117 female), mean age 21.61±6.37 **Key outcomes:** <u>Experiment 1,2 & 3</u>: a) Recognition of different facial expressions while faces are masked b) Emotion confusion	• In all experiments, facial emotion recognition was 20% worse for mased faces than unmasked faces (68% correct versus 88% correct) • Impairment was largest for disgust, followed by fear, surprise, sadness, and happiness • Participants frequently confused emotions that share activation of the visible muscles in the upper half of the face • Participants frequently misinterpreted disgust as anger, fear as surprise, and sadness as neutral	Moderate
Schlegtendal Schlegtendal, A., Eitner, L., Falkenstein, M., Hoffmann, A., Lücke, T., Sinningen, K., & Brinkmann, F. (2022). [To mask or not to mask-evaluation of cognitive performance in children wearing face masks during school lessons (MasKids)](https://doi.org/10.3390/children9010095). *Children, 9*(1), Article 95. https://doi.org/10.3390/children9010095	11 January 2022	Germany	**Design:** Randomized controlled trial **Intervention:** Face masks worn during cognitive performance tests **Sample:** 133 participants total. Group 1 had 65 (Grade 5 = 56.9%, Grade 6 = 23.1%, Grade 7 = 20%, Sport-focused class = 52.3%) and Group 2 had 68 (Grade 5 =	• Overall, there were no significant differences in cognitive performance between both groups, masks vs. NMs. Wearing face masks has no significant influence on attention and executive functions of pupils and can still be recommended during school lessons	Moderate

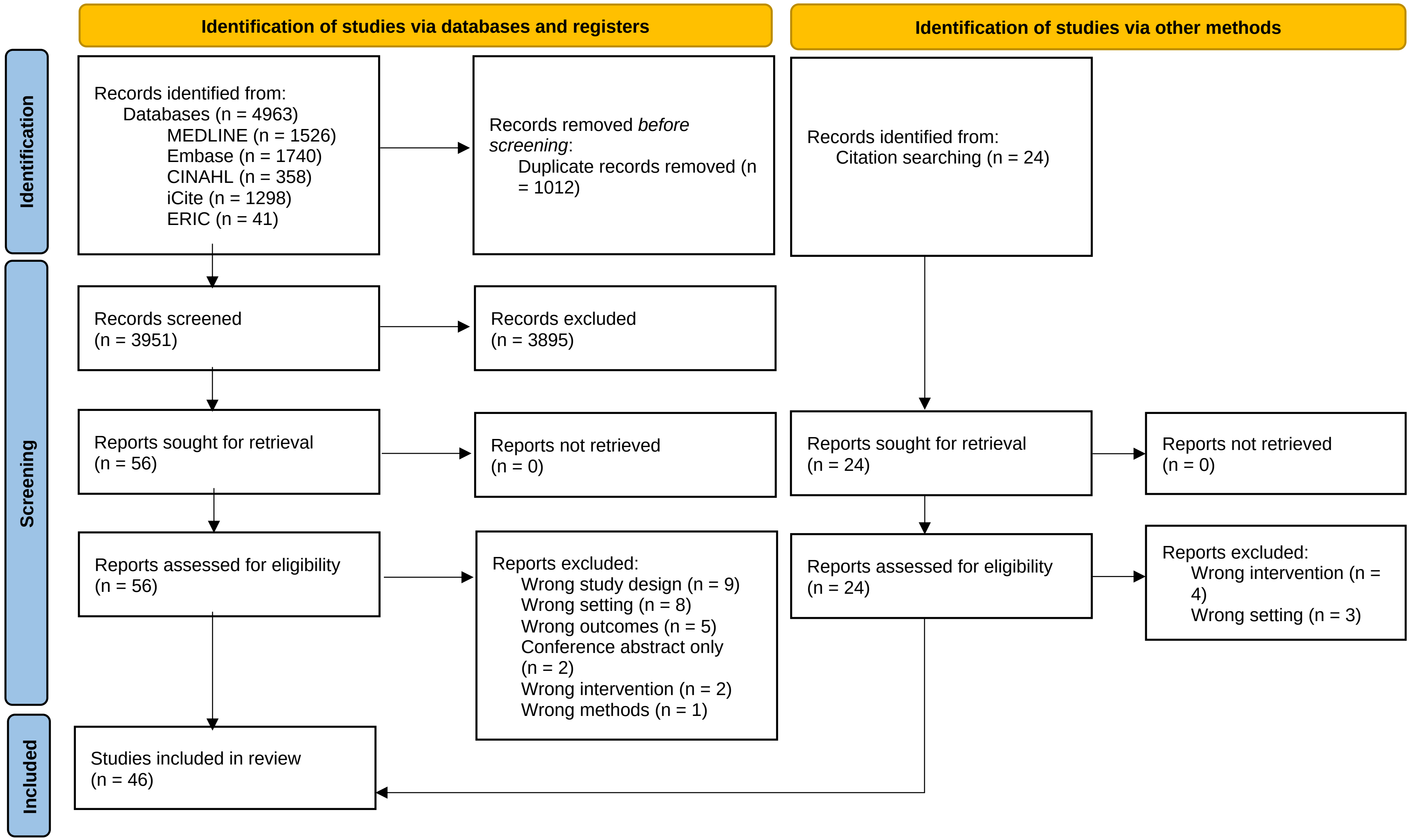
Reference	Date released	Setting	Study characteristics	Summary of key findings in relation to the outcome	JBI critical appraisal/ROB
			33.8%, Grade 6 = 41.2%, Grade 7 = 25%, Sport-focused class = 48.5%) **Key outcomes:** Cognitive performance on a) Switch task b) CORSI c) 2-back test d) Flanker test		
Shepherd, J. L., & Rippon, D. (2023). The impact of briefly observing faces in opaque facial masks on emotion recognition and empathic concern. *Quarterly Journal of Experimental Psychology*, *76*(2), 404-418. https://doi.org/10.1177/17470218221092590	16 February 2022	United Kingdom	**Design:** Randomized controlled trial **Intervention:** Facial stimuli presented wearing a mask **Sample:** 199 participants (78 male, 121 female), mean age 37.44±6.36. Intervention group (masked faces) had 102 participants. Control group (unmasked faces) had 97 participants **Key outcomes:** Emotion recognition and empathic response	• Significant main effect of "facial covering" indicated that emotion recognition was significantly lower when viewing masked faces (M = 40.33, SD = 6.73) in comparison to unmasked faces (M = 56.22, SD = 7.2), $F(1,197) = 245.06$, $P < 0.001$, $np^2 = 0.55$ • Significant main effect of "type of facially expressed emotion" on facial emotion recognition accuracy $F(5,985) = 260.59$, $P < 0.001$, $np^2 = 0.57$ • Significant interaction effect between "facial covering" and "type of facially expressed emotion" $F(5,985) = 35.9$, $P < 0.001$, $np^2 = 0.15$ • There was a simple main effect of "facial covering" in which viewing masked faces significantly reduced	Low

Reference	Date released	Setting	Study characteristics	Summary of key findings in relation to the outcome	JBI critical appraisal/ROB
				recognition of happiness, t(197)=7.60, *P* < 0.00; d = 1.09, sadness, t(197) = 13.8, *P* < 0.001; d = 1.96, fear, t(197) = 8.2, *P* < 0.001; d = 1.16, surprised, t(197) = 7.83, *P* < 0.001; d = 1.11, and disgust, t(197) = 14.18, *P* < 0.001; d = 2.01 • Participants who viewed masked faces reported higher levels of empathic concern (M = 23.35, SD = 3.44) than unmasked faces (M = 22.42, SD = 3.22), t(197) = 1.97, *P* = 0.05; d = 0.28)	
Spang, R. P., & Pieper, K. (2021). The tiny effects of respiratory masks on physiological, subjective, and behavioral measures under mental load in a randomized controlled trial. *Scientific Reports*, *11*, Article 19601. https://doi.org/10.1038/s41598-021-99100-7	1 October 2021	Germany	**Design:** Randomized controlled trial **Intervention:** Face mask (FFR) worn while solving basic arithmetic equations (addition, subtraction, multiplication, or division) **Sample:** 45 participants (24 female, 21 male), mean age 30, healthy university students **Key outcomes:** SpO_2, HR variability, task performance (ratio correct/all tasks, ratio correct/responses given, mean response time, mean response time of correct responses), perceived mental load	• None of the dimensions showed a significant difference between wearing an FFR and not wearing an FFR.	Low

Reference	Date released	Setting	Study characteristics	Summary of key findings in relation to the outcome	JBI critical appraisal/ROB
Tornero-Aguilera, J. F., & Clemente-Suárez, V. J. (2021). Cognitive and psychophysiological impact of surgical mask use during university lessons. *Physiology & Behavior*, *234*, Article 113342. https://doi.org/10.1016/j.physbeh.2021.113342	29 January 2021	Spain	**Design:** Non-randomized experimental study **Intervention:** SM worn during 150-minute lecture **Sample:** 50 participants (38 male, 12 female), mean age 20.2±2.9, university students in biomedical class **Key outcomes:** SpO_2, HR, HR variability, mental fatigue, reaction time	• HR was significantly higher while being masked (89.3± 11.1) versus unmasked (77.7±18.2) • SpO_2 was significantly lower while being masked (96±1.8) versus unmasked (98.4±0.5)	Low
Toscano, J. C., & Toscano, C. M. (2021). Effects of face masks on speech recognition in multi-talker babble noise. *PLoS One*, *16*(2), Article e0246842. https://doi.org/10.1371/journal.pone.0246842	24 February 2021	United States	**Design:** Non-randomized experimental study **Intervention:** Face masks (surgical, N95, two cloth) worn during sentence recognition **Sample:** 200 participants (127 male, 73 female), mean age 37 **Key outcomes:** Speech recognition in variety of mask conditions	• Significant main effect of signal-to-noise-ratio (b = 5.48, SE = 0.21, z = 25.81, $P < 0.001$), confirming that listeners performed better at the higher signal-to-noise ratio • Significant main effect of talker (b = 1.01, SE = 0.2, z = 5.13, $P < 0.001$), confirming that listeners were more accurate at recognizing speech produced by talker 1 (female) than talker 2 (male) • Significant talker x signal-to-noise ratio interaction (b = 0.51, SE = 0.25, z = 2, $P = 0.045$)	Moderate

NM = no mask; SM = surgical mask; SpO_2 = oxygen saturation; HR = heart rate

Figure 1: PRISMA 2020 Flow Diagram



From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71. For more information, visit: http://www.prisma-statement.org/

Appendices

Appendix 1: Detailed search strategy

Database: Ovid MEDLINE(R) ALL 1946 to February 22, 2023
Date: February 22nd, 2023
Filters:
Review - MEDLINE. Best balance of sensitivity and specificity. In Search Filters for MEDLINE in Ovid Syntax and the PubMed translation. Health Information Research Unit, McMaster University. https://hiru.mcmaster.ca/hiru/HIRU_Hedges_MEDLINE_Strategies.aspx#Reviews
Therapy - MEDLINE. Maximizes sensitivity. In Search Filters for MEDLINE in Ovid Syntax and the PubMed translation. Health Information Research Unit, McMaster University. https://hiru.mcmaster.ca/hiru/HIRU_Hedges_MEDLINE_Strategies.aspx#Therapy
Line 3 adapted from:
Adverse Events - Drugs - Standard - MEDLINE, Embase. In: CADTH Search Filters Database. Ottawa: CADTH; 2023: https://searchfilters.cadth.ca/link/2. Accessed 2023-02-15.
Golder, S., & Loke, Y. K. (2012). The performance of adverse effects search filters in MEDLINE and EMBASE. Health Info Libr J, 29(2), 141-151. https://doi.org/10.1111/j.1471-1842.2012.00980.x
Golder, S., McIntosh, H. M., Duffy, S. & Glanville, J. Developing efficient search strategies to identify reports of adverse effects in MEDLINE and EMBASE. Health Information and Libraries Journal 2006, 23, 3– 12. https://doi.org/10.1111/j.1471-1842.2006.00634.x

#	Searches
1	COVID-19/ or SARS-CoV-2/ or coronavirus infections/ or exp coronavirus/ or exp betacoronavirus/ or (covid 19* or covid19* or covid-19* or covid or severe acute respiratory syndrome coronavirus 2 or severe acute respiratory syndrome corona virus 2 or wuhan coronavirus* or wuhan corona virus* or betacoronavirus* or corona virus* or coronavirus* or ncov* or 2019 ncov* or 19 ncov* or 19ncov or cov or cov2 or hcov-19 or sars2 or sarscov or sars cov 2 or sars-cov-2 or sarscov-2 or sarscov2 or sars-cov or sars-cov2 or 2019ncov or sars coronavirus 2 or hcov).ti,ab,kf.
2	(Masks/ or Respiratory Protective Devices/ or (mask or masks or masking or face-mask or facemask or face-masks or facemasks or face covering or facial covering or mouth covering or face piece* or facepiece* or face protect* or face shield* or faceshield* or respirator or respirators or respiratory protection or respiratory equipment or respiratory device or respiratory devices or n95 or n 95 or kn95 or kn 95 or kf94 or kf 94 or ffp or ffp1 or ffp 1 or ffp2 or ffp 2 or ffp3 or ffp 3 or n97 or n 97 or n99 or n 99 or p2).ti,ab,kf.) not mechanical.ti,ab,kf.
3	(ae or co).fs. or (safe or safety or unsafe or complication? or consequence? or react* or harm* or side-effect? or side effect?).ti,ab,kf. or ((adverse* or negative* or undesirable) adj2 (effect? or event? or outcome? or incident? or impac?)).ti,ab,kf.
4	((physiolog* or physical or biolog* or health* or medical* or function* or psych* or mental* or emotion* or cogniti* or development* or economic* or finance* or environment* or eco*) adj5 (adverse* or negative* or undesirable or harm* or effect? or reaction? or event? or outcome? or complication? or incident? or consequenc* or impact? or stress* or strain or anxiet* or anxious or aggravat* or exacerbate*)).ti,ab,kf.
5	3 or 4 [unintended consequences]
6	Meta-analysis/ or meta analysis.mp,pt. or review.pt. or search*.tw.
7	clinical trial.mp. or clinical trial.pt. or random*.mp. or tu.xs.
8	Non-Randomized Controlled Trials as Topic/ or (comparative study or controlled clinical trial).pt. or (quasiexperiment or quasi experiment or quasiexperimental or quasi experimental or quasi-randomized

	or matched control or (unobserved and heterogeneity) or non-randomized or nonrandomized or non-randomised or nonrandomised or pretest-posttest).ti,ab,kf.
9	cohort studies/ or longitudinal studies/ or follow-up studies/ or prospective studies/ or retrospective studies/ or (cohort or longitudinal or prospective or retrospective).ti,ab,kf.
10	Case-Control Studies/ or retrospective studies/ or Control Groups/ or ((case and control) or (cases and controls) or (cases and controlled) or (case and comparison*) or (cases and comparison*) or control group or control groups).ti,ab,kw.
11	1 and 2 and 5 and 6 [will retrieve Reviews]
12	1 and 2 and 5 and 7 [will retrieve RCTs]
13	1 and 2 and 5 and 8 [will retrieve Quasi-experimental studies]
14	1 and 2 and 5 and 9 [will retrieved Cohort studies]
15	1 and 2 and 5 and 10
16	(or/11-15) and English.lg.
17	16 not (exp Animals/ not (exp Animals/ and exp Humans/))
18	limit 17 to yr="2020 -Current"

Appendix 2: Data extraction form

General Information:
- Covidence ID
- Lead author
- Title of article
- Country in which the study was conducted

Methods:
- Aim of study
- Study design
- Methods
- Mask type

Participants:
- Sample description
- Participant age
- Participant gender
- Inclusion criteria
- Exclusion criteria
- Exercise type (exercise studies only)
- Exercise duration (frequency and time) (exercise studies only)

Outcomes:
- Table of outcome measures (exercise studies only):

	No mask	**N95**	**Surgical mask**	**Cloth or community mask**
SpO_2				
Heart rate				
Blood pressure				
RPE/SoB/dyspnea				
Respiratory rate				
CO_2				

- Unique measures (exercise studies only)
- Key findings
- Significance
- Authors conclusions

Appendix 3: Approach to critical appraisal

JBI Critical Appraisal Tool for Assessment of Risk of Bias for Randomised Controlled Trials (Barker et al., 2023) was used to access RCTs. JBI Checklist for Quasi-Experimental Studies (Non-Randomized Experimental Studies) (Tufanaru et al., 2020) was used to assess non-randomized experimental studies. JBI Checklist for Case Control Studies (Moola et al., 2020) was used to assess case control studies. All studies included for data extraction were evaluated in full.

Quality rankings were assigned according to scores. For RCTs, high risk of bias (ROB) is 0-5/13 points, moderate is 6-9/13 points, and low is 10-13/13 points. For non-randomized experimental studies high ROB is 0-3/9 points, moderate is 4-6/9 points, and low is 7-9/9 points. For case-control studies high ROB is 0-4/10 points, moderate is 5-7/10 points, and low is 8-10/9 points.

Appendix 4: Rating of Perceived Exertion (RPE) and Borg Scale

The consistent use of the Rating of Perceived Exertion (RPE) and/or the Borg scale is noteworthy in the exercising while masked and unmasked across the review studies. Overall, authors did not clearly distinguish the two but rather seemed to use the terms interchangeably. There is some difference between the two. The original Borg scale has a range of 6-20, no exertion to maximum effort and considered to correlate with the person's heart rate (HR), and self-perception of how hard they are working. Effort was measured by selecting a number between 6-20, adding a 0 which should reflect the HR, therefore a score of 11 would equal a HR of 110. Borg also developed the modified RPE with scores ranging from 0-10, 0 meaning no exertion and 10 meaning maximum. According to Borg "1" on this scale equals lying on a couch and 10 equals pushing a car up a steep hill. This scale corresponds more with breathlessness. Studies in this review frequently used the term Borg dyspnea scale rather than RPE, however, some used both. If comparing the two scales the Borg 12-14 (moderate intensity) corresponds with the RPE (4-5) and Borg 15-17 (vigorous activity) corresponds with the RPE (6-8). The chart below is intended to assist with further understanding and interpreting the use of these scales.

In general studies reporting significant unintended consequences related to breathlessness while exercising and masked (9) used the Borg Modified RPE (0-10) scale, while those reporting significant unintended consequences related to perceived exertion used the Borg (6-20) scale. However, there was some inconsistency in the use of these instruments.

This chart gives you an idea of how these scales and activities compare.

Exertion	**RPE scale**	**Borg scale**	**Activity examples**
none	0	6	laying on the couch
just noticeable	0.5	7 to 8	bending over to put on your shoes
very light	1	9 to 10	easy chores, such as doing laundry
light	2 to 3	11 to 12	leisurely walking that does not increase your heart rate
moderate/ somewhat hard	4 to 5	13 to 14	brisk walking or moderate activity that speeds up your heart rate without making you out of breath
hard	6 to 7	15 to 16	vigorous activity, such as jogging, biking, or swimming (increases your heart rate and makes you breathe harder and faster)
very hard	8 to 9	17 to 18	the highest level of activity that you can continuing doing without stopping, such as running
maximum effort	10	19 to 20	a short burst of activity, such as a sprint, that you cannot keep doing for long