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Safety implications of mask use: a systematic review and evidence map

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Abstract

Background Widespread use of respiratory protection masks has become a critical component of public health response.

Objectives This systematic review synthesises the evidence on the acute physiological, cognitive and psychological impacts associated with different types of masks and provides an evidence map of research gaps.

Methods A comprehensive search from 2000 to 2023 was conducted across multiple databases (MEDLINE, EMBASE, Cochrane databases, Scopus and PubMed). An umbrella systematic overview was conducted for physiological outcomes using existing systematic reviews. We conducted de novo systematic reviews for cognitive and psychological outcomes. Pairs of independent reviewers determined eligibility, extracted data and assessed risk of bias. Certainty at an outcome level was appraised using the Grading of Recommendations Assessment, Development and Evaluation approach.

Results The search resulted in 13 370 potential citations, leading to the inclusion of nine systematic reviews for physiological outcomes (87 primary studies) and 10 primary studies for cognitive and psychological outcomes (3815 participants), with the majority of participants being healthy adults. Studies evaluating physiological outcomes demonstrated that various types of masks have little to no significant difference in heart rate (surgical mask (mean difference (MD): 0.96 (−1.01 to 2.93)), N95 mask (MD: 1.63 (−2.79 to 6.05)) and cloth mask (MD: −0.94 (−6.39 to 4.52))) or respiratory rate during rest or exercise (surgical mask (MD: −1.35 (−3.00 to 0.29)), N95 mask (MD: 0.10 (−3.10 to 3.29)) and cloth mask (MD: −2.57 (−6.44 to 1.29)) (low certainty for most outcomes)). Mask use may be associated with very small changes in minute ventilation (surgical mask (MD: −13.9 (−20.30 to −7.53)) and N95 mask (MD: −16.3 (−28.7 to −3.9))), tidal volume (surgical mask (MD: −0.14 (−0.23 to −0.05)) and N95 mask (MD: −0.10 (−0.33 to 0.13))), oxygen saturation (surgical mask (MD: −0.59% (−0.87 to −0.30)), N95 mask (MD: −0.35% (−0.75 to 0.05)) and cloth mask (MD: −0.50% (−1.23; 0.24))), carbon dioxide partial pressure (surgical mask (standardised MD (SMD): 1.17 (0.70 to 1.64)) and N95 mask (SMD: 0.43 (0.08 to 0.79))) and exercise performance (surgical mask (SMD: −0.12 (−0.39 to 0.15)), N95 mask (SMD: −0.42 (−0.76 to −0.08)) and

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Prior research on the effects of face masks on physiological, cognitive and psychological outcomes during rest and exercise across different mask types and participant populations to date has been inconclusive.

WHAT THIS STUDY ADDS

⇒ The current evidence showed a slight change in minute ventilation, tidal volume, oxygen saturation, maximal oxygen consumption (VO_2max), carbon dioxide partial pressure, lactate levels and exercise performance with mask use. There was a little to no significant difference in heart rate, stroke volume, cardiac output, blood pressure or respiratory rate. Studies evaluating cognitive and psychological outcomes showed mixed results. The study fills a crucial knowledge gap by systematically synthesising and analysing the current evidence on the acute physiological, cognitive and psychological impacts of face mask use during rest and exercise while providing a comprehensive understanding of the current knowledge regarding the effects of mask wearing on various health outcomes across different mask types and populations and highlighting areas of evidence gap to help guide future investigations in respiratory protection and public health.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ More research is needed on the effects of mask wearing during physical activity to inform tailored recommendations for individuals and public health policies.

cloth mask (SMD: −0.26 (−0.54 to 0.02)) (low certainty for most outcomes)). Studies evaluating cognitive outcomes showed mixed results. Some studies reported reduced mental workload, and others showed no significant effect or decreased performance. The impact on attention, errors and reaction time was variable. These studies were small and at moderate to high risk of bias. Evidence was insufficient to estimate the effect of mask use on psychological outcomes (claustrophobia, depression and anxiety) as these studies were small, non-longitudinal and at high risk of bias.

Conclusion This evidence map provides a comprehensive insight into the multifaceted impact of respiratory protection mask use, and highlights the limited certainty in the available body of evidence. This evidence map supports the development of future research agenda.

Introduction

In recent years, face masks became a crucial strategy to mitigate the transmission of infectious diseases, particularly respiratory viruses, causing a paradigm shift in the global public health landscape.[1–3] This shift extends across diverse settings, including public transport, workplaces and recreational activities. During the early stages of the COVID-19 pandemic when vaccines were not widely available, wearing masks became one of the primary methods for protection against the disease.[1] During this period, the selection of mask types has received considerable attention, driven by evidence suggesting that surgical masks and FFP2/N95 respirators offer superior particle filtration compared with cloth masks.[4] While the efficacy of masks in reducing infection transmission is widely recognised,[5] the surge in mask usage has raised concerns regarding their impact on health outcomes.[6] Particularly, questions have arisen regarding their potential effects on respiratory and physiological parameters, especially during physical activity.[7 8]

Notably, numerous studies have examined the respiratory implications of prolonged mask use, revealing diverse findings.[7] This is significant, especially given concerns regarding the increased breathing resistance and potential rebreathing of exhaled air associated with certain mask types, such as FFP2/N95 respirators and surgical masks. This effect may impact gas exchange dynamics leading to decreased oxygen intake (VO_2max), oxygen saturation (SpO_2) and increased carbon dioxide levels ($PetCO_2$) especially during physical activity.[9–12] However, existing literature presents conflicting data on the overall physiological effects of mask wearing during physical exertion.[12–14] While some systematic reviews suggest modest impacts on physiological parameters like gas exchange and pulmonary function,[12] others report minimal effect on physiological outcomes,[15] with similar results noted for exercise performance.[12 15]

Mask use may also have an effect on various cognitive aspects, such as obscuring facial expressions, creating challenges with communication and increasing cognitive load.[16] Few observational studies have touched on this, demonstrating increasing incidence of headache, attention deficit and difficulty in concentrating.[17] Overall data about the impact of face mask use on cognitive function remain limited. Furthermore, the psychological impact of face mask use is another issue that warrants thorough exploration. Facial expressions provide visible cues and play a vital role in human connection and emotional communication. Alterations induced by masks in these cues may contribute to social and emotional challenges,[18] potentially affecting mental well-being.

Considering the heightened focus on mask usage and its implications amid the COVID-19 pandemic, there has been an exponential rise in both individual studies and systematic reviews addressing this topic. However, the sheer volume of literature, coupled with the variability in findings and methodological quality among systematic reviews, poses a significant challenge for decision-makers. This abundance of information, often with conflicting results and varying levels of rigour, can obscure the actual state of evidence and potentially mislead those responsible for crafting public health guidelines and policies. Therefore, the objectives of our systematic review are to (1) synthesise the evidence on the acute physiological, cognitive and psychological impacts associated with different types of masks and (2) produce an evidence map[19] that identifies evidence gaps and inform future research.

Methods

Study design

Due to the availability of multiple systematic reviews that addressed physiological outcomes, an umbrella systematic review (ie, an overview of systematic review) was conducted to identify and synthesise data from published systematic reviews. For the cognitive and psychological outcomes, no systematic reviews were identified and therefore de novo reviews were conducted. We followed a predefined published protocol without any upfront deviations[20] and reported the methodology and findings in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement.[21 22] The detailed PICO (Population, Intervention, Comparison, Outcome) questions addressed in this comprehensive systematic review are outlined in table 1.

As our study followed a systematic review design and did not involve original research on human participants or direct patient involvement, we did not seek Institutional Review Board approval. However, we have rigorously maintained ethical standards in selecting, analysing and presenting existing literature.

Data sources and search strategy

A comprehensive search of several databases from 2000 to 28 July 2023 in any language was conducted. Databases included MEDLINE, EMBASE, Cochrane Central Register of Controlled Trials, Cochrane Database of Systematic Reviews, Scopus and PubMed. The search strategy was designed and conducted by a medical librarian with input from the study investigators. A controlled vocabulary supplemented with keywords was used to search various outcomes from wearing medical masks or air-purifying respirators (APR). The complete search strategies are available in online supplemental appendix A.

Eligibility criteria

We included studies that (1) enrolled adults (aged 18 years and older), (2) evaluated surgical/medical masks, N95 masks/filtering facepiece respirators, military, and fire service APRs, and cloth masks, with no mask use, and (3) included at least one outcome of interest. (4) The study designs available include systematic review and meta-analysis for acute physiological outcomes (Q1), and comparative individual studies for cognitive (Q2) and psychological (Q3) outcomes. Factors such as duration of masking, activity level (at rest or with exercise) and altitude level (when relevant) were considered for subgroup analyses.

Table 1 Key questions (three questions addressing acute physiological, cognitive and psychological outcomes associated with mask use)

Population of interest	► Adults 18 years and older
Intervention	► Surgical/medical masks ► N95 masks/filtering facepiece respirator ► Military and fire service air-purifying respirators (APR) ► Cloth mask
Comparison	► No mask
Outcomes	Q1. Acute physiological outcomes ► Cardiovascular responses – Heart rate – Cardiac output/stroke volume – Blood pressure ► Ventilatory responses – Respiratory rate – Minute ventilation – Tidal volume – VE/VCO_2 – Ventilation equivalent ► Metabolic response – Arterial oxygen saturation – Oxygen extraction/muscle oxygenation – Carbon dioxide/end-tidal CO_2 – Arterial partial pressure of carbon dioxide – Blood lactate ► Exercise performance – Rating of perceived exertion (RPE) – Time to exhaustion and perceived exertion – Thermal sensation and facial skin temperature Q2. Cognitive outcomes ► Mini-Mental State Examination ► Standardized Mini-Mental State Examination ► Montreal Cognitive Assessment (MOCA) ► Mini-Cog ► Functional Cognitive Assessment Scale ► Functional Activities Questionnaire ► Abbreviated Mental Test ► Six-item Cognitive Impairment Test – Distraction, total number of errors, correct responses, response time, self-perceived arousal and ability to concentrate Q3. Psychological outcomes ► Anxiety ► Depression ► Claustrophobia
Study designs	► Systematic review and meta-analysis for Q1 ► Comparative individual studies for Q2 and Q3
Timing	From 2000 to 2023
Subgroup analyses	► People working in a field with a position description that expects them to wear a face mask (pilots or qualified aircrew including flight attendants, military and public safety professionals) ► Duration of masking ► Activity level – At rest – With exercise (progressive intensity protocol applied the exercise test until exhaustion vs steady exercise state) Altitude level (when relevant)

CO_2, carbon dioxide; Q1,2,3, Question 1,2,3; VE/VCO_2, minute ventilation/carbon dioxide production.

Study selection

Pairs of independent reviewers identified eligible studies by screening titles, abstracts and then full texts. Disagreements were resolved by consensus or arbitrated by a third reviewer, if necessary. For the systematic review addressing physiological outcomes, we only included reviews that had explicit inclusion and exclusion criteria and searched at least two databases. Inclusion was restricted to publications in the English language. In cases where multiple systematic reviews existed for a particular outcome, to avoid risk of overlapping evidence, studies were prioritised based on their methodological rigour, determined by the quality of included evidence and the overall methodological quality of the systematic review, followed by the highest number of included studies and then publication year. Notably, at least one systematic review was included for each intervention under investigation.

Data extraction and risk of bias assessment

Pairs of reviewers extracted data using a standardised, piloted, electronic form. We extracted data on patient characteristics, type of interventions and outcomes. Methodological quality of the systematic reviews was assessed using the AMSTAR instrument (a measurement tool to assess the methodological quality of systematic reviews). Pairs of reviewers working independently assessed the risk of bias using the modified Cochrane Collaboration tool for randomised clinical trials[23] and the modified Newcastle-Ottawa Quality Assessment tool for observational studies[24] for Q2 and Q3. Data regarding the risk of bias for Q1 were extracted from the systematic reviews. Disagreements were resolved by discussion or arbitrated by a third reviewer. We summarised the risk of bias for all domains to produce an overall risk of bias for every study.

Data synthesis and analysis

For continuous outcomes, we estimated the effect of interventions using the weighted mean difference or the standardised mean difference. For dichotomous outcomes, we estimated the relative risk. We used the I^2 statistic and the Q statistic to assess heterogeneity. Evaluation for publication bias was not possible because of large heterogeneity that makes statistical tests for funnel plot symmetry unreliable.[25] The certainty in evidence was rated using the approach of Grading of Recommendations Assessment, Development and Evaluation and narrative adaptations.[26–28] Certainty from randomised controlled trials (RCT) was considered high but may be rated down for bias, indirectness, imprecision, inconsistency and publication bias. We rated down for inconsistency when we visually observed an important lack of overlap of CIs of individual studies. For imprecision, we rated down if sample size was <500 or the number of events was <100, or when CIs crossed the null effect with appreciable harm or benefit (<30 fewer outcomes or >30 more outcomes per 1000). For continuous outcome, we rated down for imprecision when the CI for the effect size crossed the null, except when the sample size was >800. We created a visual representation of all study outcomes (quantitative and qualitative) in the form of an evidence map. An evidence map shows the overall effects of mask use along with the risk of bias and certainty in these effects, helping decision-makers understand the possible benefits and gaps in research.[19 29]

Patient and public involvement

We did not involve patients or the public in the design, conduct, reporting and dissemination plans of this study.

Results

Literature search results

The electronic search yielded 13 370 potentially relevant citations, of which nine systematic reviews[6 7 12 15 30–34] including 87 primary individual studies (74 RCTs, 9 non-RCTs and 4 observational studies) enrolling 3404 participants were included to assess the impact of respiratory protection mask use on acute physiological outcomes, with the majority of participants being healthy adults (86.6%), followed by adults with chronic obstructive pulmonary

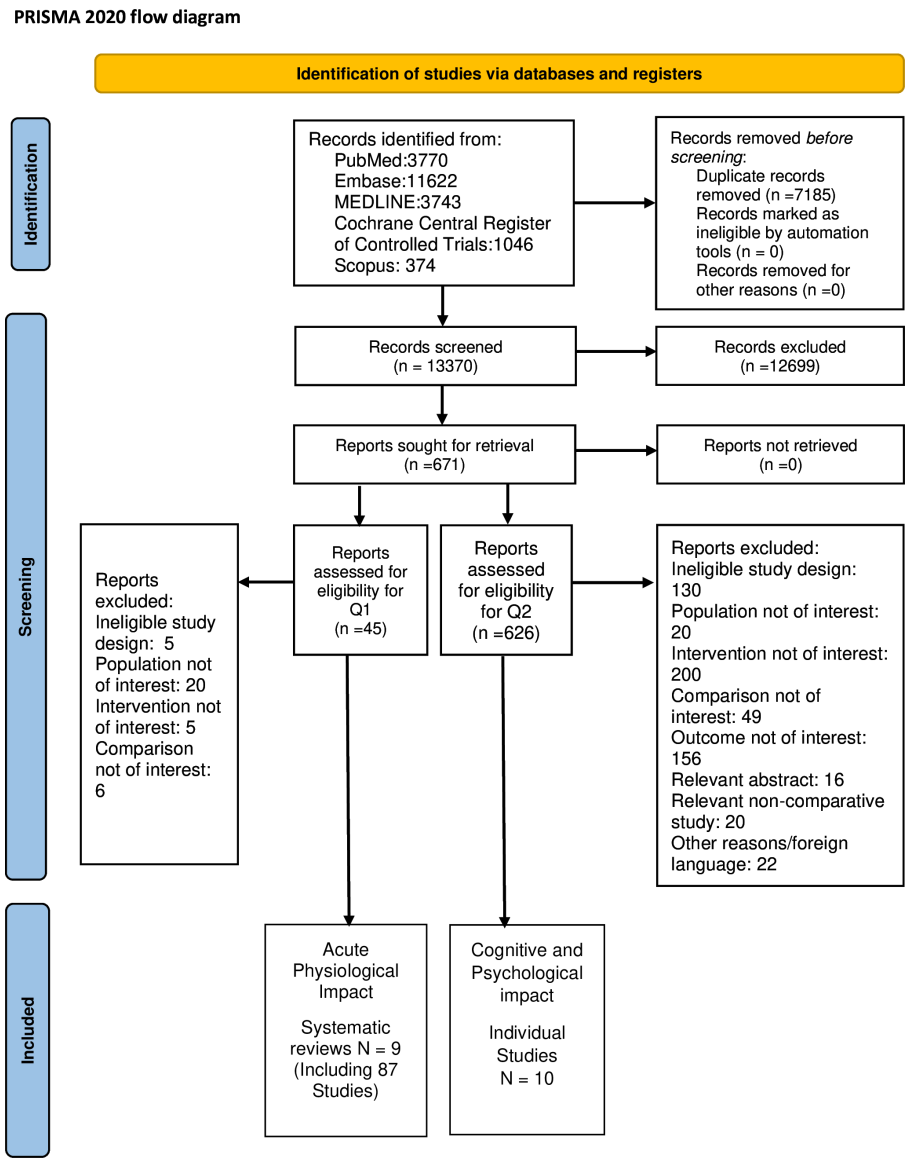

Figure 1 Flow chart. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

disease (COPD; 9.2%), and healthy children (3.1%). Additionally, one systematic review included 42 pregnant women. Additionally, 10 primary individual studies (2 RCTs,[35 36] 1 non-randomised controlled study[37] and 7 observational studies[17 38–43]) involving 411 healthy participants were included to assess the impact of respiratory protection mask use on cognitive and psychological outcomes. The screening process is illustrated in figure 1, and the key characteristics of the selected studies are summarised in online supplemental tables 1 and 2, while the methodological qualities of the included studies are summarised in online supplemental table 3 (comparative observational studies) and online supplemental table 4 (randomised clinical trials).

Outcomes

Acute physiological impact of respiratory protection mask use

The impact of respiratory protection mask use on acute physiological responses was extensively assessed across numerous systematic reviews and studies with low to very low certainty evidence.

Cardiovascular responses

Heart rate

Seven reviews reported on the impact of mask use on heart rate,[6 12 15 30–33] out of which we prioritised two systematic reviews based on their methodological rigour, number of included studies and recent publication time.[12 32] Wearing masks may cause little to no difference in heart rate compared with no mask in healthy adults or patients with COPD. In a subgroup analysis by exercise state, no significant difference was noted with mask wearing in healthy adults during the progressive exercise state; however, a slight increase in heart rate was noted during steady exercise state. Meta-analysis results are presented in table 2.

Cardiac output

An analysis from one systematic review[15] showed no significant difference on stroke volume or cardiac output with mask use compared with no mask in healthy adults. Meta-analysis results are presented in table 2.

Table 2 Effect of respiratory protection mask use on cardiovascular responses and certainty of evidence

Outcome (measurement unit)	Systematic review	Population	Comparison	Participants (included studies)	Effect size MD (95% CI)	Risk of bias	Certainty of evidence
Heart rate (measured in beats per minute (bpm))	Zheng *et al*[12]	Healthy adults	Surgical mask versus no mask	692 (28 RCTs/randomised crossover trials)	0.96 (−1.01 to 2.93)	Moderate	⨁⨁◯◯* Low
			N95 respirator versus no mask	391 (18 RCTs/randomised crossover trials)	1.63 (−2.79 to 6.05)	Moderate	⨁⨁◯◯* Low
			Cloth mask versus no mask	115 (5 crossover trials)	−0.94 (−6.39 to 4.52)	Moderate	⨁⨁◯◯* Low
			Mask versus no mask (progressive exercise state)	803 (31 RCTs/randomised crossover trials)	−0.74 (−4.48 to 2.99)	Moderate	⨁⨁◯◯* Low
			Mask versus no mask (steady-state exercise)	685 (25 RCTs/randomised crossover trials)	2.69 (1.10 to 4.28)	Moderate	⨁⨁◯◯* Low
	Chen *et al*[32]	Patients with COPD	Face mask versus no mask	97 (1 non-RCT)	4.70 (−0.30 to 9.70)	Moderate	⨁⨁◯◯† Low
Maximum heart rate	Chen *et al*[32]	Patients with COPD	Face mask versus no mask	27 (1 randomised crossover trial)	−1.90 (−10.84 to 7.04)	Moderate	⨁◯◯◯† Very low
Stroke volume (measured in millilitres (mL) per beat)	Shaw *et al*[15]	Healthy adults	Face mask versus no mask	26 (2 crossover trials)	12.33 (−4.09 to 28.75)	Moderate	⨁⨁◯◯‡ Low
			N95 respirator versus no mask	14 (1 crossover trial)	13.0 (−6.97 to 32.97)	Moderate	⨁◯◯◯† Very low
Cardiac output (measured in mL/min)	Shaw *et al*[15]	Healthy adults	Face mask versus no mask	26 (2 crossover trials)	2.26 (−0.15 to 4.67)	Moderate	⨁⨁◯◯‡ Low
			N95 respirator versus no mask	14 (1 crossover trial)	1.20 (−2.19 to 4.59)	Moderate	⨁◯◯◯† Very low
Systolic blood pressure (measured in millimetres of mercury (mm Hg))	Shaw *et al*[15]	Healthy adults	Face mask versus no mask	1088 (4 crossover trials and 2 retrospective observational studies)	−2.23 (−5.28 to 0.82)	High	⨁◯◯◯§ Very low
			N95 respirator versus no mask	130 (3 randomised crossover trials and 1 RCT)	−0.12 (−4.22 to 3.97)	Moderate	⨁⨁◯◯‡ Low
	Chen *et al*[32]	Patients with COPD	Face mask versus no mask following 6MWT	97 (1 non-RCT)	0.40 (−4.36 to 5.16)	Moderate	⨁⨁◯◯† Low
			Face mask versus no mask following maximum exercise test	27 (1 crossover trial)	−6.80 (−24.37 to 10.77)	Moderate	⨁⨁◯◯† Low
Diastolic blood pressure (measured in mm Hg)	Shaw *et al*[15]	Healthy adults	Face mask versus no mask	38 (3 crossover trials)	−0.96 (−5.32 to 3.40)	Moderate	⨁⨁◯◯‡ Low
			N95 respirator versus no mask	114 (2 crossover trials and 1 non-RCT)	−0.23 (−3.06 to 2.60)	Moderate	⨁⨁◯◯‡ Low
	Chen *et al*[32]	Patients with COPD	Face mask versus no mask at rest	97 (1 non-RCT)	2.70 (−0.34 to 5.74)	Moderate	⨁⨁◯◯‡ Low
			Face mask versus no mask following 6MWT	97 (1 non-RCT)	−0.80 (−4.13 to 2.53)	Moderate	⨁⨁◯◯‡ Low
Mean arterial blood pressure (measured in mm Hg)	Lima *et al*[31]	Adult patients	Face mask versus no mask	116 (6 crossover trials)	−0.07 (−0.32 to 0.17)	High	⨁◯◯◯§ Very low

*Low quality of evidence is due to unexplained inconsistency and imprecise results due to small magnitude of change and wide CI.
†Low quality of evidence is due to imprecise results due to small magnitude of change and wide CI and some concern with risk of bias.
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§Low quality of evidence is due to unexplained inconsistency and imprecise results due to small magnitude of change and wide CI and some concern with risk of bias.
COPD, chronic obstructive pulmonary disease; MD, mean difference; 6MWT, 6 min walk test; RCT, randomised controlled trial.

Blood pressure

Four systematic reviews examined the impact of mask use on blood pressure,[6 15 31 32] out of which we prioritised three systematic reviews based on their methodological rigour and number of included studies.[15 31 32] Wearing masks was associated with little to no difference in systolic, diastolic and mean arterial blood pressure compared with no mask in healthy adults or patients with COPD. In a subgroup analysis by exercise state, no significant difference was noted in systolic or diastolic blood pressure in patients with COPD. Meta-analysis results are presented in table 2.

Ventilatory responses

Respiratory rate

Seven reviews reported the impact of mask use on respiratory rate (RR),[6 12 15 30–33] out of which we prioritised two systematic reviews based on their methodological rigour, number of included studies and recent publication time.[12 32] Wearing masks may cause little to no difference in RR compared with no mask in healthy adults or patients with COPD. In a subgroup analysis by exercise state, no significant difference was noted in RR in healthy adults during the different exercise states. Meta-analysis results are presented in table 3.

Table 3 Effect of respiratory protection mask use on ventilatory responses and certainty of evidence

Outcome (measurement unit)	Systematic review	Population	Comparison	Participants (included studies)	Effect size MD (95% CI)	Risk of bias	Certainty of evidence
Respiratory rate (measured in breaths per minute)	Zheng *et al*[12]	Healthy adults	Surgical mask versus no mask	358 (13 crossover trials)	−1.35 (−3.00 to 0.29)	Moderate	⊕⊕◯◯* Low
			N95 respirator versus no mask	248 (11 crossover trials)	0.10 (−3.10 to 3.29)	Moderate	⊕⊕◯◯* Low
			Cloth mask versus no mask	81 (3 crossover trials)	−2.57 (−6.44 to 1.29)	High	⊕◯◯◯† Very low
			Mask versus no mask (progressive exercise state)	540 (20 RCTs/randomised crossover trials)	−1.40 (−4.02 to 1.23)	Moderate	⊕⊕◯◯* Low
			Mask versus no mask (steady-state exercise)	386 (13 RCTs/randomised crossover trials)	−0.26 (−1.83 to 1.30)	Moderate	⊕⊕◯◯* Low
	Chen *et al*[32]	Patients with COPD	Face mask versus no mask	112 (2 non-RCTs)	1.0 (0.47 to 1.53)	High	⊕◯◯◯† Very low
Minute ventilation (measured in mL/min)	Zheng *et al*[12]	Healthy adults	Surgical mask versus no mask	212 (11 crossover trials)	−13.9 (−20.30 to −7.53)	High	⊕◯◯◯† Very low
			N95 respirator versus no mask	62 (5 crossover trials)	−16.3 (−28.7 to −3.9)	Moderate	⊕◯◯◯‡ Very low
			Mask versus no mask (progressive exercise state)	217 (16 RCTs/randomised crossover trials)	−18.11 (−24.63 to −11.58)	High	⊕◯◯◯† Very low
			Mask versus no mask (steady-state exercise)	62 (3 RCTs/randomised crossover trials)	−0.07 (−4.47 to 4.33)	High	⊕◯◯◯† Very low
	Chen *et al*[32]	Patients with COPD	Face mask versus no mask	14 (1 RCT)	−0.33 (−5.08 to 4.42)	Moderate	⊕⊕◯◯‡ Low
Tidal volume (measured in millilitres)	Zheng *et al*[12]	Healthy adults	Surgical mask versus no mask	151 (6 crossover trials)	MD: −0.14 (−0.23 to −0.05)	Moderate	⊕⊕◯◯§ Low
			N95 respirator versus no mask	46 (4 crossover trials)	−0.10 (−0.33 to 0.13)	Moderate	⊕⊕◯◯§ Low
			Mask versus no mask (progressive exercise state)	168 (9 RCTs/randomised crossover trials)	−0.21 (−0.31 to −0.10)	Moderate	⊕⊕◯◯* Low
			Mask versus no mask (steady-state exercise)	80 (5 RCTs/randomised crossover trials)	−0.00 (−0.12 to 0.12)	Moderate	⊕⊕◯◯* Low
Carbon dioxide ventilation equivalent	Zheng *et al*[12]	Healthy adults	Surgical mask versus no mask	139 (5 crossover trials)	−1.69 (−3.10 to −0.27)	Moderate	⊕◯◯◯‡ Very low
			Mask versus no mask (progressive exercise state)	125 (4 RCTs/randomised crossover trials)	−1.18 (−2.42 to 0.06)	Moderate	⊕◯◯◯‡ Very low
			Mask versus no mask (steady-state exercise)	58 (3 RCTs/randomised crossover trials)	−2.39 (−4.97 to 0.19)	Moderate	⊕◯◯◯‡ Very low

*Low quality of evidence is due to unexplained inconsistency and imprecise results due to small magnitude of change and wide CI.
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§Low quality of evidence is due to imprecise results due to small magnitude of change and wide CI.
COPD, chronic obstructive pulmonary disease; MD, mean difference; RCT, randomised controlled trial.

Minute ventilation

Six systematic reviews[6 12 15 30 32 33] reported this outcome, out of which we prioritised two systematic reviews based on their methodological rigour, number of included studies and recent publication time.[12 32] Wearing masks was associated with a reduction in minute ventilation (VE) in healthy adults, with little to no difference in VE noted with mask use in patients with COPD. In a subgroup analysis by exercise state, wearing masks was associated with a reduction in VE in healthy adults during progressive exercise states with little to no difference noted during the steady exercise state. Meta-analysis results are presented in table 3.

Tidal volume

Four systematic reviews[6 12 15 33] reported data regarding the impact of mask use on tidal volume (VT), out of which we prioritised one systematic review based on methodological rigour, number of included studies and recent publication time.[12] Wearing surgical masks was associated with a reduction in VT in healthy adults compared with no mask. However, little to no difference was observed with N95 mask use. In a subgroup analysis by exercise state, wearing masks was associated with a reduction in VT in healthy adults during progressive exercise states with little to no difference noted during the steady exercise state. Meta-analysis results are presented in table 3.

Carbon dioxide ventilation equivalent (VE/VCO_2)

An analysis from one systematic review[12] showed a reduction in VE/VCO_2 with surgical mask use compared with no mask in healthy adults. In a subgroup analysis by exercise state, little to no difference was noted in VE/VCO_2 in healthy adults during the different exercise states. Meta-analysis results are presented in table 3.

Metabolic responses

Oxygen saturation

Eight systematic reviews[6 7 12 15 30–33] reported this outcome, out of which we prioritised two systematic reviews based on their methodological rigour, number of included studies and recent publication time.[12 32] Wearing surgical masks was associated with a small reduction in oxygen saturation in healthy adults and patients with COPD, with little to no difference noted in oxygen saturation with N95 or cloth mask use. In a subgroup analysis by exercise

Table 4 Effect of respiratory protection mask use on metabolic responses and certainty of evidence

Outcome (measurement unit)	Systematic review	Population	Comparison	Participants (included studies)	Effect size (95% CI)	Risk of bias	Certainty of evidence
Oxygen saturation (measured in %)	Zheng *et al*[12]	Healthy adults	Surgical mask versus no mask	589 (20 RCTs/crossover trials and 1 non-RCT)	MD −0.59% (−0.87% to −0.30%)	Moderate	⊕⊕◯◯* Low
			N95 respirator versus no mask	232 (10 RCTs/crossover trials and 1 non-RCT)	MD −0.35% (−0.75% to 0.05%)	Moderate	⊕⊕◯◯* Low
			Cloth mask versus no mask	164 (6 RCTs/crossover trials and 1 non-RCT)	MD −0.50% (−1.23%; 0.24%)	Moderate	⊕⊕◯◯* Low
			Mask versus no mask (progressive exercise state)	821 (27 RCTs/crossover trials and 1 non-RCT)	MD −0.60 (−1.02 to −0.18)	Moderate	⊕⊕◯◯* Low
			Mask versus no mask (steady-state exercise)	660 (19 RCTs/crossover trials and 1 non-RCT)	MD −0.41 (−0.73 to −0.10)	Moderate	⊕⊕◯◯* Low
	Chen *et al*[32]	Patients with COPD	Face mask versus no mask	97 (1 non-RCT)	MD −0.80 (−1.56 to −0.04)	High	⊕◯◯◯† Very low
End-tidal oxygen partial pressure (measured in mm Hg)	Zheng *et al*[12]	Healthy adults	Surgical mask versus no mask	132 (6 RCTs/crossover trials)	MD −3.17 mm Hg (−4.87 to −1.47)	Moderate	⊕⊕◯◯‡ Low
			N95 respirator versus no mask	42 (4 RCTs/crossover trials)	MD −5.10 mm Hg (−9.27 to −0.94)	Moderate	⊕⊕◯◯‡
Oxygen uptake (measured in mL/kg/min)	Zheng *et al*[12]	Healthy adults	Surgical mask versus no mask	202 (9 RCTs/crossover trials and 1 non-RCT)	MD −0.64 (−0.86 to −0.42)	High	⊕◯◯◯† Very low
			N95 respirator versus no mask	72 (5 RCTs/crossover trials)	MD −0.66 (−1.16 to −0.16)	Moderate	⊕⊕◯◯‡ Low
			Cloth mask versus no mask	51 (2 RCTs/crossover trials)	MD −0.73 (−1.96 to 0.51)	Moderate	⊕⊕◯◯* Low
			Mask versus no mask (progressive exercise state)	265 (16 RCTs/crossover trials)	MD −0.68 (−0.93 to −0.43)	High	⊕◯◯◯† Very low
			Mask versus no mask (steady-state exercise)	62 (3 RCTs/crossover trials)	MD −0.57 (−0.94 to −0.21)	High	⊕◯◯◯† Very low
Muscle oxygenation (measured in %)	Shaw *et al*[15]	Adults	Surgical mask versus no mask	40 (3 RCTs/crossover trials)	MD −0.41 (−0.86 to 0.05)	Moderate	⊕⊕◯◯* Low
VCO_2 (measured in mL/min)	Zheng *et al*[12]	Healthy adults	Surgical mask versus no mask	127 (4 RCTs/crossover trials, 1 non-RCT)	SMD −0.74 (−1.19 to −0.28)	Moderate	⊕⊕◯◯* Low
			N95 respirator versus no mask	28 (2 RCTs/crossover trials)	SMD −0.87 (−1.82 to 0.07)	Moderate	⊕⊕◯◯* Low
Carbon dioxide partial pressure (measured in mm Hg)	Wangsan *et al*[7]	Healthy adults	N95 respirator versus no mask (high-intensity exercise)	51 (4 RCTs/crossover trials)	SMD 1.17 (0.70 to 1.64)	Moderate	⊕⊕◯◯* Low
			N95 respirator versus no mask (low-intensity to moderate-intensity exercise)	54 (4 RCTs/crossover trials)	SMD 0.43 (0.08 to 0.79)	Moderate	⊕⊕◯◯* Low
Arterial CO_2 (measured in milliequivalents per litre (mmol/L))	Shaw *et al*[15]	Adults	Surgical mask versus no mask	62 (1 RCT/crossover trial and 1 non-RCT)	MD 0.41 (−2.15 to 1.33)	High	⊕◯◯◯† Very low
			N95 respirator versus no mask	54 (3 RCTs/crossover trials, 1 non-RCT)	MD 1.33 (0.02; 2.64)	High	⊕◯◯◯† Very low
End-tidal CO_2 (measured in mm Hg)	Zheng *et al*[12]	Healthy adults	Surgical mask versus no mask	269 (9 RCTs/crossover trials)	MD 2.32 (1.38; 3.26)	High	⊕◯◯◯† Very low
			N95 respirator versus no mask	213 (9 RCTs/crossover trials)	MD 2.93 (2.01; 3.86)	High	⊕◯◯◯§ Very low
			Mask versus no mask (progressive exercise state)	369 (10 RCTs/crossover trials)	MD 4.15 (2.77 to 5.53)	High	⊕◯◯◯† Very low
			Mask versus no mask (steady-state exercise)	387 (10 RCTs/crossover trials)	MD 2.09 (0.93 to 3.25)	High	⊕◯◯◯§ Very low
	Chen *et al*[32]	Patients with COPD	Face mask versus no mask	112 (1 RCT/crossover trial and 1 non-RCT)	MD 0.10 (−1.57 to 1.78)	Moderate	⊕⊕◯◯* Low
Lactate level (measured in mmol/L)	Zheng *et al*[12]	Healthy adults	Surgical mask versus no mask	160 (7 RCTs/crossover trials)	MD −0.10 (−1.11; 1.31)	Moderate	⊕⊕◯◯* Low
			N95 respirator versus no mask	28 (2 RCTs/crossover trials)	MD −1.02 (−2.09; 0.05)	Moderate	⊕⊕◯◯* Low
			Mask versus no mask (progressive exercise state)	147 (6 RCTs/crossover trials)	MD −1.06 (−1.69 to −0.44)	Moderate	⊕⊕◯◯* Low
			Mask versus no mask (steady-state exercise)	127 (4 RCTs/crossover trials)	MD −1.23 (−0.40 to 2.86)	Moderate	⊕⊕◯◯* Low
	Chen *et al*[32]	Patients with COPD	Face mask versus no mask	27 (1 RCT/crossover trial)	MD −0.90 (−1.73 to −0.07)	Moderate	⊕⊕◯◯* Low

*Low quality of evidence is due to unexplained inconsistency and imprecise results due to small magnitude of change and wide CI.

†Low quality of evidence is due to imprecise results due to small magnitude of change and wide CI and some concern with risk of bias.

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CO_2, carbon dioxide; COPD, chronic obstructive pulmonary disease; MD, mean difference; RCT, randomised controlled trial; SMD, standardised mean difference; VCO_2, carbon dioxide production.

Table 5 Effect of respiratory protection mask use on exercise performance and certainty of evidence

Outcome	Systematic review	Population	Comparison	Participants (included studies)	Effect size (95% CI)	Risk of bias	Certainty of evidence
Exercise performance	Zheng *et al*[12]	Healthy adults	Surgical mask versus no mask	541 (20 RCTs/crossover trials)	SMD −0.12 (−0.39 to 0.15)	Moderate	⊕⊕◯◯* Low
			N95 respirator versus no mask	232 (11 RCTs/crossover trials)	SMD −0.42 (−0.76 to −0.08)	Moderate	⊕⊕◯◯* Low
			Cloth mask versus no mask	114 (5 RCTs/crossover trials)	SMD −0.26 (−0.54 to 0.02)	Moderate	⊕⊕◯◯* Low
			Mask versus no mask (progressive exercise state)	917 (34 RCTs/crossover trials)	SMD −0.34 (−0.52 to −0.15)	Moderate	⊕⊕◯◯* Low
			Mask versus no mask (steady-state exercise)	283 (7 RCTs/crossover trials)	SMD 0.16 (−0.32 to 0.65)	Moderate	⊕⊕◯◯* Low
	Chen *et al*[32]	Patients with COPD	Face mask versus no mask	27 (1 crossover trial)	MD −9.90 (−28.20 to 8.40)	Moderate	⊕⊕◯◯† Low
Rating of perceived exertion	Zheng *et al*[12]	Healthy adults	Surgical mask versus no mask	424 (20 crossover trials/RCTs)	SMD 0.36 (0.21 to 0.52)	Moderate	⊕⊕◯◯† Low
			N95 respirator versus no mask	174 (10 crossover trials/RCTs)	SMD 0.17 (−0.01 to 0.35)	Moderate	⊕⊕◯◯† Low
			Cloth mask versus no mask	161 (7crossover trials/RCTs)	SMD 0.22 (−0.13 to 0.57)	Moderate	⊕⊕◯◯* Low
Time to exhaustion	Glänzel *et al*[34]	Healthy adults	Face mask versus no mask	210 (9 crossover trials/RCTs)	MD −0.29 (−0.48 to −0.10)	Moderate	⊕⊕◯◯† Low
Thermal sensation	Zheng *et al*[12]	Healthy adults	Surgical mask versus no mask	56 (4 RCTs/crossover trials)	SMD 0.46 (0.06 to 0.85)	Moderate	⊕⊕◯◯† Low
			N95 respirator versus no mask	36 (3 RCTs/crossover trials)	SMD 0.97 (−0.05 to 2.00)	Moderate	⊕⊕◯◯† Low
			Mask versus no mask (progressive exercise state)	24 (2 RCTs/crossover trials)	SMD 1.59 (0.55 to 2.64)	Moderate	⊕⊕◯◯* Low
			Mask versus no mask (steady-state exercise)	68 (5 RCTs/crossover trials)	SMD 0.35 (0.01 to 0.69)	Moderate	⊕⊕◯◯* Low
Facial skin temperature	Litwinowicz *et al*[6]	Healthy adults	N95 respirator versus no mask	86 (5 RCTs/crossover trials)	SMD 1.05 (0.48 to 1.63)	Moderate	⊕⊕◯◯† Low
Subjective rating of heat perception	Litwinowicz *et al*[6]	Healthy adults	N95 respirator versus no mask	54 (4 RCTs/crossover trials)	SMD 1.04 (−0.12 to 2.19)	Moderate	⊕⊕◯◯† Low

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†Low quality of evidence is due to imprecise results due to small magnitude of change and wide CI.
COPD, chronic obstructive pulmonary disease; MD, mean difference; RCT, randomised controlled trial; SMD, standardised mean difference.

state, a small reduction in oxygen saturation was noted in healthy adults during the different exercise states. Meta-analysis results are presented in table 4.

End-tidal oxygen partial pressure

An analysis from one systematic review[12] showed a reduction in end-tidal oxygen partial pressure ($PetO_2$) with mask use. Meta-analysis results are presented in table 4.

Oxygen uptake

Three systematic reviews[6 12 30] reported data regarding the impact of mask use on oxygen uptake, out of which we prioritised two systematic reviews based on their methodological rigour, number of included studies and recent publication time.[12 32] Wearing masks was associated with a decrease in oxygen uptake (VO_2) compared with no mask in healthy adults. In a subgroup analysis by exercise state, a small reduction in oxygen uptake was noted in healthy adults during the different exercise states. Meta-analysis results are presented in table 4.

Muscle oxygenation

An analysis from one systematic review[15] showed wearing face masks was associated with little to no significant difference in muscle oxygenation during exercise compared with no mask use in adult participants. Meta-analysis results are presented in table 4.

Carbon dioxide

Three systematic reviews[6 7 30] reported this outcome, out of which we prioritised two systematic reviews based on the methodological rigour, number of included studies and publication time.[7 12] Wearing surgical masks was associated with a small reduction in VCO_2 in healthy adults, with little to no significant difference noted with N95 mask use. In a subgroup analysis by exercise state, wearing an N95 mask was associated with a slight increase in carbon dioxide in healthy adults during the different exercise states. Meta-analysis results are presented in table 4.

End-tidal CO_2

Three systematic reviews[12 15 32] reported the impact of mask use on end-tidal carbon dioxide, out of which we prioritised two systematic reviews based on their methodological rigour, number of included studies and recent publication time.[12 32] Wearing masks was associated with an increase in end-tidal CO_2 in healthy adults with little to no significant difference noted in patients with COPD. In a subgroup analysis by exercise state, a slight increase in end-tidal CO_2 was noted in healthy adults during the different exercise states. Meta-analysis results are presented in table 4.

Table 6 A narrative review of the available evidence on the effect of mask use on cognitive performance and psychological outcomes

Author, year of publication	Participants (study design)	Outcome	Risk of bias	Certainty of evidence
Cognitive performance				
Braun-Trocchio *et al*,[37] 2022	54 (non-randomised study)	Wearing masks was associated with an increase in the internal focus score during the stepping exercise task compared with no mask.	High	⊕◯◯◯* Very low
Deng *et al*,[35] 2022	20 (RCT)	Wearing a mask was associated with reduced mental workload compared with no mask; however, mask use was associated with worse performance scores and fewer correct numbers or rates.	Moderate	⊕⊕◯◯† Low
Grimm *et al*,[36] 2022	23 (RCT)	Mask use was associated with little to no significant difference in cognitive performance, self-perceived arousal or ability to concentrate ratings during rest or exercise.	Moderate	⊕⊕◯◯* Low
Ipek *et al*,[17] 2021	34 (cross-sectional study)	Wearing N95 masks was associated with higher attention deficit rates and difficulty in concentrating compared with the face mask group.	High	⊕◯◯◯* Very low
Jahangiri *et al*,[39] 2023	40 (quasiexperimental study)	No significant difference was noted between face mask and N95 respirator groups in cognitive performance, number of correct responses or response time.	High	⊕◯◯◯* Very low
Slimani *et al*,[41] 2021	17 (cross-sectional study)	Wearing face masks was associated with improved cognitive function, resulting in fewer errors compared with no mask group.	High	⊕◯◯◯* Very low
Tornero-Aguilera and Clemente-Suarez,[43] 2021	50 (cross-sectional study)	Wearing a face mask was associated with little to no difference in mental fatigue perception or reaction time compared with no mask.	High	⊕◯◯◯* Very low
Psychological outcomes				
Chong *et al*,[38] 2022	93 (cross-sectional study)	Claustrophobia was noted in 3% of the participants while wearing face masks. Comparable results were noted while wearing an N95 respirator or surgical mask.	High	⊕◯◯◯* Very low
Khalid *et al*,[40] 2021	12 (cross-sectional study)	Higher rate of claustrophobia among the N95 respirator group when compared with the face mask group.	High	⊕◯◯◯* Very low
Su *et al*,[42] 2021	68 (cross-sectional study)	No significant difference was noted in depression or anxiety rate among the surgical mask or N95 respiratory group.	High	⊕◯◯◯* Very low

*Low quality of evidence is due to unexplained inconsistency and imprecise results due to small magnitude of change and wide CI and some concern with risk of bias.

†Low quality of evidence is due to imprecise results due to small magnitude of change and wide CI.

RCT, randomised controlled trial.

Lactate

Three systematic reviews[12 15 32] reported this outcome, out of which we prioritised two systematic reviews based on their methodological rigour, number of included studies and recent publication time.[12 32] Wearing masks was associated with little to no significant difference in lactate levels in healthy adults; however, a small reduction in lactate level was noted in patients with COPD. In a subgroup analysis by exercise type, a small decrease in lactate level was noted in healthy adults during the progressive exercise state with little to no significant difference noted during steady exercise state. Meta-analysis results are presented in table 4.

Exercise performance

Exercise performance

Four systematic reviews[12 15 30 32] assessed the impact of mask use on exercise performance, out of which we prioritised two systematic reviews based on their methodological rigour, number of included studies and recent publication time.[12 32] N95 mask use was associated with a slight reduction in exercise performance in healthy adult's rate compared with no mask, with little to no significant difference noted with surgical and cloth mask use in healthy adults and patients with COPD. In a subgroup analysis by exercise type, a small decrease in exercise performance was noted with mask use in healthy adults during the progressive exercise state with little to no significant difference noted during the steady exercise state. Meta-analysis results are presented in table 5.

Time to exhaustion and perceived exertion

Three systematic reviews[12 15 34] reported this outcome. We prioritised two systematic reviews based on their methodological rigour, number of included studies and publication time.[12 34] Wearing surgical masks was associated with higher perceived exertion (rating of perceived exertion) scores in healthy adults compared with no mask use; however, little to no significant difference was noted with N95 or cloth mask use. Additionally, a slight reduction in time to exhaustion was noted with the use of face masks compared with the no mask. Meta-analysis results are presented in table 5.

Thermal sensation and facial skin temperature

Two systematic reviews[6 12] reported this outcome. Wearing masks was associated with an increase in thermal sensation compared with no mask use in healthy adults. In a subgroup analysis by exercise type, an increase in thermal sensation was noted with mask use in healthy adults during different exercise states. Additionally, facial skin temperature significantly increased with mask use; however, no significant difference was observed in subjective ratings of heat perception between mask and no mask groups. Meta-analysis results are presented in table 5.

Cognitive influence of respiratory protection mask use

Studies examining the impact of face mask use on cognitive function during exercise have produced mixed results

Outcomes \ Comparisons	FFP/N95 respirator vs. No mask	Surgical mask vs. No mask	Cloth mask vs. No mask	All facemask vs. No mask	Face mask vs. No mask following low to moderate intensity exercise	Facemask vs. No mask following high intensity exercise
Cardiovascular Responses						
Heart Rate	–	–	–	–*		
Maximum Heart Rate				–*		
Stroke Volume	–			–		
Cardiac Output	–			–		
Systolic Blood Pressure	–			–	–*	–*
Diastolic Blood Pressure	–			–	–*	
Mean Arterial Blood Pressure				–		
Ventilatory Responses						
Respiratory Rate	–	–	–	↑*		
Minute Ventilation	↓	↓		–*		
Tidal Volume	–	↓				
Carbon Dioxide Ventilation Equivalent		↓				
Metabolic Responses						
Oxygen Saturation	–	↓	–	↓*		
End Tidal Oxygen Partial Pressure	↓	↓				
Oxygen Uptake	↓	↓	–			
Muscle Oxygenation		–				
Carbon Dioxide Partial Pressure					↑¥	↑¥
VCO2	–	↓				
Arterial CO2	↑	–				
End Tidal CO2	↑	↑		–*		
Lactate Level	–	–		↓*		
Exercise Performance						
Exercise Performance	↓	–	–	–*		
Rating of Perceived Exertion	–	↑	–			
Time to Exhaustion				↓		
Thermal Sensation	–	↑				
Facial Skin Temperature	–					
Subjective Rating of Heat Perception	–					
Cognitive Impact						
Focus/concentration				↑–		
Mental Workload				↓		
Performance	–			↓–↑		
Mental Fatigue Perception		–				
Attention Deficit	↑					
Reaction Time		–				
Psychological Impact						
Anxiety	–	–				
Depression	–	–				
Claustrophobia	↑↑	↑		↑–		

Statistically significant Effect: increase ↑, Statistically significant Effect: decrease ↓, Non statistically significant Effect/no effect: –
Type of mask N95: ¥, COPD patients: *

Certainty of evidence: Very Low | Low | Moderate | High | No available studies

Figure 2 Evidence map demonstrating the availability of evidence and its quality for the various physiological, cognitive and psychological outcomes associated with mask use. COPD, chronic obstructive pulmonary disease.

with low to very low certainty of evidence. Some studies, such as Braun-Trocchio *et al*[37] and Slimani *et al*,[41] suggest potential benefits, including improved cognitive function and increased internal focus among mask wearers. However, other research, like that by Deng *et al*,[35] indicates a reduction in mental workload but lower performance in terms of accuracy. Contrary findings were reported by Jahangiri *et al*[39] and Grimm *et al*,[36] no significant differences in cognitive performance were observed between mask types or during exercise. Additionally, Tornero-Aguilera and Clemente-Suárez[43] found no effects on mental fatigue or reaction time with surgical face mask use. Notably, Ipek *et al*[17] identified a higher rate of attention deficit among N95 respirator wearers compared with face mask wearers, suggesting potential drawbacks associated with certain mask types. Overall, while some studies suggest potential cognitive benefits, others report no significant effects or even adverse outcomes, highlighting the complexity of the relationship between mask use and cognitive function during exercise. Results are presented in table 6.

Psychological impact associated with respiratory protection mask use

The psychological impact of respiratory protection mask use, particularly regarding claustrophobia and mental health outcomes, has been investigated in several studies with varying results and limited certainty of evidence. A study conducted by Chong *et al*[38] revealed that 3% of healthcare workers experienced claustrophobia while wearing face masks. This percentage was found to be similar for both N95 respirators and surgical masks. However, Khalid *et al*[40] discovered higher rates of claustrophobia in the N95 group. On the other hand, Su *et al*[42] observed no significant difference in depression or anxiety rates between healthcare workers wearing surgical masks and those using N95 respirators. Results are presented in table 6.

Evidence map

Figure 2 provides an evidence map illustrating the main findings on various respiratory protection mask use. The map suggests a lack of comprehensive assessment regarding the acute physiological, cognitive and psychological impacts of different mask types. Physiological effects showed minimal changes, particularly in ventilation and oxygen levels. However, evidence on cognitive and psychological outcomes varied and was constrained by study limitations and various biases. Overall, the certainty of evidence ranged from very low to low for most interventions, with no high-certainty evidence available. Furthermore, there is insufficient evidence regarding the impact of mask use on different work groups, duration of masking or the effects of mask use at high altitude levels.

Discussion

To our knowledge, this is the first evidence map to examine the acute physiological, cognitive and psychological impacts of different mask types during rest and exercise. Similar to previously reported studies,[12 15 30] our study revealed modest impacts on variables such as ventilation and oxygen levels; however, the overall evidence remains inconclusive, with majority of studies indicating minimal changes in cardiovascular, ventilatory and metabolic responses, and exercise performance associated with mask use during both rest and physical activity. We noted variations in findings across different mask types and participant populations. For instance, while surgical masks and cloth masks showed no significant impact on physiological parameters, N95 respirators were associated with modest changes in VE, VT, oxygen saturation, carbon dioxide levels and exercise performance. While some of these parameters revealed statistical differences between those wearing and not wearing face masks, the level of change was small, and most values remained in the normal range.

Studies examining the cognitive effects of mask use during exercise yielded heterogeneous results, reflecting the multifaceted nature of cognitive function. While some studies suggested potential benefits in terms of improved cognitive function and increased internal focus among mask wearers, others reported no significant effects or even adverse outcomes. Communication challenges and perceptual shifts induced by mask wearing may contribute to variations in cognitive performance during physical activity. However, methodological limitations and inconsistencies across studies warrant cautious interpretation of these findings. Future research should aim to clarify the relationship between mask use and cognitive function, considering factors such as mask type, duration of use and activity level.

Similarly, the psychological impact of mask use remains a complex and understudied area. While some studies report elevated levels of claustrophobia among mask wearers, others find no significant differences in depression or anxiety rates compared with non-mask wearers. These conflicting findings highlight the need for more rigorous studies assessing the psychological effects of mask use over time, considering individual factors such as personality traits, coping mechanisms and pre-existing mental health conditions.

Strengths and limitations

The strengths of this systematic review relate to the comprehensive search and rigorous methodological approach in addition to the inclusion of diverse study designs and populations. Moreover, by synthesising evidence from multiple systematic reviews and primary studies, we provided a comprehensive overview of the current state of knowledge on mask-related health outcomes.

Despite our efforts to include high-quality studies across various settings and populations, the increased heterogeneity across studies and the methodological quality of the current available studies have led to lower certainty of evidence. The exclusion of non-English language studies and limiting our search strategies only to studies published after 2000 and the focus on acute rather than long-term effects may have limited the generalisability of the findings, although the inclusion of systematic review that included studies published before 2000 may have limited the impact of this. Additionally, most of the data regarding the psychological and cognitive outcomes were driven from studies performed on healthcare workers which may limit its generalisability to the public.

Research implications

Additionally, the predominance of observational studies and the limited number of high-quality RCTs underscore the need for more robust research in this area. Studies need to have a longer follow-up to address the short- and long-term effects of different types of face mask, fit and duration of use on different physiological, cognitive and psychological parameters. Future studies should leverage previously validated and standardised assessment tools to assess the cognitive and psychological outcomes. Qualitative research is critical to better understand barriers to face mask use and perceptions of individuals in different contexts, cultural backgrounds and professional roles.

Conclusion

This evidence map provides a comprehensive insight into the multifaceted impact of respiratory protection mask use in addition to the limited certainty in the currently available body of evidence. The evidence map approach is intended to facilitate the development of future research agenda.

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34 **Glänzel MH**, Barbosa IM, Machado E, *et al*. Facial mask acute effects on affective/psychological and exercise performance responses during exercise: A meta-analytical review. *Front Physiol* 2022;13:994454.

35 **Deng M**, Wang X, Menassa CC. Investigating the effect of wearing masks on office work in indoor environments during a pandemic using physiological sensing. *Build Environ* 2022;221:109346.

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38 **Chong LS**, Bundele A, Sumner J, *et al*. Advances in respiratory protective equipment: practical experiences of CleanSpace® HALO™ by healthcare workers. *J Hosp Infect* 2022;124:22–8.

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Appendix A: Search Strategy

A comprehensive search of several databases from 2000 to July 28, 2023, any language was conducted. The databases included Ovid MEDLINE, Ovid EMBASE, Ovid Cochrane Central Register of Controlled Trials, Ovid Cochrane Database of Systematic Reviews, Scopus, and PubMed. The search strategy was designed and conducted by an experienced medical librarian with input from the study's principal investigator. Controlled vocabulary supplemented with keywords was used to search various outcomes from wearing medical masks or air purifying respirators.

PubMed

#	Searches	Results
1	(("Respiratory Protective Devices"[Mesh] OR "Masks"[Mesh] OR "N95 Respirators"[Mesh] OR surgical mask [tiab] OR surgical masks [tiab] OR medical masks [tiab] OR medical masks [tiab] OR air purifying respirator [tiab] OR air purifying respirators [tiab]) AND (("Stress, Physiological"[Mesh] OR physiological stress [tiab] OR "Heart Rate"[Mesh] OR heart rate [tiab] OR oxygen [tiab] OR oxygenation [tiab] OR "Oxygen Saturation"[Mesh] OR carbon dioxide [tiab] OR CO2 [tiab] OR "Physical Exertion"[Mesh] OR perceived exertion [tiab] OR "Pulmonary Ventilation"[Mesh] OR ventilation [tiab] OR "Tidal Volume"[Mesh] OR "Work of Breathing"[Mesh] OR breathing [tiab] OR tidal [tiab] OR "Stroke Volume"[Mesh] OR stroke volume [tiab] OR "Cardiac Output"[Mesh] OR cardiac output [tiab] OR heart output [tiab] OR "Blood Pressure"[Mesh] OR blood pressure [tiab] OR blood lactate [tiab] OR "Dyspnea"[Mesh] OR dyspnea [tiab]) OR ("Mental Status and Dementia Tests"[Mesh] OR "Neuropsychological Tests"[Mesh] OR distraction [tiab] OR General Practitioner Assessment of Cognition [tiab] OR GPCOG [tiab] OR Montreal Cognitive Assessment [tiab] OR Mental Status Tests [tiab] OR Mental Status Test [tiab] OR Neurocognitive Tests [tiab] OR Neurocognitive Test [tiab] OR Neurobehavioral Cognitive Status Examination [tiab] OR COGNISTAT [tiab] OR Mini Mental State Examination [tiab] OR Folstein Mini-Mental State Examination [tiab] OR MMSE [tiab] OR Mini Mental Status Examination [tiab] OR Mini-Cog [tiab] OR MicroCog [tiab] OR Cognitive Assessment Screening Instrument [tiab] OR functional cognitive assessment scale [tiab] OR functional activities questionnaire [tiab] OR abbreviated mental test [tiab] OR six-item cognitive impairment test [tiab]) OR (("Phobic Disorders"[Mesh] OR claustrophobia [tiab] OR "Anxiety Disorders"[Mesh] OR "Anxiety"[Mesh] OR anxiety [tiab]) AND ("Pilots"[Mesh] OR flight attendants [tiab] OR pilots [tiab] OR airplane crew [tiab] OR "Health Personnel"[Mesh] OR health care personnel [tiab] OR healthcare personnel [tiab] OR health care professionals [tiab] OR healthcare professionals [tiab] OR "Emergency Responders"[Mesh] OR emergency responders [tiab] OR first responders [tiab] OR "Military Personnel"[Mesh] OR military [tiab]))))	5130
2	limit to 2000-2023	**3770**

OVID (**Embase** 1974 to 2023 July 27)

#	Searches	Results
1	exp respiratory protection/ or exp mask/ or exp minimally 94 percent efficient filtering facepiece respirator/ or surgical mask.ti,ab. or surgical masks.ti,ab. or medical masks.ti,ab. or medical masks.ti,ab. or air purifying respirator.ti,ab. or air purifying respirators.ti,ab.	56330
2	exp physiological stress/ or exp heart rate/ or heart rate.ti,ab. or oxygen.ti,ab. or oxygenation.ti,ab. or exp oxygen saturation/ or exp carbon dioxide/ or carbon dioxide.ti,ab. or CO2.ti,ab. or perceived exertion.ti,ab. or exp lung ventilation/ or ventilation.ti,ab. or exp tidal volume/ or exp "work of breathing"/ or breathing.ti,ab. or tidal.ti,ab. or exp heart stroke volume/ or stroke volume.ti,ab. or exp heart output/ or cardiac output.ti,ab. or heart output.ti,ab. or exp blood pressure/ or blood pressure.ti,ab. or exp lactate blood level/ or blood lactate.ti,ab. or exp dyspnea/ or dyspnea.ti,ab.	2696032
3	exp neuropsychological assessment/ or distraction.ti,ab. or General Practitioner Assessment Cognition.ti,ab. or GPCOG.ti,ab. or Montreal Cognitive Assessment.ti,ab. or Mental Status Tests.ti,ab. or Mental Status Test.ti,ab. or Neurocognitive Tests.ti,ab. or Neurocognitive Test.ti,ab. or Neurobehavioral Cognitive Status Examination.ti,ab. or COGNISTAT.ti,ab. or Mini Mental State Examination.ti,ab. or Folstein Mini-Mental State Examination.ti,ab. or MMSE.ti,ab. or Mini Mental Status Examination.ti,ab. or Mini-Cog.ti,ab. or MicroCog.ti,ab. or Cognitive Assessment Screening Instrument.ti,ab. or functional cognitive assessment scale.ti,ab. or functional activities questionnaire.ti,ab. or abbreviated mental test.ti,ab. or six-item cognitive impairment test.ti,ab.	148613
4	exp claustrophobia/ or claustrophobia.ti,ab. or exp anxiety disorders/ or exp anxiety/ or anxiety.ti,ab.	628142
5	exp airplane pilot/ or exp flight attendant/ or exp airplane crew/ or flight attendants.ti,ab. or pilots.ti,ab. or airplane crew.ti,ab. or exp health care personnel/ or health care personnel.ti,ab. or healthcare personnel.ti,ab. or health care professionals.ti,ab. or healthcare professionals.ti,ab. or exp rescue personnel/ or emergency responders.ti,ab. or first responders.ti,ab. or exp military personnel/ or military.ti,ab.	2069720
6	4 and 5	75411
7	2 or 3 or 6	2893818
8	1 and 7	17516
9	limit 8 to yr="2000 - 2023"	16281
10	limit 9 to embase	**11622**

OVID (**MEDLINE(R) ALL** 1946 to July 27, 2023)

#	Searches	Results
1	exp Respiratory Protective Devices/ or exp Masks/ or exp N95 Respirators/ or surgical mask.ti,ab. or surgical masks.ti,ab. or medical masks.ti,ab. or medical masks.ti,ab. or air purifying respirator.ti,ab. or air purifying respirators.ti,ab.	16090
2	exp Stress, Physiological/ or physiological stress.ti,ab. or exp Heart Rate/ or heart rate.ti,ab. or oxygen.ti,ab. or oxygenation.ti,ab. or exp Oxygen Saturation/ or exp Carbon Dioxide/ or carbon	1941052

	dioxide.ti,ab. or CO2.ti,ab. or exp Physical Exertion/ or perceived exertion.ti,ab. or exp Pulmonary Ventilation/ or ventilation.ti,ab. or exp Tidal Volume/ or exp "Work of Breathing"/ or breathing.ti,ab. or tidal.ti,ab. or exp Stroke Volume/ or stroke volume.ti,ab. or exp Cardiac Output/ or cardiac output.ti,ab. or heart output.ti,ab. or exp Blood Pressure/ or blood pressure.ti,ab. or blood lactate.ti,ab. or exp Dyspnea/ or dyspnea.ti,ab.	
3	exp "Mental Status and Dementia Tests"/ or exp Neuropsychological Tests/ or distraction.ti,ab. or General Practitioner Assessment Cognition.ti,ab. or GPCOG.ti,ab. or Montreal Cognitive Assessment.ti,ab. or Mental Status Tests.ti,ab. or Mental Status Test.ti,ab. or Neurocognitive Tests.ti,ab. or Neurocognitive Test.ti,ab. or Neurobehavioral Cognitive Status Examination.ti,ab. or COGNISTAT.ti,ab. or Mini Mental State Examination.ti,ab. or Folstein Mini-Mental State Examination.ti,ab. or MMSE.ti,ab. or Mini Mental Status Examination.ti,ab. or Mini-Cog.ti,ab. or MicroCog.ti,ab. or Cognitive Assessment Screening Instrument.ti,ab. or functional cognitive assessment scale.ti,ab. or functional activities questionnaire.ti,ab. or abbreviated mental test.ti,ab. or six-item cognitive impairment test.ti,ab.	229006
4	exp Phobic Disorders/ or claustrophobia.ti,ab. or exp Anxiety Disorders/ or exp Anxiety/ or anxiety.ti,ab.	332772
5	exp Pilots/ or flight attendants.ti,ab. or pilots.ti,ab. or airplane crew.ti,ab. or exp Health Personnel/ or health care personnel.ti,ab. or healthcare personnel.ti,ab. or health care professionals.ti,ab. or healthcare professionals.ti,ab. or exp Emergency Responders/ or emergency responders.ti,ab. or first responders.ti,ab. or exp Military Personnel/ or military.ti,ab.	754620
6	4 and 5	15855
7	2 or 3 or 6	2177473
8	1 and 7	5117
9	limit 8 to yr="2000 - 2023"	**3743**

OVID (**EBM Reviews - Cochrane Central Register of Controlled Trials** June 2023)

#	Searches	Results
1	exp Respiratory Protective Devices/ or exp Masks/ or exp N95 Respirators/ or surgical mask.ti,ab. or surgical masks.ti,ab. or medical masks.ti,ab. or medical masks.ti,ab. or air purifying respirator.ti,ab. or air purifying respirators.ti,ab.	2097
2	exp Stress, Physiological/ or physiological stress.ti,ab. or exp Heart Rate/ or heart rate.ti,ab. or oxygen.ti,ab. or oxygenation.ti,ab. or exp Oxygen Saturation/ or exp Carbon Dioxide/ or carbon dioxide.ti,ab. or CO2.ti,ab. or exp Physical Exertion/ or perceived exertion.ti,ab. or exp Pulmonary Ventilation/ or ventilation.ti,ab. or exp Tidal Volume/ or exp "Work of Breathing"/ or breathing.ti,ab. or tidal.ti,ab. or exp Stroke Volume/ or stroke volume.ti,ab. or exp Cardiac Output/ or cardiac output.ti,ab. or heart output.ti,ab. or exp Blood Pressure/ or blood pressure.ti,ab. or blood lactate.ti,ab. or exp Dyspnea/ or dyspnea.ti,ab.	223095
3	exp "Mental Status and Dementia Tests"/ or exp Neuropsychological Tests/ or distraction.ti,ab. or General Practitioner Assessment Cognition.ti,ab. or GPCOG.ti,ab. or Montreal Cognitive Assessment.ti,ab. or Mental Status Tests.ti,ab. or Mental Status Test.ti,ab. or Neurocognitive	30554

	Tests.ti,ab. or Neurocognitive Test.ti,ab. or Neurobehavioral Cognitive Status Examination.ti,ab. or COGNISTAT.ti,ab. or Mini Mental State Examination.ti,ab. or Folstein Mini-Mental State Examination.ti,ab. or MMSE.ti,ab. or Mini Mental Status Examination.ti,ab. or Mini-Cog.ti,ab. or MicroCog.ti,ab. or Cognitive Assessment Screening Instrument.ti,ab. or functional cognitive assessment scale.ti,ab. or functional activities questionnaire.ti,ab. or abbreviated mental test.ti,ab. or six-item cognitive impairment test.ti,ab.	
4	exp Phobic Disorders/ or claustrophobia.ti,ab. or exp Anxiety Disorders/ or exp Anxiety/ or anxiety.ti,ab	66801
5	exp Pilots/ or flight attendants.ti,ab. or pilots.ti,ab. or airplane crew.ti,ab. or exp Health Personnel/ or health care personnel.ti,ab. or healthcare personnel.ti,ab. or health care professionals.ti,ab. or healthcare professionals.ti,ab. or exp Emergency Responders/ or emergency responders.ti,ab. or first responders.ti,ab. or exp Military Personnel/ or military.ti,ab.	21432
6	4 and 5	1588
7	2 or 3 or 6	252392
8	1 and 7	1308
9	limit 8 to yr="2000 - 2023"	**1046**

OVID (**EBM Reviews - Cochrane Database of Systematic Reviews** 2005 to July 25, 2023)

#	Searches	Results
1	(surgical mask or surgical masks or medical masks or medical masks or air purifying respirator or air purifying respirators).ti,ab.	3
2	(physiological stress or heart rate or oxygen or oxygenation or carbon dioxide or CO2 or perceived exertion or ventilation or breathing or tidal or stroke volume or cardiac output or heart output or blood pressure or blood lactate or dyspnea).ti,ab.	968
3	(distraction or General Practitioner Assessment Cognition or GPCOG or Montreal Cognitive Assessment or Mental Status Tests or Mental Status Test or Neurocognitive Tests or Neurocognitive Test or Neurobehavioral Cognitive Status Examination or COGNISTAT or Mini Mental State Examination or Folstein Mini-Mental State Examination or MMSE or Mini Mental Status Examination or Mini-Cog or MicroCog or Cognitive Assessment Screening Instrument or functional cognitive assessment scale or functional activities questionnaire or abbreviated mental test or six-item cognitive impairment test).ti,ab.	54
4	(claustrophobia or anxiety).ti,ab.	425
5	(flight attendants or pilots or airplane crew or health care personnel or healthcare personnel or health care professionals or healthcare professionals or emergency responders or first responders or military).ti,ab.	156
6	4 and 5	24
7	2 or 3 or 6	1038

8	1 and 7	**0**

Scopus (Elsevier)

1	TITLE-ABS (({surgical mask} OR {surgical masks} OR {medical masks} OR {medical masks} OR {air purifying respirator} OR {air purifying respirators}) AND (({physiological stress} OR {heart rate} OR oxygen OR oxygenation OR {carbon dioxide} OR co2 OR {perceived exertion} OR ventilation OR breathing OR tidal OR {stroke volume} OR {cardiac output} OR {heart output} OR {blood pressure} OR {blood lactate} OR dyspnea) OR (distraction OR {General Practitioner Assessment of Cognition} OR gpcog OR {Montreal Cognitive Assessment} OR {Mental Status Tests} OR {Mental Status Test} OR {Neurocognitive Tests} OR {Neurocognitive Test} OR {Neurobehavioral Cognitive Status Examination} OR cognistat OR {Mini Mental State Examination} OR {Folstein Mini-Mental State Examination} OR mmse OR {Mini Mental Status Examination} OR {Mini-Cog} OR microcog OR {Cognitive Assessment Screening Instrument} OR {functional cognitive assessment scale} OR {functional activities questionnaire} OR {abbreviated mental test} OR {six-item cognitive impairment test}) OR ((claustrophobia OR anxiety) AND ({flight attendants} OR pilots OR {airplane crew} OR {health care personnel} OR {healthcare personnel} OR {health care professionals} OR {healthcare professionals} OR {emergency responders} OR {first responders} OR military))))	406
2	(EXCLUDE (DOCTYPE , "cp") OR EXCLUDE (DOCTYPE , "cr"))	391
3	2000-2023	**374**

Table-1: Characteristics of The Included Systematic Reviews for Acute Physiological Impact of Respiratory Protection Mask Use:

Investigator	Included Studies	Participants	Intervention	Comparison	Exercise Protocol	Outcomes Reported
Chen, 2022(1)	6 studies (3 randomized crossover trials/RCT and 3 non-randomized controlled trials)	313 COPD patients	Surgical facemask, N95 respirator, Dual cartridge half-face facemasks and disposable non-filter medical facemasks	No mask	6-minutes' walk, Steady Exercise state, High-intensity exercise	Ends tidal carbon dioxide, RR, HR, Oxygen saturation, Pulmonary function, Blood pressure, Blood lactate, Minute ventilation and inspiratory time, Six-Minute walking test, expected relative exercise capacity, Work rate
Engerof, 2021 (2)	14 studies (14 randomized controlled crossover trials)	246 Healthy individuals	Surgical mask, FFP to/N95 respirator with and without exhalation valve	No facemask	Rest, Steady exercise state, Graded exercise	Oxygen Uptake and Saturation, Carbon Dioxide Exhalation and Partial Pressure, Pulmonary Function, Physical Performance
Glanzel,2022(3)	36 randomized cross-over studies	749 healthy adults	Clothing (CM), surgical (SM), FFP2/N95, and exhalation valved FFP2/N95	No facemask	NR	Discomfort, Subjective stress responses, Dyspnea, Time-to-exhaustion performance, Power output performance, Muscle force and exercise performance

Investigator	Included Studies	Participants	Intervention	Comparison	Exercise Protocol	Outcomes Reported
Lima, 2023(4)	10 studies (13 randomized crossover trials/randomized controlled trial)	306 (1 study with 106 participants were children aged 7-14)	N95/FFP2 respirators	No facemask	Aerobic exercise	HR, RR, Blood pressure, Oxygen saturation (SpO2), Perceived exertion
Litwinowicz, 2022 (5)	26 studies (25 Randomized crossover studies and one retrospective observational study)	751 Healthy individuals	Surgical facemask, (FFP1, FFP2, FFP3/ N95, N97, N99 respirators), Cloth masks	No face mask, Different type of facemask	Low intensity activities, Moderate to high-intensity activities	Heart rate, Respiratory rate, Pulse oximetry measures - oxygen saturation (spo2), Oxygen uptake, Tidal volume, Transcutaneous carbon dioxide pressure (tcpco2), Systolic blood pressure (SPB), Thermoregulation measures and subjective heat perceptions, Perception of exertion
Roeckner, 2020 (6)	4 studies (1 randomized crossover trials/3 prospective trial)	42 Pregnant women	N95 respirators	Non pregnant women, No facemask	Rest, Progressive exercise state	Heart rate, Respiratory rate, Blood pressure, Fetal heart rate, Oxygen saturation, Transcutaneous CO2, Perceived exertion
Shaw, 2021(7)	22 studies (13 randomized crossover trials, 7 non-randomized crossover trials, and 2 retrospective	1573 Participants (1 study with 106 participants were children aged 7-14)	Surgical face mask, FFP2/N95 respirators, Cloth masks	No facemask	Low to moderate exercise, Progressive exercise state	Exercise performance, Arterial oxygen saturation, Muscle oxygenation, End-tidal and

Investigator	Included Studies	Participants	Intervention	Comparison	Exercise Protocol	Outcomes Reported
	studies)					arterial CO2, RPE, Cardiac output and stroke volume, Blood pressure, Respiratory rate, Ventilation and tidal volume, Lactate
Wangsan, 2022 (8)	13 studies (8 randomized cross-over studies, three non-randomized studies, and two observational studies)	260 participants	N95/FFP2 respirators	No facemask	Low-Moderate Physical Workload, High Physical Workload	Oxygen Saturation, Partial Pressure of Carbon (PCO2) Dioxide
Zheng, 2023 (9)	45 studies (42 Randomized crossover studies, 2 RCT and one non-randomized repeated measure study)	1264 Healthy individuals (1 study with 106 participants were children aged 7-14)	Surgical face mask, FFP2/N95 respirators, Cloth masks	No mask	Steady exercise protocol, Progressive intensity protocol	Heart rate, VO2, SpO2, PetCO2, RPE, Thermal sensation, Blood lactate, Respiratory rate, Minute ventilation, Tidal volume VE/VCO2

CM, Cloth Mask; CO2, Carbon Dioxide; COPD, Chronic Obstructive Pulmonary Disease; FFP, Filtering Face Piece; HR, Heart Rate; NR, Not Reported; PCO2, Partial Pressure of Carbon Dioxide; PetCO2, End-expiratory carbon dioxide partial pressure; RPE, Rating of perceived exertion; RR, Respiratory Rate; SBP, Systolic Blood Pressure; SM, Surgical Mask; SpO2, Saturation of Peripheral Oxygen; tcpo2, Transcutaneous carbon dioxide pressure; VO2, rate of oxygen consumption; VE/VCO2, minute ventilation/carbon dioxide production.

Table-2: Characteristics of the included studies for Cognitive and Psychological impact of respiratory protection mask use:

Author, year	Study design	Population / Country	Total number of participants	Age Mean (SD)	Female (%)	Interventions	Control	Outcomes
Braun-Trocchio, 2022(10)	Non-randomized control study	Healthy university students and staff/ United States	54	21.2 (5.5)	70%	Face mask	No mask	Task Specific Motivations, Task Duration, Commitment Check, Attention

Author, year	Study design	Population / Country	Total number of participants	Age Mean (SD)	Female (%)	Interventions	Control	Outcomes
								Allocation, Ratings of Perceived Exertion (RPE)
Chong, 2022(11)	Cross sectional study	Healthcare workers/Singapore	93	38.1 (8.4)	58%	Surgical face mask, N95, PAPR, Clean Space HALO	No mask	Disruption of communication w/ patients, Claustrophobia
Deng, 2022(12)	RCT	Healthy university students and staff/US	20	20 to 30	45%	Surgical mask, Cloth mask	No mask	Effect of wearing a mask on work engagement, Effect of wearing a mask on mental workload, Skin conductance level
Grimm, 2022(13)	RCT	Healthy adults/ Germany	23	23.5 (2.1)	56.5%	Surgical mask, Filtering face piece type 2 (FFP2)	No mask	Hemodynamic parameters, Metabolic response to mask wearing, Self-reported data including cognitive performance
Ipek, 2021(14)	Cross sectional study	Health care workers /Turkey	34	31.3 (6.4)	56%	Surgical mask	N95 masks.	Attention deficit and difficulty in concentrating
Jahangiri, 2022(15)	Quasi-experimental study	Healthy university students /Iran	40	26.5 (3.9)	47.5%	Face mask	N95 mask	Continuous performance test (CPT), N-back test, Correct responses and response time
Khalid, 2021(16)	Cross sectional study	Gastroenterologists/USA	12	NR	NR	Surgical mask	SM and N95 FFR, Powered air-purifying respirator	Claustrophobia
Slimani, 2021(17)	Cross sectional study	Healthy students/ Tunsia	17	17.6	47%	Cloth mask	No mask	Concentration Performance, Total Number

Author, year	Study design	Population / Country	Total number of participants	Age Mean (SD)	Female (%)	Interventions	Control	Outcomes
								of Errors, Rate of Perceived Exertion
Su, 2021(18)	Cross sectional study	Health care workers/Taiwan	68	41	23.5%	Surgical mask	N95 respirator	Anxiety, Fatigue, Depression, Difficulty talking (determined via questionnaire)
Tornero-Aguilera, 2021(19)	Cross sectional study	Healthy university students/ Spain	50	20.2(2.9)	24%	Surgical face mask	No mask	Mental fatigue perception, Reaction time, Heart rate variability

Clean Space HALO, CleanSpace® HALO™ mask; CPT, Continuous performance test; FFP, Filtering Face Piece; NR, Not Reported; PAPR, Powered Air Purifying Respirator; RCT, Randomized Controlled Trial; RPE, Rating of perceived exertion; SM, Surgical Mask; US, United State; USA, United State of America

Table-3: Methodological Quality of Comparative Observational Studies (Newcastle Ottawa scale)

Study Label	Selection Bias	Baseline Imbalances Between Groups	Was Outcome Assessment Blinded?	Overall
Braun-Trocchio, 2022(10)	Moderate risk	Low risk	High risk	High risk
Chong, 2022(11)	High risk	High risk	High risk	High risk
Ipek, 2021(14)	Moderate risk	Low risk	High risk	High risk
Jahangiri, 2022(15)	High risk	Low risk	High risk	High risk
Khalid, 2021(16)	High risk	Low risk	High risk	High risk
Slimani, 2021(17)	High risk	Low risk	High risk	High risk
Su, 2021(18)	Moderate risk	Low risk	High risk	High risk
Tornero-Aguilera, 2021(19)	High risk	Low risk	High risk	High risk

Table-4: Methodological Quality of Randomized Clinical Trials

Author, Year	Bias Arising from the Randomization Process	Bias due to Deviations from Intended Interventions	Bias Due to Missing Outcome Data	Bias in The Measurement of the Outcome	Bias in Selection of The Reported Result	Other	Overall
Deng, 2022(12)	Low risk	Low risk	Low risk	Moderate risk	Low risk	Moderate risk	Moderate risk
Grimm, 2022(13)	Low risk	Low risk	Low risk	Low risk	Low risk	Moderate risk	Moderate risk

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